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Assessment of Farmers' Perception on the Status , Classification and Management Practices of Soil Fertility in Comparison to Scientific Practices: in the case of Ada'a district, central highlands of Ethiopia

A Thesis Submitted to the College of Social Sciences, Addis Ababa University in Partial fulfillment of the requirements for the Degree of Master of Arts in Geography and Environmental Studies specialization: Land resources management

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This is to certify that the thesis prepared by Amelework Kindihun, entitled: "Assessment of farmers' perception on the status of soil fertility,classification and management practices in comparison to scientific practices: in smallholders' farming systems of Kumbursa village, Ada'a District, central Ethiopia" submitted in partial fulfillment of the requirements for the Degree of Master of Art in Geography and Environmental Studies, specialization: Land resources Management complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

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Abstract

A field study was conducted in Kumbursa village, Ada'a district, Central highland of Ethiopia to assess farmer's perception of the status of soil fertility and the accompined management practices and then to compare the result with scientific criteria used by researchers.To address this issue, three farm wealth groups (rich, medium and poor) were distinguished based on farm size, number of oxen and grain stocks through stratified random sampling method. From a total of 277 households 83 Households were interviewed using structured questionnaire to gain insight into soil fertility management practices, local methods used to assess the fertility status of a field, and perceived trends in soil fertility. Farmers were asked to identify their most fertile, moderately fertile and infertile fields. Characteristics of the fields in terms of the indicators that were mentioned by the farmers in the interviews are recorded. The SPSS software has been used for data analysis. This study indicates that Farmer's local knowledge of soil fertilitystatus were based on observable plant and soil related characteristics namely; soil colour, soil texture, soil depth, crop productivity, soil water holding capacity, stoniness and difficulty to work. 30 soil samples were taken at a depth of 0-15 cm and15-30cm to characterize the fertility status of each soil types classified by farmers as fertile, moderately fertile and infertile. The soil sample analyses results indicated that the soil types perceived as fertile by farmers are in a favorable ranges of pH and clayey in texture with medium organic matter, medium organic carbon, medium total nitrogen and High available phosphorus,potassium and medium Sodium content and have good bulk densities than soils classified as moderately fertile and infertile. The overall result shows that there is good agreement between the soil physical and chemical analysis and farmers' assessment of soil fertility status.Therefore, the study shows the importance of recognizing farmer's knowledge and perception about assessment of soil fertility status to design more appropriate research and to facilitate clear communication with farmers. So inorder to design more appropriate research and to facilitate communication with farmers, researchers need to understand farmers' perceptions and assessments of soil fertility status.

Keywords: soil fertility, farmers'perceptions, indicators, soil color and texture

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Acronyms

ADAO	Ada'District Agriculture office
ADARDO	Ada'a District Agricultural and Rural Development Office
ADLI	Agricultural Development Led Industrialization
ADOOLEP	Ada'a District Office of Land and Environmental Protection
AEZs	Agro Ecological Zones
ANOVA	Analysis of Variance
ARD	Agricultural Research and Development
CIDA	Canadian International Development Agency
CSA	Central Statistics Agency
DAP	Di ammonium Phosphate
DA	Development Agent
DZMS	Debire Zeit Metrological Station
EEA	Ethiopian Economic Association
FAO	Food and Agricultural Organization of the United Nation
GDP	Gross Domestic Product
GIS	Geographic Information System
ISSS	International Soil Science Society
IPMS	Improving productivity and market access
LU/LC	Land Use/ Land Cover
Masl	Meter above Sea Level
MoA	Ministry of Agriculture
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
SPSS	Statistical Package for Social Science
SSA	Sub-Sahara African
TOT	Transfer of Technology
TSBF	Tropical Soil Biology and Fertility
USDA	United States Development Agency

CHAPTER ONE

INTRODUCTION

1.1 Background and Justification of the study

Ethiopia, with about 1.12 million square kilometer area of land is one of the most Populous countries in Africa with a total population of 87.95 million (CSA, 2013). This growing population requires better agricultural production performance than ever before to ensure food security. However, the agricultural sector in the country is characterized by small-scale and subsistence-oriented farming system due to an adverse combination of climatic variability, demographic, economic and institutional constraints and shocks.

In most of Sub-Saharan African (SSA) countries, agriculture is the main economic sector (TSBF, 2002). In Ethiopia agricultural sector contributes about 46.3% of the country's GDP, employs 83% of total labor force and contributes 90% of exports (EEA, 2012). The sector plays a pivotal role to induce the industrialization process in the country. Therefore, enhancing the productivity of such sector is crucial not only for the development of the sector itself but also for the development of other sectors of the country's economy.

One of the most fundamental resources to agricultural sector is Soil. The significance of soil to human beings sometimes not understood until it risked agricultural production (Humberto & Rattan, 2008). According to FAO (1994), a good soil is characterized by its ability to provide sufficient nutrient for the plant. Its optimal texture and structure are easy for air and water penetration and conducive for microorganisms in which they decompose organic matter and release nutrients for the plant.

The ways soils are managed have its own positive or negative effects on its fertility. If soils are used improperly the soil will be degraded due to erosion, salinization, depletion of nutrients and acidification. If the soils are utilized properly, physical loss of soil can be minimized; soil fertility can be maintained; and consequently good and sustainable agricultural production. Among others, some of the good management methods of soils are use of cover crops, using different soil conservation methods, application of organic matter, and careful use of chemical fertilizers (Peter et al., 2000).

Soil fertility declining is a fundamental impediment to agricultural growth and a major reason for slow growth in food production in Sub-Saharan Africa (SSA) (Sánchez *et al*., 1995). Soil fertility decline in much of sub-Saharan Africa has been referred to as an "orthodoxy" where the existence, extent and cause of the problem are accepted without question (Roe, 1995; Leach & Mearns, 1996). Ethiopia faces a wide set of soil fertility loss issues such as top soil erosion, soil acidity, depletion of organic matter, depletion of physical soil properties, depletion of macro and micro-nutrients and soil salinity that require beyond the application of chemical fertilizers(Gete *et al*., 2010).

The problem is more serious in the highlands where most of the human and livestock population is found (Assefa, 2005 & Hailu, 2010). This is mainly due to the complete removal of crop residues from farm lands for household energy and livestock feed, use of manure as a source of fuel instead of using it for soil fertility maintenance, low levels of chemical fertilizer application and lack of appropriate and in-situe SWC practices (FAO, 1998; Eyasu, 2002; Haileslassie *et al.*, 2005; Aklilu, 2006).Thus, the mitigation of soil fertility depletion is currently a pressing issue and major national concern. Even though, the application of chemical fertilizer are higher than the average for Sub-Saharan Africa (FAO, 2001) there is evidence which suggests that fertilizer applied in Ethiopia is not as effective as could be hoped because of different factors like the amount of chemical fertilizer applied, agro-ecology, soil fertility, and physical management practices, as well as the resulting interactions between chemical and physical soil properties.

Soil fertility decline has become a major concern of policy makers worldwide. In sub-Saharan Africa, the issue has taken on a note of urgency as diminishing food production is linked to subsistence crises (Scoones & Toulmin, 1999). To respond to these concerns, many international organizations are proposing wide-reaching initiatives. The World Bank, for example, has recently adopted a Soil Fertility Initiative for sub-Saharan Africa. The current government of Ethiopia adopted Agricultural Development Led Industrialization (ADLI) strategy since 1994/95 and focuses on productivity improvement of smallholder's agriculture through diffusion of fertilizers, improved seeds and setting up credit schemes (MOARD, 2008). However, soil fertility decline and accompanied low level of agricultural production have been stated to be still among the serious challenges of the strategy.

In order to give a sustainable solution to all these challenges, collaborative research between researchers and farmers is very crucial because perception influences how human beings adapt to the changing environment. However, until recently, farmers knowledge of soil fertility has been largely ignored by soil professionally biased researchers. Therefore, their adoption of improved techniques has been inadequate (shrestha et al., 2000). But with increasing use of participatory research approaches, it is becoming clear that farmers have a well-developed ability to perceive differences in the level of fertility between and within fields on their farms. They also understand the actual fertility of a soil at any time as a function not only of these longer-term soil properties, but also of the current and past management regime. However, in Ethiopia the information about how farmers understand soil fertility at farm level is minimal.

There is a strong need to compare the indicators used by farmers with those used by researchers. Farmers' understanding of soil fertility varies with different Soil types. A number of studies have overlooked farmers' understanding of soil fertility for different soil types. Besides, indigenous knowledge of soil and soil fertility management is location specific, specific to the socio-cultural and biophysical environment of an area (Getahun, 2006).

A number of studies were conducted on farmers' perception of soil fertility status (Desbiez et al., 2004; Getahun, 2006). There have also been studies of indigenous knowledge in the evaluation of soil fertility (Dea & Scoones, 2003). These studies indicate that farmers' understanding of soil is more general than that of scientists. Farmers use various indicators to evaluate soil fertility status. For instance, farmers in Dejen district of Ethiopia use soil color, soil depth, water holding capacity and crop yield performance to evaluate soil fertility (Getahun, 2006). In Western Kenya, crop growth vigour, soil colour and types of weeds grown in farmlands are major indicators of soil fertility status (Odendo *et al*., 2010).

Farmers in Tigrai region of Ethiopia make use of crop yield, degree of weed infestation, appearance of rocky outcrops and crop wilting to evaluate soil fertility (Corbeels *et al* ., 2000). Studies from several places in Africa also illustrate that farmers have a broad knowledge of soils, which include soil names, soil distribution and soil-plant relationships (Dolva & Renna, 1990; Steinr, 1998; Gray & Morant, 2003).

Therefore, this study aimed to assess farmers' perception of soil fertility, their priorities for soil fertility management techniques and comparing them with the scientific criteria used by researchers in Kumbursa village, Central Ethiopian Highlands. Therefore the findings of this paper were build cooperative researches between farmers' perceptions on the assessment of soil fertility in line with the scientific criteria of soil fertility used by researchers.

1.2 Statement of the problem

Ethiopia is an ecologically diverse country with an agricultural sector which contributes the major share of Gross National Product and practically all export earnings. About four fifths of the population depends upon agriculture for their livelihood (FAO, 2014). The quality of the soil determines the potential for agricultural development and then the capacity of smallholders to attain food security and improve their livelihood (FAO, 2014).

Soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in Sub-Saharan Africa (Sanchez *et al*., 1997). Agriculture in Ethiopia also has many constraints which impede improvements in production and productivity. Among which soil fertility depletion is the major one. In line with this, Befekadu and Berhanu (1999) reported that among the major factors behind the poor performance of Ethiopian agriculture are: diminishing farm size and subsistence farming, soil degradation, lack of financial services, imperfect agricultural market, poor use of modern inputs such as fertilizers, improved seeds and extension services and apart from this, the internal inefficiency of the farmers in using the available agricultural resources such as land and labor.

The presumption is that soil fertility decline also relates to population growth, mismanagement of soil resources, and under-capitalization of farmers (Cleaver & Schreiber, 1994). Therefore, increasing productivity of the sector is essential. Its productivity can be increased through technology adoption, improvement in efficiency of production and/or resource reallocation.So far, most research activities concern on determining the appropriate amount and type of fertilizer needed to obtain the best yields. This approach emphasized the use of external inputs and expensive technologies and often disregarded the farmers' knowledge and the resources at their disposal (Corbeels *et al*., 2000).

Although much of this is due to poor dissemination pathways resulting from inadequacies in the agricultural extension system, an important factor may be the different ways that farmers, extension workers and researchers all perceive and assess soil fertility, leading to differences in the problems perceived and solutions required.

Different measures and approaches had been developed to replenish soil fertility in Africa over the last decades. Research promoted several technologies to improve soil fertility. In the 1960s, those technologies were primary focusing on mineral fertilizer use and the classical top down approach for technology diffusion was used. But since then, this approach in Agricultural Research and Development (ARD), in Sub-Saharan Africa received numerous critics (Spielman *et al*., 2009; Sumberg, 2005).

In many parts of the world, especially in western countries, the linear model of technology development also called the Transfer of Technology (ToT) approach (researchers develop and release the technology that will be then delivers to farmers by extension staff) generated good results and increased considerably the land productivity; however, this approach did not succeed in enhancing poor people’s livelihood in SSA (Sumberg, 2005).

The ToT approach does not see farmers as innovator and local knowledge is not taken into consideration during the development of the technology but only for the fine tuning during on-farm testing. This approach succeeds well for simple technologies such as High Yielding Varieties in favorable environment.

Then, from the 1980s, the focus changed toward a more biological approach to soil fertility management and the use of more participative approach. The mid-1990s, research and development conceded that inorganic fertilizers are required to increase the productivity of African lands but as they are expensive, they need to be combined with organic matter (Vanlauwe et al., 2001).

Today, the African agricultural sector is changing with the association of new actors (NGOs, private sector), relationships (partnership private-public) and policy (Common Agricultural Policy CWA). Moreover, the main goal of Research and Development (R&D) in developing country became to enable rural innovation.

During the last decades, soil fertility became the watchword in Agricultural Research and Development (ARD) in SSA and in the agendas of policymakers (e.g. African Fertilizer Summit in Abuja, Nigeria in 2006 and NEPAD, CAADP1, 2003) and donors (e.g. AGRA program financed by the Bill and Melinda Gate Foundation and the Rockefeller Foundation).
Therefore, to achieve this goal, there is a need to understand how innovation happens and unfold. Still, very little is known about the innovation process involving multiple stakeholders and little research had been done into what each farmer contributes.

Endrias *et al*. (2013) conducted study on the determinants of farmers' decision on soil fertility management options for maize production in southern Ethiopia. Desta (2012) also had undertaken his study on the determinants of farmers" land management practices in south west Shewa zone. Moreover, many examples of successful studies were conducted. However, none of them have thoroughly linked the problem of soil fertility depletion with farmer's knowledge.

Hence, in order to design more appropriate research and development programs geared to improving soil management practices, researchers need to understand farmers' perceptions of soil fertility (Corbeels *et al*., 2000). So this study is intended to fill the gap in existing literature regarding this silent form of farmer's perceptions on soil fertility status, classification and management practice and comparing them with the criteria of soil fertility used by researchers in small holder farms of Kumbursa village, Ada'a District, Central high lands of Ethiopia.

To achieve the stated objective, both primary and secondary data were collected. soil samples were taken at the depth of 0-15 cm and 15-30 cm and the selected physical and chemical parameters were analyzed in Debire zeit Agricultural Research center to determine the soil fertility status of the study area and results have been compared with the result of farmer‟s perception. SPSS (Version-20) was employed to analyze the overall numerical values.

1.3 Objective of the study

1.3.1 General objective

The general objective of this study was to assess farmer's perceptions on soil fertility status, classification and management practices in comparison to scientific practices in small holder farms of Ad'a district, central highlands of Ethiopia.

1.3.2 Specific objective

Based on the stated general objective of the study, the following specific objectives have been Formulated to:-

- assess farmers' perception and experience to define the status of soil fertility;
- identify the major indicators given by farmers to classify the status of soil fertility;
- assess farmers' major soil fertility management practices;
- document farmers perceived value of soil fertility for crop yield;
- assess physical and chemical properties of soil on selected samples based on farmers'perception and soil depth.

1.4 Research questions

Therefore, In order to achieve the above objectives the study attempts to answer the following research questions:

- What are farmers' experiences to define the status of soil fertility of their own soils?
- What are the major reasons listed by farmers for the change in the fertility status of soil at different farm land?
- What are the major indicators used by farmers to use particular soil management

practice?

- How many groups of soils there are based on the indicators used by farmers?
- How has the soil fertility management practices been carried out in the study area by farmers?
- Which soil fertility management practice is common in the area?
- What is the value of each soil type for different types of crops produced in the area?
- Are all physical properties of the soil tested at different depth linked with farmer soil classification?
- Are all chemical properties of the soil tested at different depth linked with farmer soil classification?.

1.5 Significance of the study

Soil fertility management is critical for improving productivity of agriculture; thus contributing more for alleviating problems of food security. Soil fertility management is an important issue for small-scale farmers. Different stakeholders (Government and NGOs) involved in rural development are highly concerned with SFMPs to intervene in improving agricultural productivity and to maintain the existing soil fertility.So it is believed to contribute to achieving food security program.

Therefore, extension agents, researchers, non-governmental organizations and policy makers need to understand soil fertility management practices used by farmers and the determinants of using various soil fertility management practices to develop appropriate technologies and design effective policies and strategies that enhance soil fertility and productive land use. Generally, the finding of the study can play an important role for government on the assessment of farmer's perception of soil fertility status, classification and management practices in small holding farms.

Therefore, extension agents, researchers, non-governmental organizations and policy makers need to understand soil fertility management practices used by farmers to develop appropriate technologies and design effective policies and strategies that enhance soil fertility and productive land use. The findings will be helpful especially for Ministry of Agriculture (MoA) and respective agricultural institutions in planning and decision making in the future. It will also serves as a baseline literature for further study.

1.6 Scope of the study

This study has spatial, temporal and analytical scopes. Spatially this study is limited and undertaken in Kumbursa *village*, Ada'a district, and central highlands of Ethiopia. The study consider only a onetime data collected in 2016/17 through structured questionnaries and focus group discussion to gain insight into soil fertility management practices, local methods used to assess the fertility status of a field, and perceived trends in soil fertility,and soil samples were taken for physicochemical analysis in a laboratory. The study encompasses rural farmer households and carried on the assessment of farmers' perception about soil fertility status, classification, management practices in comparison to scientific practices in small holder farming. The extent of the research is very limited to an area.

1.7 Definition of Soil Fertility and Related Terms

Soil fertility: In its broadest sense, soil fertility can be seen as a combination of soil chemical, physical and biological factors that affect the potential of land (Wopereis & Maatman, 2002). It can be also define as the capacity of the soil to supply nutrients to the plant. Soil fertility differs in the landscape because of natural processes, such as wind erosion and dust deposition, erosion and sedimentation of soil particles with moving water and due to human interventions such as fertilization, burning vegetation, grazing livestock etc (Wopereis & Maatman, 2002).

Farmers perception: Perception is closely related with attitudes. It is the process by which organisms interpret and organize sensation to produce a meaningful experience of the world (Lindsay & Norman, 1977). Farmers are challenged with various management and production situations. They interpret the situation into something meaningful to them based on prior experiences. However, what an individual farmer interprets or perceives may be significantly different from reality.

Indicators: Indicators are criteria or measures against which changes can be assessed. They may be pointers,facts,numbers,opinions or perceptions used to point out changes in specific conditions or progress towards particular objectives (CIDA,1997).

Soil color: Soil color is the most understandable and simply determined soil characteristic. It is one of the important basic properties which helps to identify the kinds of soils and recognize the successions of soil horizons or layers in soil profiles. It has long been used for identification of soil and qualitative measurements of soil properties and is a supportive field soil property for soil type characterization (Noshadi *et al*., 2013).

Texture: Soil texture is essential aspect of the soil and the one most often used to characterize its physical make-up, having a bearing on such soil behaviors as nutrient and water holding capacity, organic matter (OM) level and decomposition, aeration, infiltration rate, drainage and/or permeability and workability (Hillel, 1980; Sys *et al*., 1991a).

Kebele: The *kebele*, also referred to as a peasant association, is the smallest administrative unit of Ethiopia. It is part of a district, itself usually part of a *Zone*, which in turn are grouped into one of the Regions based on ethno-linguistic communities that comprise the Federal Democratic Republic of Ethiopia (FDRE, 1997).

Village: A *village* is a clustered human settlement or community smaller than a town, with a population ranging from a few hundred to a few thousand(FDRE,1997).

1.8 Limitation of the study

Anumber of problems need to be noted regarding the present study. The main limitatioins are time and soil laboratory. The data that used in this research was generated through field survey, and laboratory analysis. So that, for laboratory test and result analysis, time was a critical constraint. The other constraint was limited access to soil laboratory. Addis Ababa University has soil lab but there is aproblem of chemical. So getting soil laboratory center that can give all the result on time is the major problem. Because of these two major problems the researcher has been forced to reduce the number of chemical properties that are needed to be tested. Further research would have been more convincing if the researcher have better time and relate more physical and chemical properties of soil with farmers perception.

1.9 Organization of the Study

This thesis is organized into five chapters. The first chapter encompasses introduction part and it consist background, statement of the problem, objective of the study, significance of the study , scope and limitation of the study. The second chapter deals with review of literature which includes theoretical, conceptual frameworks on farmer’s perception on soil fertility status and physical $ chemical properties of soil have been reviewed. The third chapter is devoted to brief description of the study area and a thorough explanation of the methodologies employed for data collection and analysis. Chapter four deals with the results and discussion and finally chapter five present conclusion and recommendations of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The literature review pointed out that most of the research work about farmers perception on soil fertility done till now has been only limited to developed countries like United States and other developing countries. But research is still inadequate in case of Ethiopia. It was also observed that, hardly any extensive study has been carried out in Ethiopia to examine the insight of Farmers.

Further, the existing studies have focused their attention predominantly on the usage of chemical fertilizer or organic fertilizer and their effects on soil fertility but mostly discounted the impact of farmer's perception on soil fertility. The contemporary study considers the factors like farmer's perception, different soil fertility management practices, soil color, soil texture, soil depth and soil chemical property. It also evaluates the present status and developments of soil fertility in Ethiopia.

In this chapter definition of soil fertility and related terms, soil fertility management practices, soil fertility in Ethiopia, indigenous knowledge of soil fertility and its management,soil classification,relation ship between soil fertility and crop productivity, determinants of soil fertility status and conceptual framework of the study are presented.

2.1 Indigenous Knowledge of Soil Fertility and Its Management

Indigenous knowledge refers to farmer's perception about their social and natural environment, which they use to adopt, adapt and develop technologies to their local environment (Teklu & Gezaheny, 2003). Indigenous knowledge of soil is defined as the knowledge of soil properties and management Practices possessed by people living in a particular location for some period of time (Winklerprins, 2002).

Taye and Yifru (2010) study on assessment of soil fertility status with depth in wheat growing highlands of southeast Ethiopia originate that farmers in the study areas have their own common criteria to evaluate and identify their soils. In order to classify soil in to different groups they use soil color, texture, water holding capacity, workability and fertilizer requirement as criteria. Corbeels *et al*. (2000) also study about Knowledge of farmers on soil fertility and local management practices in Tigray region of Ethiopia and reported that farmers use appearance of some weed species (Echinipshispidus and Xanthium spinosum*)*, rocky out crops and crop wilting as sign of soil fertility decline or low soil fertility in Tigray region. They classified their land into three classes: reguid meriet (fertile), mehakelay meriet (moderately fertile), and rekik meriet (infertile). Based on soil colour and texture farmers in the region distinguish between four different soil types. These are walka or tselim meriet (black, clay soil), keyih meriet (reddish, medium-texture soil), andelewayi (brownish, medium-texture soil) and bahakal (light coloured, lightly textured soil). Similarly, in the Siaya District of Kenya, farmers base their classification of soil on the surface layer, taking into account the colour, texture, and heaviness of working (Mango, 2002). In southern Rwanda also soils classified into nine based on criteria such as crop productivity, soil depth, soil structure, and soil colour (Habarurema & Steiner, 1997).

According to Barry and Ejigu (2005), based on their study conducted in Wolaita, farmers rank the best soils as those which require little input to enrich them, the current fertility of a soil depends very much on nearness to the home, and therefore the amount of manure received, and overall soil management. Soil are classified as fertile where it comprises high organic matter and clay content, adequate supply of growth factors, large supply of plant nutrent,high water holding capacity , high infiltration rate and high biological activity with neutral PH where as infertile soils have low organic matter content, presence of cementing materials (Al,Fe2o3 heavy clay) and low biological activity,physical ,chemical and biological limitation ,low PH ,high PH and shallow in depth (Mrema et al. ,2003).

2.2 Soil Classification and Soils of Ethiopia

2.2.1 Soil classification: An overview

According to Ahn (1993), classification of soil is a technique whereby soils are grouped together in different ways and according to various criteria to categories on the basis of pedogenic differences and similarities. Soils classify in to groups at varying levels of generalization according to their physical, mineralogical, and chemical properties (Buol *et al*., 2003).Soil classification is one of the most important phases in natural resources assessment and soil map is one of the basic tools for planning any agricultural development (Rabia *et al*., 2013).

Today, there are different approaches and classification schemes in the world like USDA Soil Taxonomy, USSR, Australian, Canadian, South African, etc, and most have been on a national basis (Foth, 1990). The classification systems differ one from the other because they are based on different appreciation of soil formation, use different criteria, and different hierarchical sub-divisions.

Soil scientists classify soils by several systems of classification and taxonomy. Formerly, the classification of soil at national level was based on easily identifiable features and relevant soil properties for cropping. Soil-type names were commonly well understood by farmers. Even on a higher classification level, the division into zonal soils (mainly formed by climate), intrazonal soils (mainly formed by parent material or water) and azonal soils (young alluvial soils) was easy to understand for farmers (Foth, 1990).

The most common soil classification systems used worldwide are the FAO/UNESCO soil map of the world and the USDA Soil Taxonomy of the United States (Buol *et al*., 2003).These classification systems are also commonly used for all soil studies in Ethiopia. Knowledge of either system makes use of the other system possible with minimal adjustment (Foth, 1990). According to the modern FAO/UNESCO classification the total land surface of the world is covered by soils of humid tropics, e.g. Ferralsols (Oxisols), etc.; soils of arid regions, e.g. Calcisols (Calcid), etc.; mountainous soils, Leptisols (Umbrept); soils of steppe region, e.g. Chernozems (Udolls); Podzols (Spodosols) and similar soils; Clay soils of subtropics, Vertisols (Vertisols).

2.2.2 Soils of Ethiopia

The types of soils in different region of Ethiopia are different. This is occured due to high variation in soil forming factors such as climate, topography, parent material and vegetation from place to place (Hurni *et al*., 2007). According to the study of FAO (1998), there are 19 major soil groups in Ethiopia. These major types of soils include Leptosols (14.7%), Nitosols (13.5%), Cambisols (11.1%), Vertisols (10.5%), Xerosols (4.8%), Soloncacks (4.1%), Fluvisols (7.9%), Luvisols (5.8%), Regosols (12.0%), Acrisols (5.0%), Yermosols (3.1%), Phaeozemes (2.9%), Rendizinas (1.5%), Andosols (1.2%), Arenosols (0.81%), Gleysols (0.47%), Histosols (0.42 %),Solonetz (0.04%) and Chernozems (0.07%).

In addition to the above soil types Mulugeta and Sheleme (2011) at the Kindo Koye Watershed shown the existence of Ultisols, Inceptisols and Entisols soil orders of the USDA Soil Taxonomy along the toposequences in an area that was previously mapped as Eutric Nitosols, respectively. These were further categorized as Acrisols, Cambisols and Fluvisols major groups according to the FAO/WRB Classification Legend, respectively.

2.2.3 Fertility status of Ethiopian Soil

Reports of field trials carried out before 1966 were limited. In 1968 Murphy published a valuable report on the fertility status of specific Ethiopian soils. Altogether about 2200 soils wily distributed all over Ethiopia were collected and carefully analysed. According to Murphy about 79% of the soils were under medium to high range in total nitrogen, 60.5 percent medium to high in available phosphorus and over 90 percent high in available potassium. For the Central Highlands his figures show adequate amounts of nitrogen and potassium and low amounts of available phosphate.

As recently as 1966 figures on the fertility of Ethiopian soils was somewhat sparse and scattered. They were repeatedly described as fertile but this was not supported by yields. Now Agriculture in Ethiopia has long been a focus of national policy such as Agricultural Development Led Industrialization (ADLI) and different large scale programs such as the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (Alemayehu, 2008).

Spielman *et al*. (2011) reported that when measured in terms of quantity, the use of fertilizer in Ethiopia has increased from 250,000 tons in 1995 to 400,000 tons of product in 2008. But Ethiopia faces a wider set of soil fertility issues beyond application of chemical fertilizer which has historically been the most important focus for extension workers, researchers, policymakers and donors. These issues relate with loss of soil organic matter, macronutrient (N, P & K) and micronutrient (Fe, Mn, Zn, Cu, B, Mo and Cl) depletion, topsoil erosion, acidity, salinity and deterioration of other physical soil properties (Gete *et al.*, 2010).

2.3 Soil fertility and crop productivity

Soil fertility is the major component of overall soil productivity that deals with its existing status of nutrient, and its ability to offer nutrients out of its own reserves and through external applications for crop production. It is a combination of several properties of soil (biological, chemical and physical), all of which has its own effect on nutrient dynamics and availability directly or indirectly (Woodfine, 2009).

The whole world in general and developing world in particular, need reliable information and knowledge on soil fertility and agriculture productivity which are the most challenging issue of rural livelihoods. In order to attain sustainable crop production improving crop nutrition through approperiate soil fertility management is highly essential.

Numerous studies have found that, most of African countries encountered different factors that make agriculture challenging and inturn reduce crop productivity. Poor soil fertility management practice is the one that decrease productivity, in certain parts of the Continent and at large it may force large regions of marginal agriculture out of production (Woodfine, 2009). Ethiopia is also among the countries in SSA that is largely challenged by different factors that affect its agricultural sector productivity.

Generally,crop production is highly dependant on the level of soil fertility. However, only a small portion of world soils has a very good level of fertility. Most soils have only well to medium range of fertility and some have very low fertility, and are often stated as marginal soils. Commonly such areas should not be used for cropping but only for grazing in a controlled manner.

2.4 Determinants of Soil Fertility Status

There are Several factors that contribute to the decline on fertility status of Ethiopian soils.The major one is land degradation because of great deforestation, human and livestock population pressure, inadequate use of crop residue and animal dung and little or no use of modern technologies to restore soil fertility (Taye & Yifru, 2010). The most important determinant factors of soil fertility status are morphological,physical and chemical properties of soil. Different physical and chemical properties of the soil relate one to another and hence, the presence of one can indicate the status of the other (Brady & Weil, 2004).

2.4.1 Morphological properties

In order to place a soil in its perfect position in the classification system, a detailed knowledge on its morphological characteristics is necessary. Morphological properties of soil are the most important tool than physical and chemical properties of soil in soil classification because it is perceived under natural undisturbed condition (Sharma, 2002).

1) Soil color

One of the most important properties which support to identify the kinds of soils and recognize the sequences of soil horizons or layers in soil profiles is Soil color. It has long been applied in order to identify soil and for qualitative measurements of soil properties and is a supportive field soil property for describing soil types (Noshadi *et al*., 2013).

According to Wakene (2001), color of each soil type is a function of pH, redox reaction and organic matter content. A change in soil color from adjacent soil also indicates a differnce in the mineral origen of soil (parent material) or in soil development (Sharma, 2002), geologic origin and degree of weathering of the soil material, and leaching or accumulation of chemical compounds such as iron, which may seriously influence the quality of soil (Fisher & Binkley, 2000).

Hossain *et al*. (2011) also stated that the alternate wetting and drying conditions in the soils lead to the reduction and subsequent release of iron oxides, which were stored in the form of brown, light olive brown, dark brown and dark yellowish brown mottles in the middle zone of the soil profiles. Dark color (low chroma) of soils could be related to the strong impregnation of the soil profile by organic matter in the course of pedogenesis or to prolong waterlogging (Dengiz *et al*., 2012).

2) Soil structure and consistence

Soil structure is highly affected by cation effect, interaction of clay particles, iron and aluminum colloids, organic matter and soil moisture conditions in the soil (Scott, 2000; Brady & Weil, 2008). Soil structure has a major impact on the capability of soil to support growth of plants, receive and store water and to resist soil erosion, and the dispersal of chemical of anthropogenic origin (Sumner, 2000). Ashenafi *et al*. (2010) stated that higher level of clay particle content in the soil could be reason for better soil structure development.

Six *et al*. (2000) reported that soil aggregate distribution and stability measurements have been proposed as indicators of soil quality. Aggregate dynamics of soil is mostly influenced by soil OM content and particle size distribution (Tobiasova *et al*., 2013).

Soil consistence refers to the action of physical forces of cohesion and adhesion on soil material attributes at these moisture contents that determines the resistance of soil material to crushing or rupture and its capacity to change the shape or to be moulded. Mostly consistence is described for three moisture levels; namely: wet, moist, and dry (Buol *et al*., 2003).

2.4.2. Soil physical properties

The physical properties of soils mainly control the water and air supplying capacity of soil's to plants and their adaptation ability to cultivation and the level of biological activity that can be supported by the soil. Many soil physical properties vary with changes in the system of land use and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion losses (Sanchez, 1976).

1) Texture

The size composition of elementary grains in a soil is referred as soil texture. It determines a number of physical and chemical properties of soils and has its own influence on infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Foth, 1990).

Atofarati *et al*. (2012) stated that the distribution of clay profile increased with depth and total sand fraction highest in topsoil may be as a result of clay eluviation – illuvation in the soil. The rate of increase in stickiness or ability to mould as the moisture content increases is a function of silt and clay particle content, the degree to which the clay particles are bound together into stable granules and the OM content of the soil (White, 1997). Over a very long period of time, different kinds of pedogenic processes such as erosion, deposition, eluviation and weathering can change the textures of various soil horizons (Brady & Weil, 2002). Berhanu (1985) reported that the Vertisols in Ethiopia generally contain more than 40% clay content in the surface layer (0-20 cm depth).

The silt to clay ratio is one of the indices used to assess the rate of weathering and determine the relative stage of soil development. A ratio of silt to clay below 0.15 is considered as low and indicative of an advanced stage of weathering and/or soil development while >0.15 indicates that the soil is young containing easily weatherable minerals (Young ,1976).

2) Bulk, particle densities and total porosity

Soil bulk density shows the compactness of the soil (Debela *et al*., 2011). It has inverse relationship with the amount of pore space and soil organic matter content. Textural differences between soils influence the value of bulk density (for example, clay, silt clay and clay loam surface soils show low bulk density as compared to sands and sandy loam soils which show high bulk density values) (Gupta, 2000). Bulk density of a soil increases with the increase in soil profile depth because of variations in organic matter content, porosity and compaction (Ahmed, 2002; Pravin *et al*., 2013).

White (1997) stated that values of soil bulk density varies from < 1 g/cm^3 for soils high in organic matter content , 1.0-1.40 g/cm^3 for well- aggregated loamy soils and 1.2 to 1.8 g/cm^3 for sands and compacted horizons in clay soils. Bulk density commonly decreases as mineral soils become finer in texture. Soils having low and high bulk density show favorable and unfavorable physical conditions respectively (Mitiku *et al.*, 2006). Low bulk density values (generally below 1.3 gm cm^{-3}) indicate a porous condition of soil (FAO, 2006).

Soil Particle density refers to the average density of the soil particles not including fluid or pore space and commonly stated in grams per cubic centimeters (g cm^{-3}). The particle density for various mineral soils ranges from 2.60 to 2.75 g cm^{-3} (Hillel, 1980). Ahmed (2002) reported that surface soil layers possessed lower particle density values than the sub surface soil horizons. Soil porosity is also part of the soil volume, which is not occupied by solid particles, but occupied with water and air. Its rate generally varies from 30% in compacted subsoil to more than 60% in well-aggregated, high organic matter surface soils (Brady &Weil, 2008).

3) Soil Water Characteristics

Soil water content is the basic factor required in order to answer the wetness, quantity of water held in the soil, the amount of water absorbed before the beginning of surface runoff, and the amount of water a particular soil supply to maintain optimal growth (Kamara *et al.*, 1992). Soil water lubricates the soil permitting root penetration, essentially for microbial mobility and action, and it allows nutrient mobility (Sharma, 2002). Thus, it can be said that water is a controller of soil physical, chemical and biological processes (Gupta, 2000). These processes, in turn, influence every part of soil development and behavior ranging from minerals weathering to the decomposition of organic matter, from the growth of plants to the pollution of groundwater (Brady & Weil, 2008).

According to Hazelton and Murphy (2007), the water-holding capacity of the soil is highly dependent on different soil properties include: particle size distribution (with coarse sands, clays, silts and fine sands holding the least water, the most and in the available water range respectively), the type of clay particles (montmorillonite or swelling clays holding more water than kaolinite type clays), the amount of organic matter in the soil, the bulk density and structure of the soil.

2.4.3. Soil chemical properties

Soil chemical properties are those soil properties which are responsible in the chemical reactions and processes of soil and are the result of soil mineral component weathering, decomposition of OM in the soil and the activity of plants and animals pertaining to plant and animal growth and human development (Kimmins, 1997; Sims, 2000). The chemical reactions that arise in the soil highly affects processes leading to soil improvement and soil fertility build up.

1) **Soil reaction and electrical conductivity**

Soil reaction (usually expressed as pH) is the measure of the concentration of H+ ions in the soil solution or degree of soil acidity or alkalinity, which is caused by particular chemical, biological and/or mineralogical environment. Thus, it is one of the most significant chemical characteristics of the soil solution because both higher plants and microorganisms respond to their chemical environment (Troeh & Thompson, 1993). values commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4-7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0) and very strongly alkaline (pH > 9.1) (Jones & Benton , 2003).

The degree and nature of soil reaction influenced by diverse anthropogenic and natural activities including leaching of exchangeable bases, acid rains, organic materials decomposition , use of commercial fertilizers and other farming practices (Brady & Weil, 2002). It also influenced by the response of different nitrogenous fertilizer absorption and releases of nutrients at the soil water interface (Mahajan & Billore, 2014). Most soil and plant organisms prefer pH range between 6.0 and 7.5 (Hazelton & Murphy, 2007).

According to Berhanu (1985), about 61% of the Vertisols have pH values between 5.5 and 6.7, 21% have pH values of 6.7-7.3, and 9% have pH values of more than 8. Organic matter decomposition can produce carbonic acid, carboxylic acid and inorganic acids (Brady & Weil, 1999) that causes acidic pH in the high organic matter content region.

2) Soil organic Carbon(SOC) and organic matter (OM)

Organic carbon is one of the most important components of crop yield, crop residue and other organic sources such as manure. Any living or dead plant and animal materials in the soil that contains a wide range of organic species such as humic substances, carbohydrates, proteins, and plant residues is referred as soil organic matter (Foth & Ellis, 1997). It is the source of nutrients for crops that maintain soil fertility and Crop productivity in farming systems. Soil organic matter is usually more or less uniformly distributed with depth in Vertisols (Getachew *et al.*, 2014).

Due to low amount of organic materials applied to the soil and complete elimination of the biomass from the field most cultivated soils of Ethiopia are poor in SOM contents (Yihenew, 2002). Organic matter, including total carbon content generally decreases with soil depth. This could be due to the association of humic substances with Ca forming Ca-humate (Abayneh & Ashenafi, 2006).

3) Nitrogen

The forth plant nutrient taken up by plants in highest quantity next to carbon, oxygen and hydrogen is Nitrogen (N) (Mesfin, 1998). Most of Ethiopian black or dark grey soils are N-depleted and more than 50% of cultivated land soils are N-responsive (Yihenew, 2002).

Nitrogen occurs in the soil in both organic and inorganic compound form of which plants absorb N in its cationic form (NH_4^+) and anionic form (NO_3^-) and get readily available N forms from various sources. The major source in soil is bacteria and cynobacteria which fix atmospheric nitrogen, Precipitation, ground and surface water drainage (Mahajan & Billore, 2014). Average total N decreased with increasing depth from surface to subsurface soils (Nega, 2006).

Total N contents in Central highlands and Eastern lowlands of Ethiopia Vertisols are varied from 0.08 to 0.22% and the C: N ratio about 11-18. Furthermore, other research works (Tekalign *et al.*, 1988 & Mohammed, 2003) conducted in Vertisol of Ethiopia also indicate that N is the most deficient nutrient element than any other necessary element in these soils and has called for the application of inorganic fertilizers and need for a sound management of soil OM (Berhanu,1980).

As much as 93 to 97% of the total N in the soil is closely associated with OM (Meysner *et al.*, 2006). Mohammed *et al*. (2005) also indicated that the higher content of total N related with soil layers having high OM content, whereas the soil layers with lower total N had lower OM contents. Due to their low SOM content, most of the Vertisols in Ethiopian highlands have low total N content and there is a high crop response to N fertilizers in these areas (Desta, 1986).

4) Carbon to nitrogen ratio

Carbon (C) to nitrogen (N) ratio (C/N) is an indicator of net N mineralization and accumulation in the soil. Organic matter that is rich in carbon offers a large source of energy to soil microorganisms. Subsequently, it brings expansion of microorganism population and higher consumption of mineralized N. Dense populations of microorganisms inhibit the upper surface of the soil and have an access to the soil N sources. If the ratio is high there will be no net mineralization and accumulation of N (Attiwill & Leeper, 1987). They further noted that as decomposition proceeds, carbon is released as CO_2 and the C/N ratio of the substrate falls. Narrow C: N ratio at the surface soils of cultivated land occures due to higher mineralization of OC than N because of better aeration during tillage and increased temperature (Achalu *et al*., 2012).

5) Available phosphorus

One of a critical element in natural and agricultural ecosystems is Phosphorus (P). For the production of healthy plants and profitable yields its management need is second only to the need for the management of N (Brady & Weil, 2002). In Vertisols agriculture P is the most limiting nutrient Next to N (Finck & Venkateswarlu, 1982) and this holds true for Ethiopian soils including Vertisols when tested by chemical methods; yet, with the addition of P fertilizers, field crop P responses on these soils, particularly in the central highlands are low, even under improved drainage conditions (Tekalign *et al*., 2002).

Total P status of some representative major types of soil in Ethiopia is low (Piccolo & Huluka, 1985). 70% of Ethiopian highlands Vertisols are reported low in available P content which is below 5 ppm (Berhanu, 1985). There is high available phosphorus on the surface leyers of a farm land than the subsurface. This may be related to the application of animal manure, compost, household wastes like ashes and DAP fertilizer for soil fertility management (Awdenegest *et al.*,2013). Girma and Endalkachew (2013) also indicats that the high available phosphorus in top soil might be attributed to supply of external phosphorus and phosphorus carry over from fertilization.

6) Potassium

Next to N and P the third most essential element that plants require in the largest amounts is Potassium (Marschner, 1995). It is involved in photosynthesis, sugar transport, movement of water and nutrient, protein synthesis and starch formation (Zublena, 1997). Soils with greater proportion of clay minerals are high in K, the greater will be the potential K availability in soils (Tisdale *et al.*, 1995). Soil K is mostly occur in a mineral form and the daily K needs of plants are little affected by organic associated K, except for exchangeable K adsorbed on SOM. Jobbagy and Jackson (2001) reported that nutrients strongly cycled by plants, such as K, were more concentrated in the surface soil than nutrients usually less limiting for the growth of plants.

7) Exchangeable bases (K, Na, Mg and Ca)

The exchangeable base properties of soils have its own influence on plant nutrition and the desirability of the soil as a medium of growth. The levels of exchangeable cations is of great importance. For example soil structure and nutrient uptake by crops are highly influenced by the relative concentration of cations as well as their absolute levels (Landon, 1991).

Soils in the areas of high rainfall and in continuous cultivation and fertilization with inorganic N containing fertilizers are characterized by low contents of exchangeable bases and the consequent deficiencies of Ca, Mg and K (Saikh *et al.*, 1998). Conversely, Vertisols and soils with high OM content retain more basic cations, which are primarily dominated by exchangeable Ca and Mg (Eylachew, 2001).

In productive agricultural soils the predominant exchangeable cations are present in the order, $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$ (Berhanu, 1985). Research works conducted on soils of Ethiopia point out that exchangeable Ca and Mg cations dominate the exchange sites of most soils and mainly in total percent base saturation of Vertisols they contributes higher (Mesfin, 1998; Eyelachew, 2001).

8) Exchangeable acidity

Exchangeable hydrogen (H) and exchangeable aluminum (Al) are identified as soil exchangeable acidity. Acidity of a Soil occurs when acidic H+ ion occurs in the soil solution to a larger extent and when an acid soluble Al3+ reacts with water and results in the release of H+ and hydroxyl Al ions into the soil solution (Brady & Weil, 2002). As soils become strongly acidic, they may develop adequate amount of Al in the root zone and the amount of exchangeable basic cations reduced, availability of some toxic plant nutrient rise and the activities of soil microorganisms reduced, subsequent in accumulation of SOM, reduced mineralization and lower availability of some macronutrients like N, S and P and limitation of growth of crop plants (Rowell, 1994).

9) cation exchange capacity and percent base saturation

The Cation exchange capacity (CEC) of a soil is define as the ability of a soil to keep cations such as potassium (K^+), ammonium (NH^{4+}), hydrogen ($H^{+)}$, calcium (Ca^{++}) and magnesium (Mg^{++}) in a form that is available to plants (Ilaco, 1985). Cation exchange capacity is an essential parameter of soil because it provides an indication of the type of clay minerals exist in the soil, its capacity to hold nutrients against leaching and evaluating their fertility and environmental behavior. The content of soil exchangeable cations increased with increasing soil depth. The increment was due to the leaching of exchangeable cations and the strong association between organic carbon and CEC (Ashenafi *et al*., 2010).

10) Micronutrients (Fe, Mn, Zn and Cu)

Chemical elements necessary only in a very small amount for the growth of plants is called Micronutrients (Foth & Ellis, 1997). Micronutrients include the four cationic micronutrients *viz*; iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) and others like boron (B), molybdenum (Mo) and chlorine (Cl). In Ethiopian soils Copper is most likely deficient, Zn contents are variable and, Fe and Mn contents are at an adequate level (Abayneh, 2005). However, micronutrient elements are required in small amount, they are as necessary as the macronutrients and any decisions and recommendation of soil fertility without micronutrients is no longer complete (Nazif *et al*., 2006).

Although the role of micronutrients is well-known, the current fertilizer recommendation in Ethiopia is merely for macronutrients; continuous application of one or two macronutrients may deplete the soil reserve of other nutrients and limit crop yield (Yifru & Mesfin, 2013).

2.5 Soil fertility management

The major reasons for the decline in the fertility status of Ethiopian soils are extra pressure on land due to increased population, reduction in the amount of manure available for soil fertility. Though, farmers are responding to the decline in the level of soil fertility in various ways. Some of the ways are adapting their system of farming or shifting their social behavior and replying through action to improve the soil itself (Barry & Ejigu, 2005).

Major types of soil fertility management practices commenly applied by farmers are fertilizers, crop residues, leaf litter, composting, fallowing, soil conservation practices, alley cropping, Crop rotation, green manuring, cover crops and etc (Barry & Ejigu , 2005).

2.5.1 Fertilizers

Substances that are added to the soil inorder to correct the deficient nutrents in the soil are called Fertilizers. Fertilizers are divided in to two. These are namely chemical and organic fertilizers (Ezekiel, 2004). Farmers need to be familiar with the use of both organic and chemical fertilizers in a complementary manner rather than replace each other (Corbeels *et al*., 2000).

1) **organic fertilizer**

Organic fertilizers contribute directly to the accumulation of soil organic matter(SOM) and providing vital plant nutrients for plant, have the ability to hold water and serve as storage for dry season and especially supportive for sandy soils which contain nutrients in a small amount and they are also important for soil organisms. Compared with inorganic fertilizers nutrients are released slowly from organic resources and provide a continuous supply of nutrients over the cropping season (Mark et al., 2007).

Organic inputs used for soil fertility management commenly contains livestock manures, crop residues, woodland litter, organic refuse from household, compost, green manures, cover crops and any plant biomass harvested from the farm environment (Fairhurst, 2012).

a) **Manure**

Manure is a mixture of dung, urine, straw or leaves. The oldest and most commonly practiced means of nutrient replenishment in Ethiopia is manure (Mengistu, 2011). The quality of animal dung and urine is largely determined by the type of food that the animal is consuming (Laura & Rienke, 2004).

The content of nutrient in manure is highly influenced by the duration of storage and its contact with the rain. If the manure contacts with rain, it can be eroded. So manure has to be stored in a safe area. Balanced nitrogen and other macro and micro nutrients can offer from manure fermented for a long period of time (Mark et al., 2007). Application of manure has to be with cautious because excess use of manure may result in accumulation of salt and leaching (Mellissa & Sven, 2003). In the study area the common practices used in order to improve soil fertility as manuring is the use of animal dung, ash and household trash to crop land (Bogale, 2014).

b) **Green Manure**

An organic matter in which cover crops are ploughed while they are fresh and green is known as Green manure. When green manures mix with the soil, the soil gets nutrient and moisture that allows microorganisms to feed on it and the organisms improve the quality of the soil (Mellissa & Sven, 2003).

c) **Compost**

Compost enhances soil fertility by changing waste materials into nutrients and restores soil nutrients (Doug et al., 2013). Due to its balanced chemical composition and high water holding capacity Compost is better than chemical fertilizer (Laura & Rienke, 2004).

2) **Use of Chemical fertilizer**

Chemical fertilizers are those fertilizers whose chemical compositions are known. It can be applied in different ways and time. Fertilizers may spread over the whole field after ploughing of the land; it can be applied in rows next to the seed and can be used once the crop has grownup known as top dressing (Laura & Rienke, 2004).

In order to increase the productivity of crop fertilizers have a dominant role. But its availability to the majority of farmers is questionable. There is a well-known supply limitation which is related to foreign currency shortage at national level, lack of loan facilities and inefficient system of distribution (Anthony, 1990).

2.5.2. Minimizing losses of added nutrients

Nutrients added to the farming system in the form of mineral fertilizers or crop residues and manure can be recycled many times with good soil fertility management practices. Added nutrents can be lost through erosion, leaching and any other causes. The Losses of added nutrients can be reduced by water and wind erosion control measures, by reducing the effect of leaching, reducing gaseous losses through denitrification and volatilization and crop residue management (Shiferaw & Holden, 1998). For these problems effective soil and water conservations practices with active involvement of farmers are necessary. (Shiferaw & Holden, 1998).

2.5.2.1 Terrace

Terraces are channels made across a specific interval on contour lines to collect water that comes in the form of runoff and increase infiltration by controlling erosion. Terraces intercept and delay runoff for soil infiltration or direct it to an outlet at non erosive speeds (Ezekiel, 2004). Terraces are effective in areas threatened by soil erosion (Marcine, 2011).

2.5.2.2 Contour Ploughing

Contour ploughing is a ploughing practice following the contour lines. It is the inverse of up to down of the farming of the sloppy area. Contour ploughing can be applied in sloppy areas where the gradient of the slope is up to 10%. To safely discharge water from the contours in the steep slope area with >10% gradient contour ploughing should be go with other conservation methods like, grass water ways (Humberto and Ruttan, 2008).

2.5.2.3 Strip Cropping

Strip cropping is the cultivation of different crops with different erosion resistance capacity. One strip carries less resistant to erosion crops than the next strip which carries crops that are more resistant to erosion (Hill et al., 2005). Crops which are able to resist erosion are grown down slope so that they can absorb water and diminish the velocity of water (Ruttan, 1995). Mostly this method is effective on gentle slope < 7 % (Hill et al., 2005).

2.5.2.4 Cover Crops

Additional crops grown with the main crop to keep the soil against erosion is known as cover crops (Keven, 2012). Cover crops can fix and trap nutrients, rise organic matter to the soil, and decrease nitrate leaching, nutrient runoff, and soil erosion (Mark et al., 2007). In order to renew the quality of soil by adding organic matter and most importantly nitrogen using leguminous as a cover crop is the best method. If cereals are used as a cover crop it drops nitrogen loss by immobilizing nitrogen and avoiding leaching of nutrients (William, 2005).

2.5.2.5 Crop Rotation

Crop rotation is a system in which diverse crops are grown consecutively on the same field in alternate seasons or years (Humberto & Ratan, 2008). Crop rotation is applied to encourage soil fertility, decrease erosion, control pests and minimize financial risks that may create from the failure of crop. If farmers use legumes crops in crop rotation the availability of nitrogen increases because legumes can fix nitrogen from the atmosphere (Mellissa & Sven, 2003).

In addition to the above listed soil fertility management practices Allan (1965) reported that the appropriate falloing practice(for more than eight years) helps to improve the fertility level of soil. Similarly, Mansfield (1973) claimed that 15-20 years fallow period is required for soil recovery.

2.6. Existing literature gaps on the importance of local knowledge

In many parts of sub-Saharan Africa (SSA) the level of soil fertility is decreasing from time to time (Stoorvogel et al., 1993). In the past, most research comprised of trials to determine the appropriate amount and type of fertiliser required in order to obtain the best yields for particular soil types and specific agro-ecological locations. This approach emphasized on the use of external inputs and expensive technologies, and often ignored knowledge of farmers'and the resources at their disposal. Numerous studies undertaken to assess local knowledge of farmers about soil has primarily focused on documenting how farmers classify their soils (Talawar & Rhoades, 1997).

Less attention has been paid to understand farmer's perception about soil fertility status and management practices and how various physical, morphological and chemical properties of soil interact. Because of this many projects and policies of development have collapsed (Schoonmaker -Freudenberger, 1994). Since then, research has steadily moved to an approach based on local systems of knowledge, as they relate to definite locations and are based on experience and understanding of local conditions. Such systems are a source of place specific ecological information, and provide the key in order to understand farmers' conditions (Pawluk et al., 1992).

The objective of this study was to assess farmer's perception on the status of soil fertility and management practices in kumbursa village, Ada'a disrict, Oromia regional state. It then goes on to analyse how the dominant local systems of knowledge perceived the status of soil fertility and influence soil fertility management practices and at the last the farmers perception were compered with the scientific view.The insights from this study should make it possible to develop more appropriate practices for maintaining and enhancing soil fertility in the area.

2.7 Conceptual framework of the study

Farmers have deep understanding of their soils and there is a strong relation ship between farmers' assessment of soil fertility and scientific perspectives. Approaches to combination of farmers and scientific knowledge should aim at creating opportunities for the intensive sharing of knowledge and experiences, combined learning and mutual respect, involving farmers and scientists using truly participatory approaches are better than transferring messages (Engel, 1997).

A recommended framework of linkages for the integration of local farmers and scientific soil knowledge is given in Figure 1 below. The influence of these two knowledge systems constitute the main driving forces that controls farmer technical practices that give rise to existing agro-ecosystem structure and their dynamics. However, sharing common central concepts, both knowledge systems have gaps, that can be filled by each other through facilitating roles of different groups, especially the Agricultural Ministry, NGOs and other extension agencies, working in the district in a truly participatory manner (Barrios et al., 2006).

Generally, the conceptual framework of the study is designed based on the literature reviewed on the assessment of farmer's perception of soil fertility status and management practices on small holder farmers.

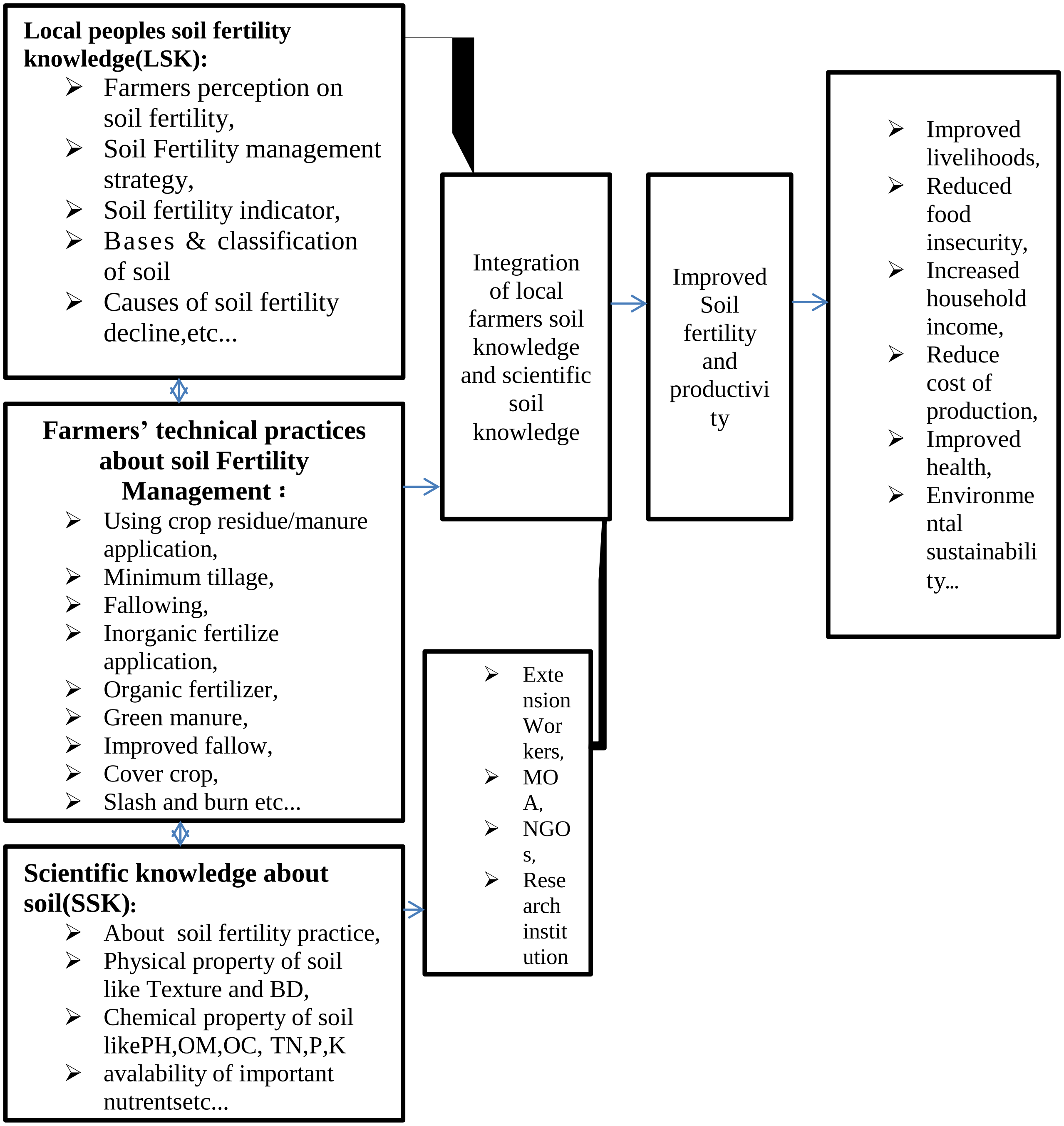

Figure 1 Conceptual Framework of the study

The above conceptual framework supposes that, successful soil fertility management practice adoption by farmers is a function of two major interconnected aspects; local farmers practice, and scientific Knowledge.This helps for improved soil fertility and productivity hence improved Livelihoods by reduced food insecurity increased household incomes and improved health. The study examines the perception of farmers about soil fertility and management practices.

CHAPTER THREE

Discreption of the study area Research Methods, Materials and Procedures

3.1. Discreption of the study area

Description of the study area is one of the essential components of any scientific study. Hence, the Oromia National Regional State, East Shewa Zone, Adea district and Ude *kebele* (study *village*) are briefly described in this chapter.

3.1.1. Geographical location

Adea district is located in Oromia National Regional State, East Shewa Zone, and South East of Addis Ababa in the central High lands of Ethiopia. The district capital town Bishoftu has the distance of 47km and 52km from Addis Ababa and Adama, respectively. Ada'a district is one of the 11 districts in East Shewa Zone of Oromia Regional State (ADOoLEP, 2015).

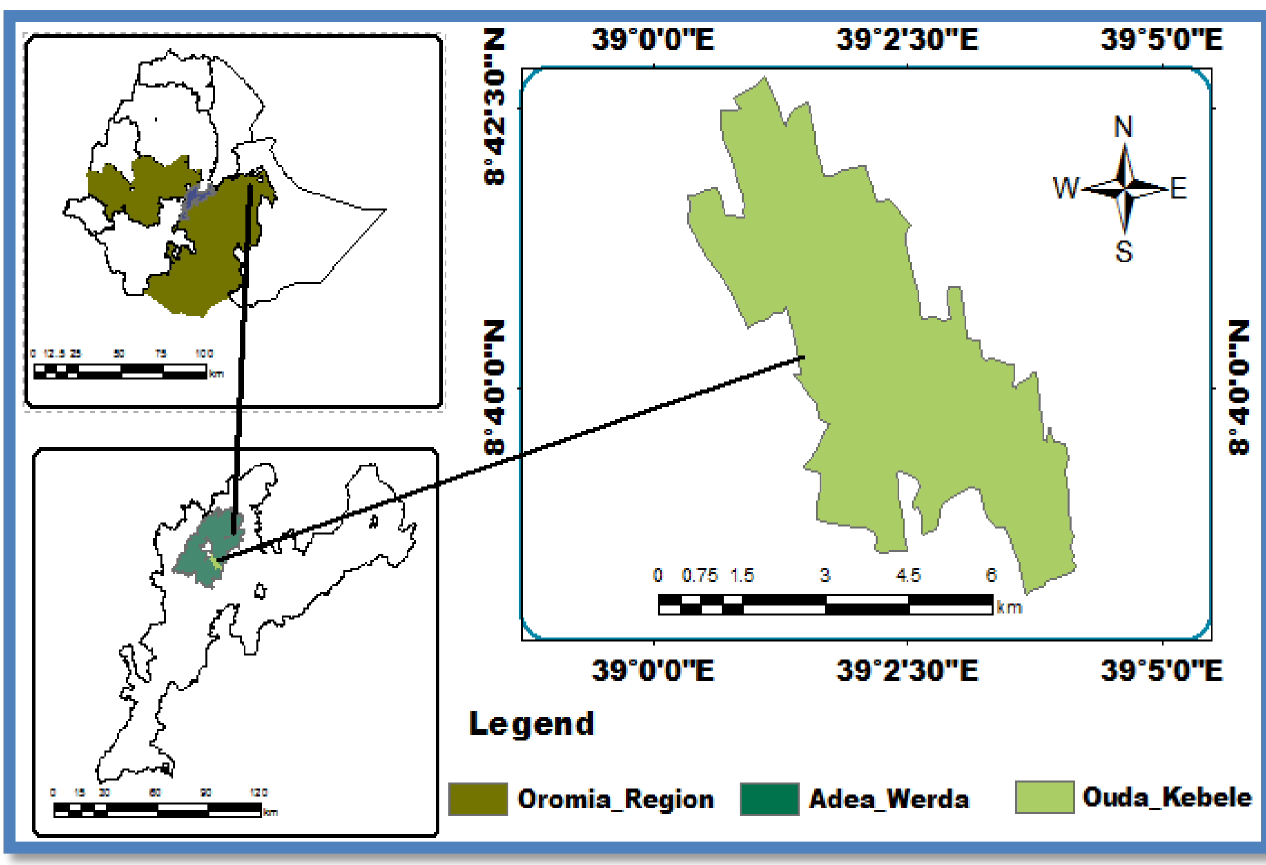

Figure 2. Location map of the study area; Author's skill map from Ethio GIS (2009), 2017

The total area of the district and Ude *kebele* is 89,430 ha and 2,448 ha respectively. Relatively, the district is bounded by Lume district in the East, Akaki Kality sub City in the West, Bora and Liben-Zukala district in the south and Ginbichu district in the north. Astronomically, the district is located at 8^0 40’ 0”- 8^o 42’ 30” North & 39^o 0’ 0”E- 39^o 2’ 30" East (Figure 2). The district constitutes a total of 23 Peasant Associations (PAs) and Ude is the Peasant association where the study *village* Kumbursa is found. Kumbursa is located at distance of about 55.5 km East of Addis Ababa.

3.1.2 Topography

The topography of Adea district is grouped in to three; namely, Mountain (10%), rugged topography (65%), and flat land (25%) (ADAO, 2015). The relief of Ada’a district varies with an altitudinal ranges of 1800 to 2400 masl while the altitudinal variations of Ude *kebele* rages from 1908 to 2036 masl (Figure 3) and the study area Kumbursa has an altitude of 1888-1992 meters amsl (Bogale, 2014). The district is characterized by Dega and Weyena dega agro climatic zonation which ranges from 1500 to 3200 masl (Ethio GIS, 2009).

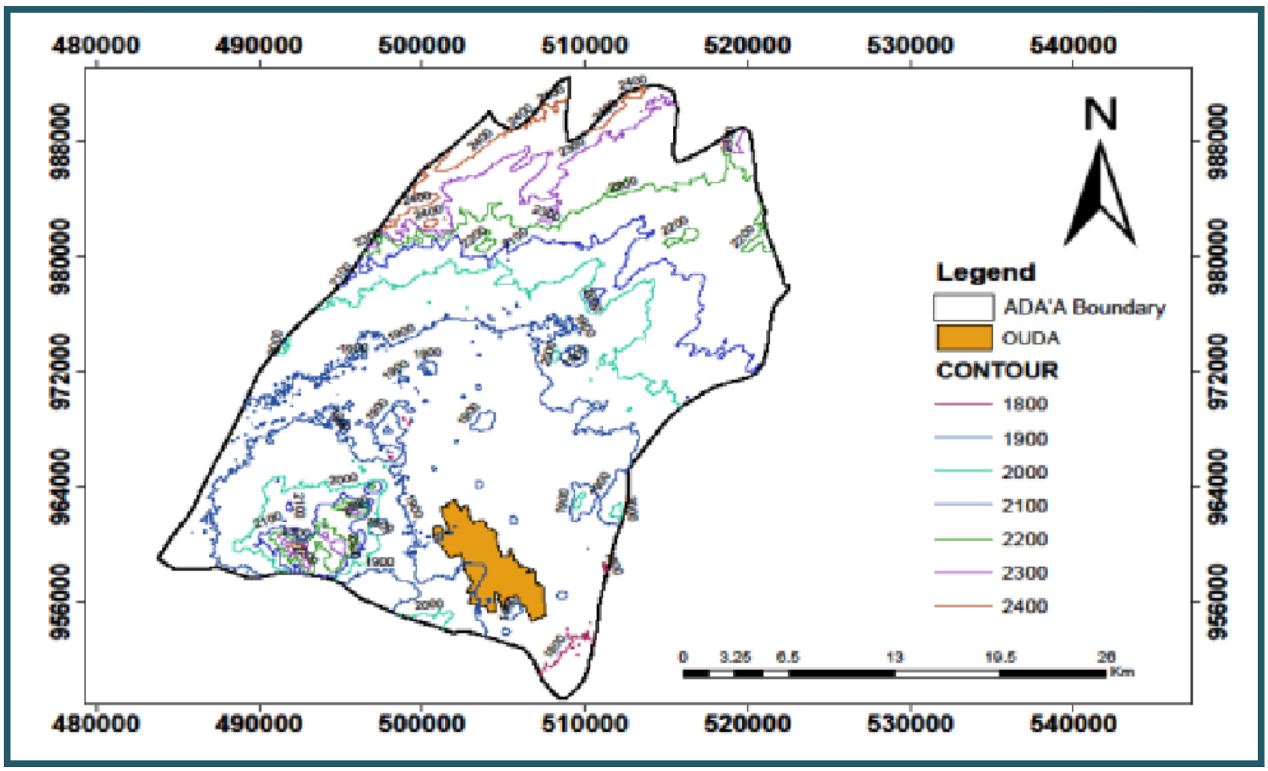

Figure 3. Contour map of the study area; Author’s skill map from Ethio GIS (2009), 2017

3.1.3. Temperature and Rainfall

Based on 51 years climate data (1965-2016), the mean minimum and maximum annual air temperatures of the district are 16.79 ^{0} C and 19.78 ^{0}C, respectively, with mean annual air temperature of 17.4 ^{0}C (Figure 4, Appendix E). Referring to the time series mean value, the warmer month was found to be May followed by April and March while the colder month of the time period was November (Figure 4).

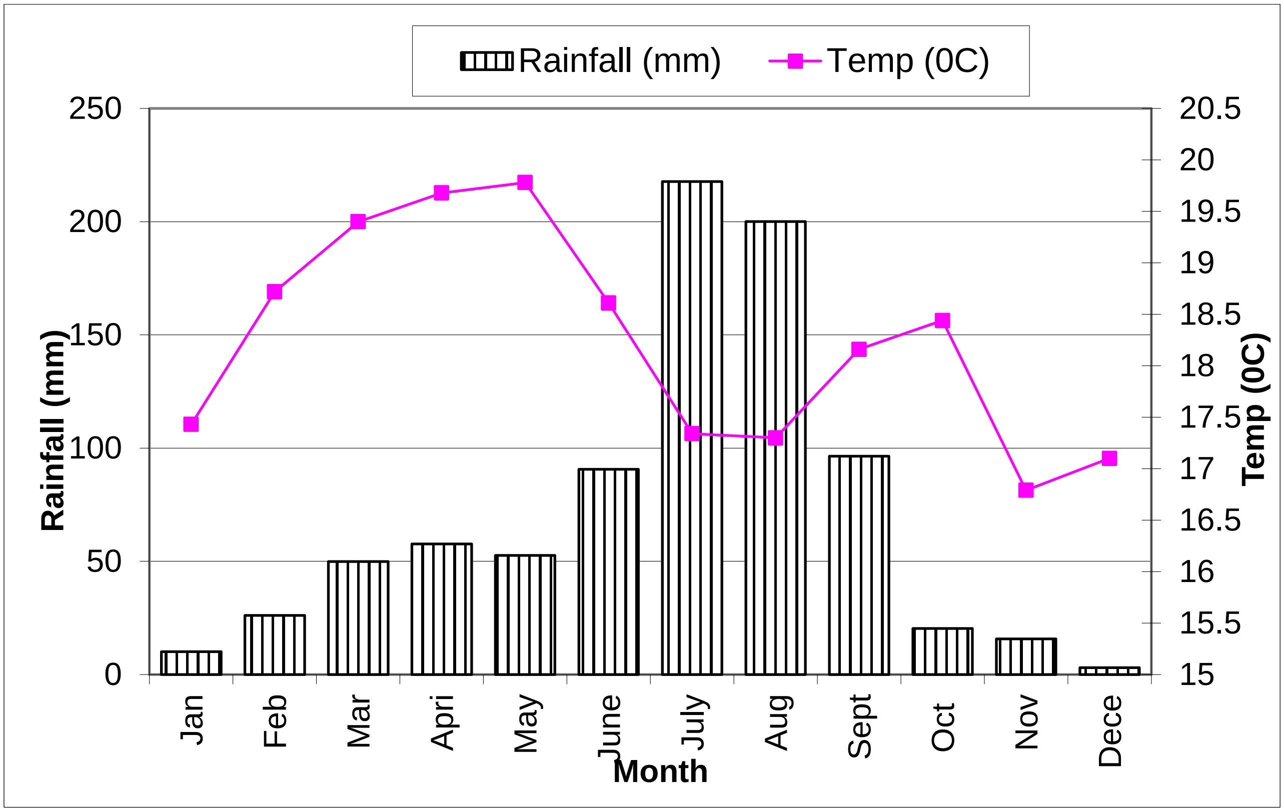

Figure 4. Mean Monthly temperature (^{0}C) and rainfall (mm) of Ada'a District, average of **51** years (1965 – 2016; DZMS, 2017)

Source: Deberezeit meteorological station

As per the information obtained from Debere zeit meteorological station most of the time the rainfall pattern for the growing season is characterized by uncertainty both in amount and distribution and starts from May if it is early or in half June if it is late and extending to September and the dry season covers the rest.

The main rainy season (summer) ranges from June to September when the ITCZ is to the North of the equator. The small wet season is usually occurring during the first two months of spring

(March to April). The average annual rainfall in Ada’a district amounts to 839.69 mm but varies considerably between years, and from an agricultural point of view it is actually unimodal, because farmers can only grow one rain-fed crop per year (Figure 4). The growing period lasts between 60 to 120 days. The main wet season takes place from March to September, with mean monthly rainfall varying from 3.07 to 217.1 mm with highest amount occurring between June to September (DZMS) (Figure 4 , Appendix D).

3.1.4 Vegetation

The land cover is dominated by scattered trees and shrubs which are found around settlements, farmlands, shrubs, trees and grasses in the enclosure areas. Important forests include the government protected Dirre-Garbicha, Tedecha and Ude community forests (Bogale, 2014). The vegetation in the area has been categorized under the Semi-humid woodland with a mixture of broad and narrow leaved species.The dominant climax vegetation types of the district are Juniprus forest, Juniperus woodland and Podocarpus forest (Genizeb, 2015).

3.1.5 Soil type

Ada’a district has six soil units; Chromic Luvisols, Eutric Cambisols, Luvic Phaeozems, Orthic Solonchaks, Pellic Vertisols and Vertic Cambisols which accounts 12066 ha (13.5%), 1248 ha (1.4%), 1409.6 ha (1.6%), 358.6 ha (0.4%), 53373.8 ha (59.6%) and 20974 ha (23.5%) of the total area respectively. The dominant soil unit of the district is pellic Vertisols which covers about 59.6 % of the district followed by vertic Cambisols and soil type of the study *kebele* (Ude) is vertisols (Ethio GIS, 2009) (Figure 5).

Vertisols is one of the most fertile soils, with good moisture holding capacity, but with water logging problems in those areas where the land slope is below 8% (IPMS, 2004). They are hard and crack during dry season and sticky when it is wet in the rainy season (summer). Texturally, the soils of the area are classified as sand silt (3%), clay (88%) and clay loam (9%) (Bogale, 2014).

The average soil depth is between 0.65 to 1.05m with medium infiltration rate and medium water holding capacity (OIDA, 2002).

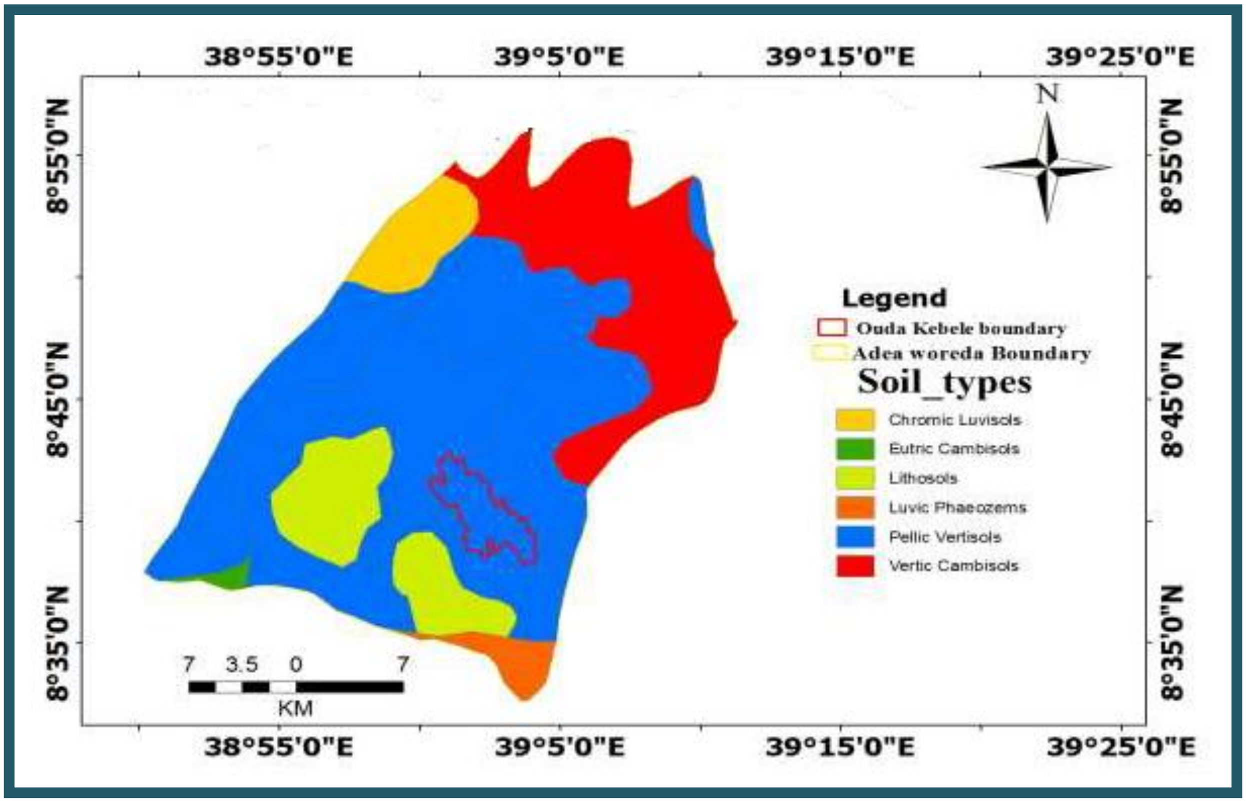

Figure 5. Soil distribution map of Ada'a woreda; Autors skill map from Ethio GIS (2009), 2017

3.1.6 Agro Ecology Zonation

The district is divided into two Agro Ecological Zones (AEZs); Dega (moist) and Woyena Dega (moist and dry). Moist Dega accounts 49 ha (0.05%) and Moist Woyena Dega and dry WoyenaDega accounts 67,344 ha (75.3) and 22,037 ha (24.6%) of the total area respectively. Therefore, the study *kebele (*Ude) falls under Moist dry Woyena Dega Ecological Zone (Ethio GIS, 2009) (Figure 6).

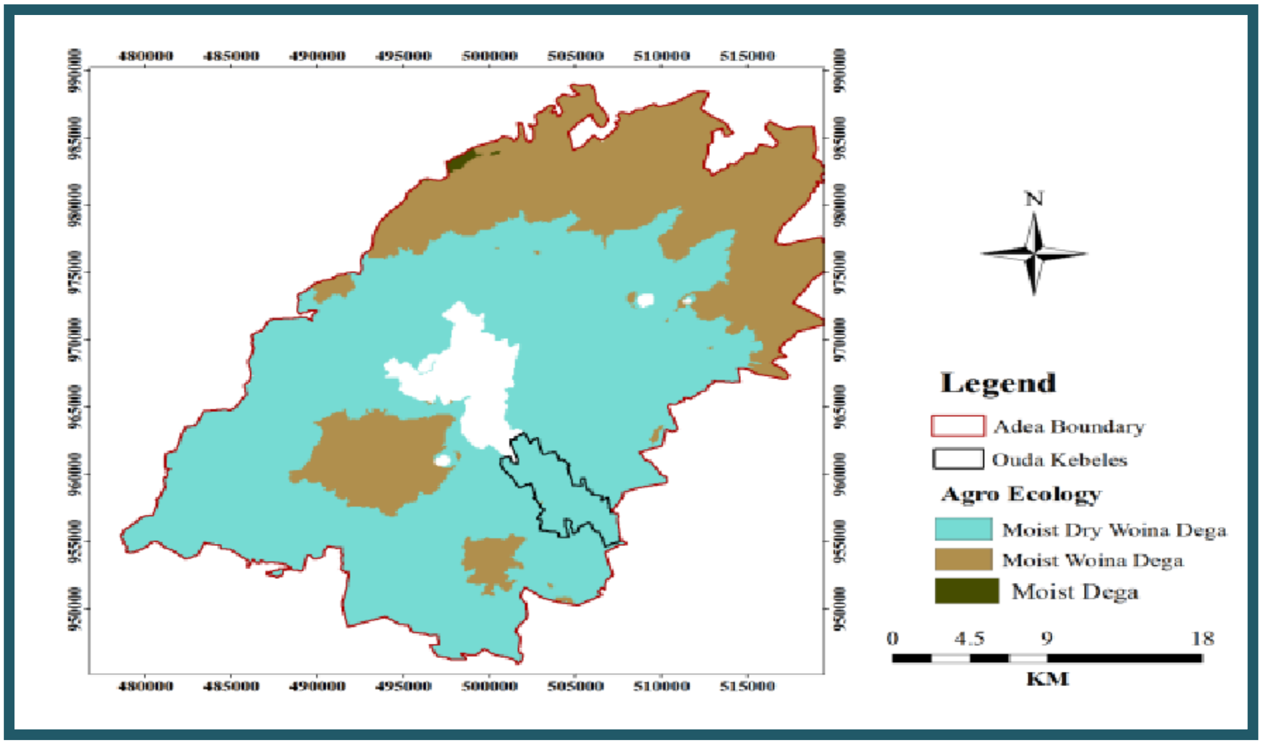

Figure 6. Agro ecological zone map of the study area; Author's skill map from Ethio GIS (2009), 2017

3.1.7 Land Use/Land Cover

The dominant Land use and Land cover (LU/LC) types of Ada'a district is cropland which covers 51% while degraded land (the land that is functionally lossen due to human disturbance), settlement/building, forest land, water body and pasture/grazing land account for 19.2%, 8.9%, 7.4%, 7.1% and 6.4% of the total area respectively(ADAO, 2015).

The land cover is dominated by scattered trees and shrubs which are found around settlements, in farmlands, and shrubs, trees and grasses in the closure areas. Important forest includes the government-protected Dirre-Garbicha and the Tedecha and Ude community forests (ADAO, 2015).

Table 1: Land Use Patterns of Ada’a district

No	Land use types	Area in hectar	Area in percent
1)	Crop land	45,609	51
2)	Degraded land	17,171	19.2
3)	Settlement/building	7959	8.9
4)	Forest land	6618	7.4
5)	Water body	6350	7.1
6)	Pasture/Grazing land	5723	6.4
Total		89,430ha	100

Source:- Compiled from ADAO, 2015

Land use and Land cover (LU/LC) of the study area (Ude *Kebele*) also dominated by Cultivated land which covers 85.5 % while Homestead area, Pasture/Grazing land, Forest land and water body account for 5.6%, 3.74%, 3.68%, and 1.53% of the total area respectively (Ude *kebele* agricultural Beuro, 2017). Table 2 below presents the different types of land-use patterns and the area they cover in Ude *Kebele*.

Table 2: Land use patterns of ude *Kebele*

No	Types of land use	Area in hectar	Area(%)
1)	Cultivated land	2093	85.5
2)	Home stead area	136	5.6
3)	Grazing land	91.5	3.74
4)	Forest land	90	3.68
5)	Water body	37.5	1.53
	Total	2448	100

Source: Ude *kebele* agricultural Beuro, 2017

3.1.8 Population

Total population of Ada'a district is 355,343 of these 175,788 are men and 179,555 are women; with the annual growth rate of 2.9%. And 142,866 or 40.2% of its population are urban dwellers which is greater than the Zone average of 32.1% (CSA, 2007).

Ada'a district has an estimated population density of 220.64 people per square kilometer, which is greater than the Zone average of 181.7(CSA, 2007). Ude peasant association has 852 households of which 277 households are in the study *village* /kumbursa (ADAO, 2014). Out of the total population of Adea district, the adult population were 183,002 (51.5 %), the young population were 164,524 (46.3 %), and the elder population were accounts for 7817 (2.2 %) of the total population (ADAO, 2015).

Based on the above information, the population pyramid of Adea district is wide at the base (bottom) and very narrow at the top. This in turn shows the emerging and flourishing young population with an increasing demand that can create pressure on resource uses. The age distribution of the Adea district population can be grouped as children (0-14), adult population (15-64) and elder population (above 64 years) (ADAO, 2015).

Table 3: Age Structure of Adea districtPopulation

No	Age group	Group of population	Frequency	Percent
1)	0-14	Young(children)	164,524	46.3
2)	15-64	Adult	183,002	51.5
3)	>65	Aged(Elder)	7817	2.2
Total			355,343	100

Source: Compiled from ADAO, 2015

3.1.9 Livelihood of the population

The main source of livelihood for farmers in the District is sedentary mixed farming. The People of the area practice different livelihood and income generating activities mainly crop production and animal husbandry. In addition to these activities, the people engage in petty trading, construction and daily labor in horticulture industries.

Crop production plays a major role in income generation in the area and cereals such as teff, wheat, pulse crops such as lentil and Chickpea are the major crops grown. The farmers also keep cattle, equine, but small numbers of sheep & goats are kept by few farmers (ADAO, 2015).

3.1.10 Farming system

Smallholder farmers manage crop and animal production in an incorporated way, to maximize returns from their limited land and capital, minimize production risk, diversify sources of income, and provide food security and increase productivity (Assefa, 2005).

The agricultural activities carried out in the area include crop production and animal husbandry with traditional and indigenous knowledge inherited farming practices and farm implements (*Maresha*). The farming system in the area is therefore, represented by close integration of crop cultivation and animal husbandry, where the production and productivity of one is not separated from the other (Bogale, 2014).

3.1.10.1. Crop production

The total agricultural land in Adea district is 46,923 hectares. Out of this, ten economically important crops cover 45,609 ha. The remaining cultivated land is occupied by the other productions. *Teff* and wheat production dominates the agricultural production system. Adea district is nationally known for its best qualify *teff* production, which dominates the agricultural production system (ADAO, 2015).

Pulse crops, particularly chickpea, are full-grown in the bottomlands and on residual moisture in selected areas. Lentil is also grown to a smaller extent. Horticultural crops, mainly vegetables are produced under irrigation. There are a number of rivers and lakes that are being used for irrigated agriculture, particularly for horticultural crops production. Currently, there is also a huge investment on flower cultivating factories in the area (ADAO, 2015).

Table 4: Adea district Ten Major Crops Areal Coverage in Hectares and Crops Production in Quintals

No	Types of crop	Crops and their areal coverage		Crop production	
		In Hectar(ha)	In percent(%)	In quintals(qt)	In percent(%)
1)	*Teff*	20,019	43.9	645,879	34.6
2)	Wheat	11,704.27	25.7	633,434.25	33.98
3)	Check peas	7,032.75	15.4	334,520	17.9
4)	Lentil	4568.96	10.02	184,207.9	9.89
5)	Fababeans	796.72	1.75	18,978	1.02
6)	Maize	380	0.82	21,976	1.19
7)	Haricot	314	0.68	6224	0.34
8)	Fieldpeas	304.3	0.66	4762.95	0.26
9)	Barley	249	0.55	7921	0.43
10)	Roughpeas	240	0.52	7146	0.39
Total		45,609	100	1,865,049.1	100

Source: Compiled from ADAO, 2015

3.1.10.2. Livestock production

Livestock production is an integral part of the production system under taken in line with crop production. Livestock plays an important role in the economy of small holder farmers. The total livestock population of Adea district is 366,476 (ADOoARD, 2015). Production of cattle, sheep, goats, donkeys, horses, mules, and poultry is a very common practice which accounts 25,629, 59,294, 34,241, 18,740, 19,224, 22,624 and 186,724 of the total livestock population respectively (ADOoARD, 2015).

Table 5: Livestock Population of Adea district

No	Type of livestock	Number of livestock	TLU	In percent(%)
1)	Sheep	59,294	5929.4	16.2
2)	Goat	34,241	3424.1	9.34
3)	Cattle	25,629	17940.3	6.99
4)	Mules	22,624	18099.2	6.17
5)	Horses	19,224	15379.2	5.25
6)	Donkeys	18,740	9370	5.1
7)	Poultry	186,724	1867.24	50.95
Total		366,476	72,009.44	100

Source: Compiled from ADOoARD, 2015

The animals are used as a source of milk, meat, eggs, honey, draught powers for cropping, fuel and soil fertilizer and for means of transport. Amount produced from livestock, such as milk, meat and eggs are important sources of food for the farm household. Sales of animal products and live animals are important sources of cash and means of savings.

3.2 Research Design

The study followed both qualitative and quantitative method of data collection and analysis. Research mechanisms such as sampling, household questionnaire, personal observation, key informant interviews, and focus group discussions were used to get trustworthy data. Soil sample laboratory analysis and document studying were also used based on the nature of the specific objectives of the study.

3.2.1 Selection of study site

According to Murphy (1968), soil in Central Highlands show adequate amounts of nitrogen and potassium and low amounts of available phosphate. It is suspected from the extensive erosion found in the area with low application of soil fertility management practices. Oromia region has the largest number of population in Ethiopia .Because of this Farmers application of appropriate soil fertility management practices becomes low especially in central high lands.

Ude *kebele* specifically Kumbursa village is select as a site for this research because of the fact that the study area is found in central highlands and has been identified as one of the areas strongly affected by soil fertility depletion with poor management practices (Bogale, 2014). So, on this study the researcher have tried to cooperate farmer's knowledge of soil fertility with scientific view for better soil fertility level.

3.3. Sampling Technique and Sample Size

Households of the village were classified in to three different wealth categories (rich, medium and poor), depending on the local community's criteria and the socio-economic conditions of the households in the village. The criteria used were land holding size, oxen number and the stock of grain for seed, consumption and market. The classification was based on the information collected from Ude *kebele* administration office.

Farmers in the ''rich''group possessed land > 3 ha, oxen ≥ 5, and had excess production[1] in stock to cover the requirements for seed, consumption and market, farmers in the ''medium'' group possessed 1-3 ha, 2-4 oxen and sufficient production in stock to cover the requirements for seed, consumption and market, and the ''poor'' group possessed land holdings <1 ha and owned one or no oxen, and had insufficient grain in stock for seed, consumption and market (Assefa, 2005).
Through stratified random sampling proportionally 13 households from the rich, 56 from the medium and 14 from the poor group were selected from the households of the village. The total number of farmers and the number of sample drawn were presented in Table 6.

Table 6: Total households and Sample size by wealth category, Kumbursa village, Ada'a district, central Ethiopia, 2017.

Wealth category	Total number of house hold heads			Number of sample households					
	MHH	FHH	Total	MHH	%	FHH	%	Total	% of the sample size
1)Rich	31	13	44	9	15.26%	4	16.7%	13	15.66%
2)Medium	126	62	188	38	64.42%	18	75%	56	67.46%
3)Poor	37	8	45	12	20.32%	2	8.3%	14	16.87%
Total;	194	83	277	59	100%	24	100%	83	100%

Source: field survey, February, 2017

[1] Excess production means the amount of production that is more than the usual or nessessary amount used for market or home consumption.

3.4. Data Types, Sources of Data and Methods of Data Collection

3.4.1 Types and Sources of Data

The study was based on both primary and secondary data. Primary data were collected from the sample farm households soil sampling, questioner, focus group discussion and interview. Secondary data, which are relevant for the study to back up the primary data were collected from different governmental sources available in the study areas such as CSA, ADAO, ADOoLEP, Das, ADOoARD and others. In addition to this, published and unpublished documents of different sources such as books, magazines, journals, reports, and articles were reviewed.

3.4.2 Data collection instruments

In order to capture the local indicators and farmers perception of soil fertility on the study site, participatory rural assessment tools (house hold survey questionery, direct observation, focus group discussion and interviews with key informants) were conducted. Field work was taken to verify some of the information and data gathered during the discussions and interviews. Issues that were immerged from observation were used to guide interviews and discussions with selected farmers. The following techniques were employed to collect the primary data.

3.4.2.1. Personal field Observation

At the beginning, based on the nature of data required a general personal field survey of the area was carried out by the researcher to have a general view of the study area. The observation encompassed visit of topography, vegetation cover, settlement pattern and the overall aspects of soil management practices of the study area. Thus, the researcher’s opinion based on her visit of the study area was included in the analysis**.**

3.4.2.2. Key Informant Interview

A key informant interview is important in getting information about farmer’s perception. Through such instrument, information regarding the views of experts from District Agriculture office and Development Agents (DAs) were collected.

Figure 7:Discussion with Development agents of *Ouda Kebele*
Source: Field photo by the author, February 2017

3.4.2.3. Questionnaires

To gather data about the perception of small holding farmers on soil fertility in the study area questionnaires were developed and administer to the farmers. The questionnaire had five parts. The first part of the questionnaire entertained general information regarding respondent farmers. Part two of questionnaire assessed farmer's perception on soil fertility level. Part three carried questions related to the most common soil fertility management practices in the study area. The Fourth part of the questionnaire assessed about soil classification made by farmers.The last part of the questionnaire examined major crop production with different soil types.

The questionnaire consisted of both close and open ended questions. The sampled households were selected through stratified random sampling from a list of total households collected from the representatives of the village (includes: household details and farming system, soil classification, crop and animal production, technology access, etc.) to gain insight into soil fertility management practices, local methods use to assess the fertility status of a field, and perceived trends in soil fertility. Questionnaires developed for this purpose was used after pretesting and improvement was made based on the feedbacks obtained from the pre-testing exercise to generate reliable data. During the household interviews, information was obtained on the family size, land holding size, number of cattle, types of crops harvested and source of off farm finance.

3.4.2.4. Focus group discussion

The focus group discussion was used as one of the critical sources of primary data in addition to the household surveys. One focus group discussion, involving 21 participants (7 participants from each wealth group) was conducted in the village with the help of development agents. For this, interview guide was prepared to get deep information regarding farmers perception of soil fertility status, local indicators used to classify soil and appropriate methods for better soil fertility management. Participants were composed of both men and women.

Table 7: The participants of Focus Group Discussion

No	Participants	Number of participants
1)	Rich farmers	7
2)	Medium farmers	7
3)	Poor farmers	7
Total		21

Figure 8: Interview with selected farmers
Field photo by the author, February 2017

Figure 9: Focus group discussion
With the help of DA experts

3.5 Research methedology phase

The overall activities of this study was classified in to three phases. The first phase was pre field activities. The second phase was field work and the last phase was post field activities(Figure 7).

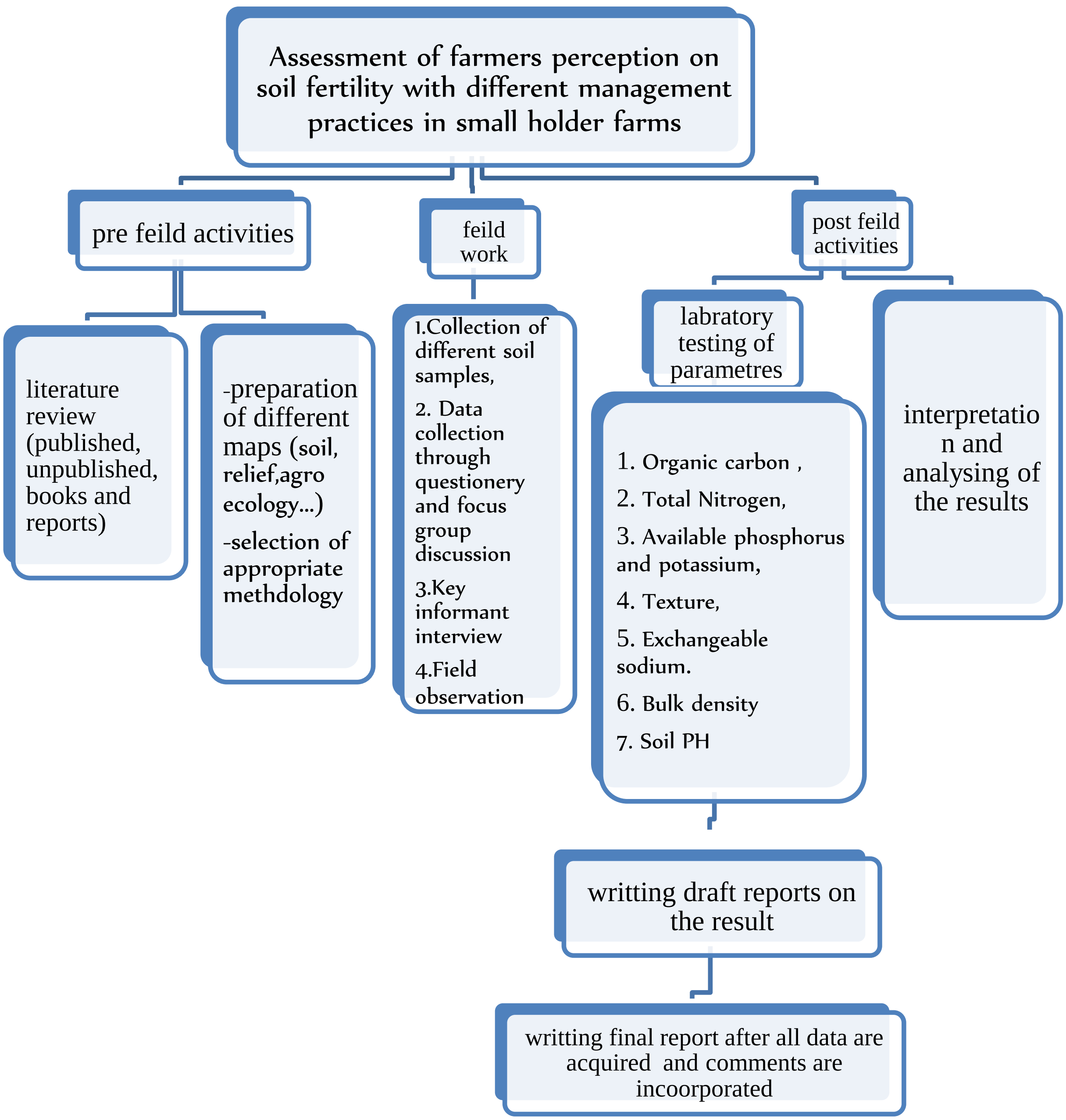

Figure 10. General Methodology followed for study

3.6. Soil Sample Preparation and Analysis

3.6.1. Soil sample preparation

From those interviewed farmers, a subset of 21 farmers were selected at random from three wealth groups and invited for focus group discussion and asked to indicate their most fertile, moderately fertile and and infertile field. Each of the fields was characterized according to its own physical and chemical property. 15 Representative soil sampling sites were purposely selected (5 from the most fertile soil, 5 from moderately fertile soil and 5 from infertile soil) based on cultivation history and indigenous local indicators of soil fertility groups using farmer's perceptions**.** Soil sampling was based on the soil fertility groups. In each soil group, Soil samples were collected with an auger at two sampling depths of 0-15cm (to represent the surface) and 15-30cm (to represent the sub surface) in February 2017. Thus, a total of 30 soil samples were collected at the two depths.

The soil samples were bagged, properly labeled and transported to the laboratory for preparation and analysis following standard laboratory analysis methods.Thus, soil physical properties (texture and bulk density) and chemical properties (pH, Na, available phosphorous, available potassium, organic carbon and total nitrogen, were taken, tested and analyzed. Fifteen holes were used to collect 30 samples on February at the study village.

Figure 11: Holes from which samples were Collected at the study area

Figure 12: Sample collection on the field

Source: Field photo by the author, February 2017

3.6.2 Method of Data Analysis

3.6.2.1 Soil Laboratory Analysis

3.6.2.1.1 Analysis of Soil Physical Properties

Hydrometer method (Gee & Bauder, 1979) was applied to determine soil texture distribution (clay, silt and sand) of the study area. Soil textural class names were assigned based on the relative contents of the percent sand, silt, and clay separates using the soil textural triangle of the USDA. Soil bulk density was determined from undisturbed (core) samples which were dried at 105 ^{0}C for 24 hours (Baruah & Barthaku, 1997).

3.6.2.1.2 Analysis of Soil Chemical Properties

Soil pH was measured potentiometrically using a digital pH meter in a 1:2.5 soil water suspension (Van Reeuwijk, 1992). Soil Organic carbon (OC) was determined by wet digestion method of Walkley and Black (Nelson & Sommers, 1982) and following the assumptions that SOM is composed of 58% carbon, the conversion factor, 1.724 was used to convert the OC in to OM (Walkley & Black, 1934). Total nitrogen was determined using Kjeldahl method (Bremner & Mulvaney, 1982 and Okalebo et al., 1993). Available phosphorus was determined colorimetrically using Olsen's method (Olsen, 1952). K and Na was measured using flame photometer (Chapman, 1965).

3.6.2.2 Statistical Data analysis and interpretation

Analysis of variance (ANOVA) using Statistical Package for Social Science (SPSS Version-20) were performed to show differences on the soil physicochemical properties at surface soils (0-15 cm) and subsurface soil (15-30 cm) of bad,medium and good soil groups and results were presented with mean, standard deviation and coefficient of variation.

Data generated by structured questionnaires were analyzed by using descriptive analysis such as mean, frequency, percentage to describe and investigate the characteristics of the farmers' perception. The data obtained from laboratory analysis were analyzed and summarized in to tables and graphs by using Microsoft office excel spreadsheet and Statistical Package for Social Studies (SPSS) version 20. Qualitative data generated from key informant interview, focus group discussion and secondary sources was analyzed by narrative description.

CHAPTER FOUR

Results and Discussion

This chapter focuses on analysis and interpretation of the collected data. This study was carried out during 2017 to assess farmers perception of soil fertility status, classification and management practices in comparison to scientific practices in the case of Ada'a district central highlands of Ethiopia. Data collected from the study area and laboratory analysis were subjected to statistical analysis and the results obtained are presented and discussed in the following sections.

4.1 Socio-economic and demographic Characteristics of the Sample Households

Socioeconomic characteristics of the household respondents were gathered from different perspectives. The reason why the study had incorporated such information was to provide general highlight about the demographic and economic situation of the respondents and later on to see how some of the attributes influence farmers' perception towards soil fertility status in the study area.

4.1.1 Sex and age of the respondents

Participants were composed of both sex selected from the entire three farmers wealth categories (rich, medium and poor). About 71.1% and 28.9 % of respondents were male and female headed house holds respectively. This showed that in the study area land possession was dominated by male.

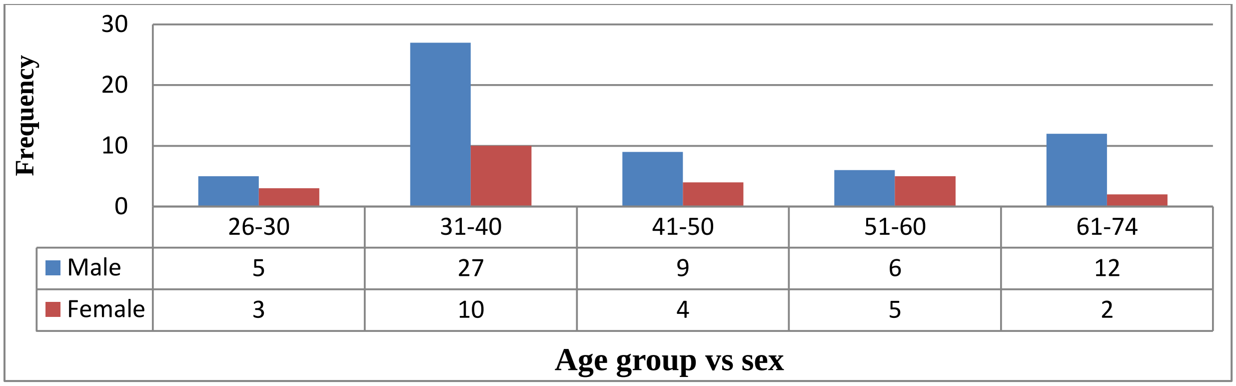

Figure 13: Percentage distribution of the respondents by their age and sex group, Kumbursa, 2017

The minimum age of the respondent was 26 while the maximum age was 74. The modal age group of respondents is 31-40 years old, accounting for 45.3 % of the respondents (Figure 8). This has indicated that the majority of the household respondents were grouped in the working age group. About 16.6, 15.8, 12.7 and 9.6% of the respondents were from the age groups between 61-74, 41-50, 51-60, and 26-30 respectively (Figure 8).

The average age of the respondents is 39 years. That means on average the respondents are in the category of active labor force, which could have positive implication in terms of coordinating family labor and soil fertility management.

Like age Farmers' duration of stay in the area helped them to observe changes through time. In this regard, about 5.7%, 14.67, 13.3% and 66.33 % of respondents have lived in the study area < 10 years , between 10-20 years, between 20-30 years and >30 years respectively.

4.1.2 Educational level

Education is an instrument used to enhance the quality of labor through improving the managerial skill and the tendency to accept new technologies. Therefore, education together with increased experience could enable farmers to better manage their farming activities. About 37.3 and 29.6% of the respondents was illiterate and read and write respectively, while 14.6 and 9.3 % of the respondents attended Junior high school and elementary school. Those with Secondary high school and higher education (diploma) educational level were only 8.6 and 0.6% of the respondents respectively (Figure 9).

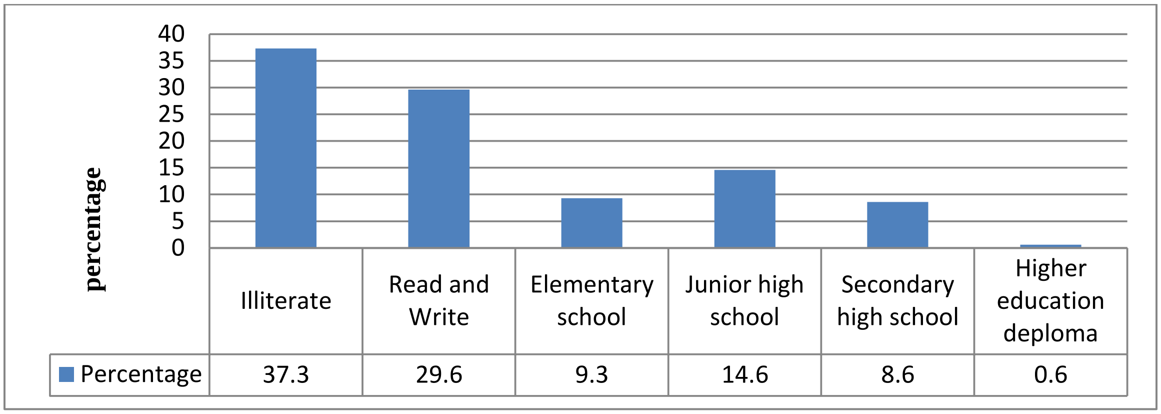

Figure 14: Percentage distribution of respondents by their educational level, Kumbursa, February, 2017

In general, the educational status of the sample HHHs is low. About 66.9 % of the respondents are illiterate and can read and write only. Because all the households are farmers and they do not have enough access to attend education. The other important reason behind is that with the low level of their economy at their disposal, they could not afford to continue their education. This, in turn, could have its own implication on household's perception and their management practices of soil.

4.1.3 Marital status

About 73%, 9.1%, 10.2%, 3.6% and 4.1% of the total respondents are married, widowed, Widower, divorced and single respectively (Figure 10). Since significant numbers of household heads (73%) are married, they may get the support of their spause so as to involve in management of their own soils, while the other groups (single, widowed,Widower and divorced) may be disadvantageous in this regard.

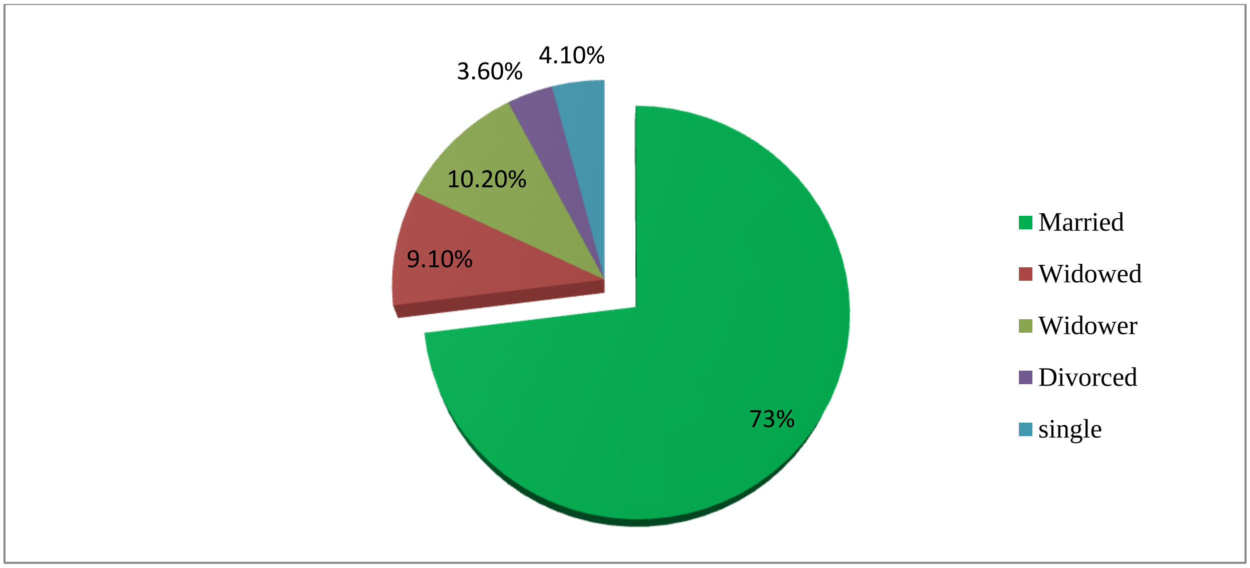

Figure 15: Percentage distribution of marital status of the respondents, kumbursa, February 2017

4.1.4 Family size

The total family size of the respondents was 650, of which male and female members of the households of the respondents were 312 and 338 respectively. The average family size of the respondents by wealth category is 9, 8 and 7 for poor, medium and rich respectively. The mean value for the respondents is 8 which are higher than the districts average family size of 7.39 persons per household in 2013 population projection of CSA and ranging between of 2 and 15 persons (CSA, 2013). Family size determines the labor force of the households, which are important in all agricultural activities.

4.1.5 Number of livestock

A Tropical Livestock Unit (TLU) is an animal unit used to aggregate different classes of livestock. One TLU equals an animal of 250 kg live weight (FAO, 1987). To convert different animals to TLU, the numbers of different animals were multiplied by the corresponding conversion factors as follows: cattle 0.7, sheep/goat 0.1, horse=0.8, donkey=0.5 and chicken=0.01(http://www.fao.org/wairdocs/ILRI).

Concerning the ownership of animals, 89.6% of respondents owned animals and the rest 10.4 % responded that they did not have animal. According to Ada'a district livelihood zone report (2007), one of the most important determinants of wealth in rural area is the ownership of livestock in general and ownership of Plough oxen in particular. Ownership of a pair of oxen allows better off households to prepare their land on time and rent-in the land of poor households on a contractual basis. In relation to this, among those who have owned animals 21.7% had single ox and 67.9% had a pair of oxen and the remaining 11 % did not have ox at all. More than half of the respondents owned a pair of oxen. This showed that those farmers without ox were forced either to rent their land based on crop sharing agreement or pay the oxen labor in a sum of money. In the study village the average livestock (TLU) holding for rich, medium and poor farm groups was 8.48, 5.03.and 2.69 respectively (Figure 11).

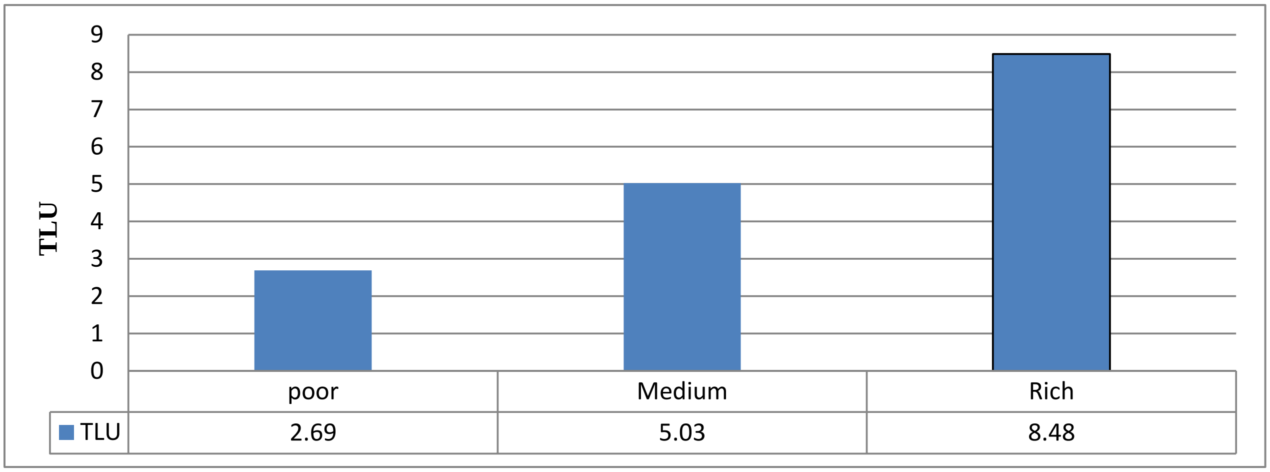

Figure 16: Average livestock holding (TLU) by farm wealth group in Kumbursa village

Having large size TLU means that there is a chance to produce more manure which may be used for better soil fertility level. However in the study area nearly 90% of the manure produced is used as source of household fuel and 7.8% is sold to the market, whilst only 2.2% is used for soil fertility amendment (Bogale, 2014).

4.1.6 Labour force

Labor is one of the most important socio-economic characteristics that influence soil fertility management. Cultivating,sowing, weeding of plants and ttransportation and application of organic fertilizer such as manure and compost to the distant plots require human labor and transportation. 83% of the family members age is between 6 - 60 years. The age group < 6 and >60 years is only 17% of the total. In the study village about 63.4 % (16-60 years old) represents active labour force (Figure12). This is greater than the national average which is about 52% (CSA, 2007). The families in the age group between 6-15 years (19.6%) can also perform some activities. They look after cattle, collect firewood, fetch water and perform other similar agricultural activities.

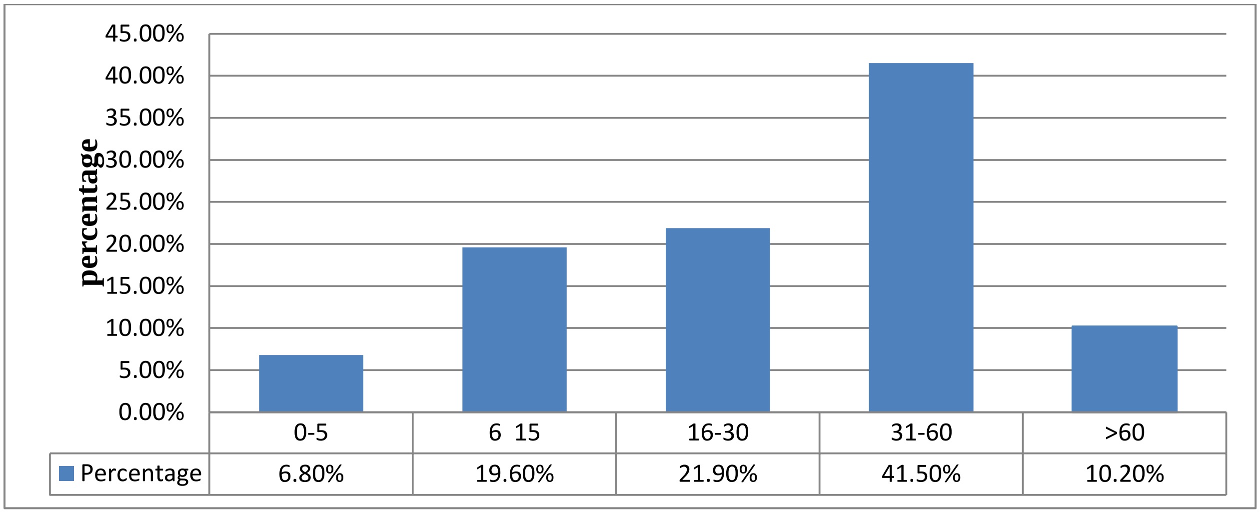

Figure 17: labour force of the respondents in kumbursa village, Juanry, 2017

4.1.7 Land holding size

Land holding size influences the wealth status of the households. Those households that have large land size are rich because they produce more crop yield than those households that own smaller land sizes. There is significant difference (at $P<0.001$) among the different wealth categories of the village in terms of landholding sizes. Rich households have significantly highest holding size than medium and poor wealth farm groups and land holding size of medium wealth farm group is higher than land holding size of poor wealth farm groups. The average land holding size for the poor, medium and rich farm group is 1.11, 1.24 and 3.05 hectares respectively (Figure 13).The average land holding size of the respondent's is 1.8 hectares. This is much larger than the national average land holding size, which is nearly one hectare (CSA, 2007). Land is prepared with an ox drawn plough, *maresha*, and the main crops produced are wheat and teff.

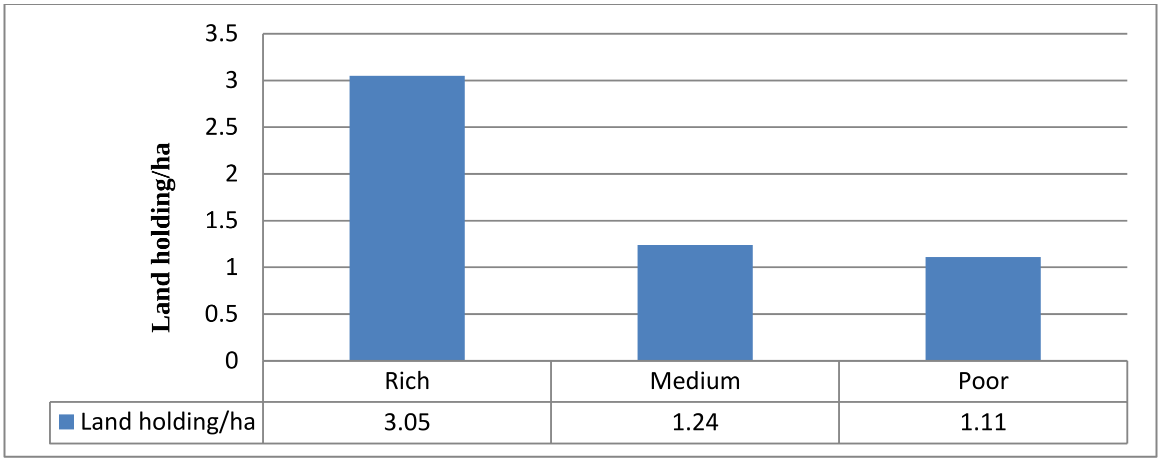

Figure 18: Average land holding size (ha) by farm wealth category, kumbursa village

4.1.8 Off farm source of livelihood

The study result indicated that the off farm source of livelihood of the respondent house hold are petty trading, construction, and daily labor accounts for 24 (53.3 %), 12 (26.7 %) and 9 (20 %) respectively. Out of the total 83 respondant house hold heads 45 (54.2%) have got off farm source of livelihood in addition to farming activities. Therefore, according to the survey results information, 38 (45.8 %) of the sample households do not have off farm source of livelihood.

Table 8:- Sample house holds off farm source of livelihood

Farmers off farm source of livelihood	Farmers wealth group							
	Rich		Medium		Poor		Total(%)	
	M (%)	F (%)	M (%)	F (%)	M (%)	F(%)	In NO	In (%)
Construction	0.6	-	2.64	6.3	7.56	10.2	12	26.7
Pitty trade	2.1	2.6	7.1	12.4	10.6	18.5	24	53.3
Daily labor	1.01	-	2.1	-	10.6	7.3	9	20
Total						45	100	

4.2 Farmers' perceptions and experiance of soil fertility status

It became clear from questionnaires collected and group discussions held in kumbursa *village* that farmers and scientists understand the status of soil fertility in almost similar ways. But there understanding has some differences. Most often scientists only take account of the soil's nutrient status, without considering its physical properties. They express fertile land as a land that is capable of producing constantly high yields in a wide range of crops.

Farmers' perceptions of soil fertility status are not only limited to the soil's nutrient status. Fertility is assessed through different factors such as crop performance, its distance from the home, workability and includes all soil factors affecting plant growth.

Interpretation of soil fertility status given by farmers' reveals the definition used by the International Soil Science Society (ISSS). The ISSS describes it as the capacity of a soil in its normal environment to produce a specified plant or sequence of plants under a specific system of soil management (ISSS, 1996). In their critical analysis of how farmers in different settings classify and manage soils, Talawar and Rhoades (1997) also stated that farmers perceive soil fertility as a multi-faceted concept. It includes factors such as the soil's capacity for sustainable productivity, its permeability, water holding capacity, drainage, tillage and manure requirements, and how easy it is to work.

Farmers in the study area use various easily observable indicators to assess the current conditions of their soil fertility status and to examine whether soil fertility is declining or not. Almost more than 90% of respondants from each wealth group is agreed on the decline on the fertility level of their soil. But there is a difference on the perception of different wealth groups about the rate of decline of there soil fertility level. About 96% of Poor male and female farmers state that their soil fertility level is significantily decresed from time to time and at present the level of their soil fertility is low (less fertile). The other 4% of them also agree on the high level decline of the soil fertility level but they said that their soil is moderately fertile.

Medium wealth group farmers also agree on the decline in the fertility status of a soil.About 90% of medium male farmers state that the fertility level of their soil is declined some what from previous and it is now less fertile. The remaining 10% also state that the fertility status of their soil is low and is declined not on alesser extent rather on asignificantly higher extent.With similar to 10% of medium male all of Medium female farmers also agree on the low level of soil fertility but they said that the decrease the soil fertility level is not some what rather high.

About 95% of both rich male and rich female farmers also state that the fertility level of their land is decline some what but it is still moderately fertile. The other 5% state that the fertility level of the soil is decreased with a lesser extent but still it is highly fertile with the help of organic and chemical fertilizers.

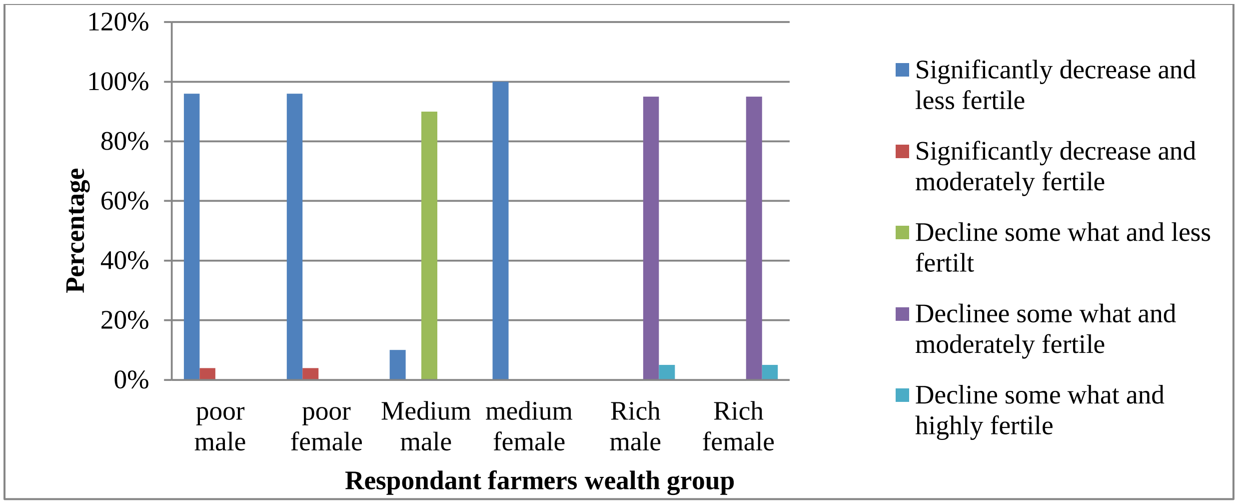

Figure 19: Farmers perception on the fertility level of their own soil

Participants of focus group discussion and development agents also agreed on the decline of soil fertility status in the area. Development agents stated that soil fertility decline in the study area occurs due to low attention given by farmers to appropriate soil fertility management practices like the use of organic fertilizer in addition to inorganic fertilizer. Similarely Tilahun et al., 2001 stated that Soil nutrient depletion and related low agricultural productivity are serious problems in the highland parts of Ethiopia

More than 90% of all wealth group respondants from both sex group states that they determine the fertility status of their soil through visual inspection and by examining their level of productivity. The other 10% also said that in addition to its color and productivity they use its texture in order to determine its fertility level manually by fingers and by visually observing and feeling the soil .

Three texture classes were perceived. For the majority of respondents, it appeared that infertile soils were sandier than moderately fertile and less fertile soils. But they said that determination of soil texture takes much experiance and skill, it can be improved with experiance. In this area soil moisture conservation is also often regarded as the most critical factor for successful crop production. Farmer perception of soil fertility is therefore closely linked to the soil's water holding capacity.

4.3 Indicators given by farmers to classify soil fertility status

Farmers in Kumbursa *village* was asked to identify the major indicators they use in order to classify their soil. They put there own local indicators of soil fertility and made distinction between fertile, moderately fertile and infertile soils.

The indicators used by each wealth group was almost similar. Out of the total sample respondents, 72% of rich respondents said that they identify their soil fertility level based on soil depth, crop productivity, types of crops grown,soil organic carbon and soil color; and the remaining 28% of rich farmers use water holding capacity, soil color, soil depth,distance from home types of crops grown and crop productivity as a major indicators to identify their soil fertility level. About 29% of Medium farmers use soil color, topography, types of vegetation grown, soil organic carbon and crop productivity to classify their soil and 71% of the midium group farmers use soil color, soil water holding capacity to identify their soil fertility level. From the poor farmers group 78% uses soil color,distance from home and crop productivity; and the other 22% use water holding,crop productivity and soil color as amajor indicator to identify their soil fertility level.

As atotal the principal indicators mentioned by the three groups of farmers were soil colour (mentioned by 85.54% of the farmers), soil water holding capacity (80.7 %), soil texture (62.25%), soil depth(60.24%), distance from home (59.44 %),Topography (59.4%),soil organic matter content (57.43%),and soil drainage (41.4%) as very important (below Table 10).

Past studies show that distance from home is the dominant factor to classify soil fertility in addition to its color and perceive that fields closer to the household are fertile but farmers in kumbursa *village* stated that, distance from home could not be aleading factor to soil fertility because they focus on the practice or condition they believed generates or destroys soil fertility as on the properties themselves, for instance modified by human beings by addition of manure and ashes or polluting materials make the soil bad/polluted.

Table 9: Local indicators used to assess soil fertility status (83 respondants)

Indicators	Soil fertility				
	Not important	Least important	Undecided	Important	Very important
Soil colour	-	-	-	3	80
Soil depth	3	1	8	19	52
Waterholding capacity	-	-	-	5	78
Soil texture	-	7	9	15	52
Topography	-	6	12	29	36
Soil drainage	-	11	16	24	32
Organic matter content	-	-	3	13	67
Distance from home	9	6	4	17	47
percentage based on Rank	12/664=1.81%	31/664=4.66%	52/664=7.83%	125/664=18.82%	444/664=66.86%
	Crop production				
Soil colour	-	-	-	4	79
Soil depth	8	9	5	15	46
Water holding capacity	-	-	-	2	81
Soil texture	-	-	12	16	55
Topography	8	5	7	29	34
Soil drainage	-	5	28	24	26
Organic matter content	-	-	11	18	54
Distance from home	2	2	4	9	66
Percentage based on rank	18/664=2.71%	21/664=3.16%	67/664=10.09%	117/664=17.62%	441/664=66.42%
	Soil degradation (physical form of degradation i.e Soil Erosion)				
Soil colour	-	-	14	15	54
Soil depth	-	-	7	24	52
Water holding capacity	6	6	14	15	42
Soil texture	2	3	8	22	48
Topography	-	-	-	5	78
Soil drainage	1	7	11	19	45
Organic matter content	21	25	3	12	22
Distance from home	3	4	10	32	34
Percentage based on rank	33/664=4.97%	45/664= 6.78%	67/664=10.09%	144/664=21.68%	375/664=56.48%
Aggregate or mentioned by %	3.16%	4.87%	9.34%	19.38%	63.25%

Similar indicators were used in northern Ethiopia (Corbeels et al., 2000) and three different soil fertility classes are distinguished by farmers according to yield, topography, soil depth, colour, texture, water holding capacity, and stoniness. Similarly, in the Siaya District of Kenya, farmers base their classification on the surface layer of the soil, taking into account the colour, texture, and heaviness of working (Mango, 2002).

In southern Rwanda also soils are classified into nine major soil types based on criteria such as crop productivity, soil depth, soil structure, and soil colour (Habarurema and Steiner, 1997). In all of these studies, soil colour is the most widely used indicator used by farmers to classify their soils. This was also the case in the study area. They classify black soils (*kooticha*) as the most fertile, and very dark grey soils (*Cari*) are the least fertile.

Although weeds were not spontaneously mentioned by farmers in our study as indicators of soil fertility, most of them recognised that there are more present in the fertile fields than infertile. This view is supported by visual observations.

Indicators listed by farmers were further classified according to there reliability for soil fertility, crop productivity and soil degradation (Table 9). Results show that interms of crop productivity the leading indicators are soil water holding capacity (81 respondants), color (79 respondants) and distance from home (66 respondants) respectively. According to soil degradation topography (78 respondants),soil color (54 respondants) and depth (52 respondants)are the three most important factor respectively. Interms of soil fertility soil color (80 respondants),soil water holding capacity (78 respondants) and soil organic matter content (67 respondants) is the leading factor respectively.

Table 10: Indicators rank based on their importance

Indicators	**Rank based farmers' perceptions**				
	Not important	Least important	Undecided	Important	Very important
Color	-	-	14/249=9.6%	22/249=8.83%	213/249=85.54% (1st)
Soil depth	11/249=4.42 %	10/249=4.02%	20/249=8.03%	58/249=23.29%	150/249=60.24% (4th)
Water holding capacity	6/249=2.41%	6/249=2.41%	14/249=5.62%	22/249=8.83%	201/249=80.7% (2nd)
Soil texture	2/249=0.8%	10/249=4.02%	29/249=11.65%	53/249=21.3%	155/249=62.25% (3rd)
Topography	8/249=3.21%	11/249=4.42%	19/249=7.63%	63/249=25.3%	148/249=59.4%
Soil drainage	1/249=0.40%	23/249=9.42%	55/249=22.1%	67/249=26.9%	103/249=41.4%
Organic matter content	21/249=8.43 %	25/249=10.04%	17/249=6.83%	43/249=17.27%	143/249=57.43%
Distance from home	14/249=5.6%	12/249=4.82%	18/249=7.23%	58/249=23.29%	148/249=59.44%

Farmers have developed a local system of soil classification based on their previous experience of the potential and constraints of their soils. Based on the above indicators farmers in the study area distinguish between three different soil types (Table 11). The three types of soil are locally known as *Kotticha* (deep with a color of dark), *Gombore* (moderately fertile, medium in depth with brown color) and *Cari* (low in fertility, low in depth and red in color.

Table 11: local name of soil types in the study areas identified by farmers based on possible indicators (Soil color)

Local indicators	**Fertile soil**	**Moderately fertile soil**	**Infertile soil**
Black(Kotticcha)	83	-	-
Brown(Gombore)	78	5	-
Red (cari)	9	15	59

Among Eighty three interviewed farmers only nine farmers said that Cari is fertile (Table 11). On the other hand, fifty nine farmers said that Red soils were most commonly used to describe infertile/bad soil. The reason was because of its low water holding capacity; making it less productive in low rainfall years and its low nutrient retention capacities.

According to farmers in the area, due to its high water holding capacity black or dark color soils (*Kotticha*) give better yield than other soils at times of low rainfall. To the farmers, this is a preferred type of soil for crop production because of its workability and fertility status.The major limitation of dark soil is sticky when wet and hard when dry; making it difficult to till.

In addition to soil color,water holding capacity and texture farmers in the study areas recognize that land with better soil depth have better soil fertility status and land with shallow soil depth have a lower soil fertility status. They have determined the depth of each soil type by evaluating the extent of labor nedded to plow the land. They said that if the soil is shallow, tilling is a difficult task due to the presence of large amount of stones which limits ox and hoe movement. This is not the case for deep soils.

Moreover, farmers in the study areas perceive that soils with a better crop productivity is considered as fertile and a less productive one is considered as less fertile or infertile soil. They also perceive that lands on which broad leaved plants grow and high organic matter content are considered as fertile.

Most systems of classification are developed for a particular purpose, and reflect the priorities of their inventors. In the study sites the local systems of classification reflect the limited availability of water. These systems focus on soil color, soil water holding capacity and soil’s depth, which affects the availability of soil moisture, and its texture, which determines its workability and water holding capacity.

Other studies in various settings have also shown that farmers commonly classify their soils using a range of well-identified criteria that are relevant to their local situation. The most common criteria noted in studies on local systems of soil classification reflect the physical properties of soils, or related factors such as texture, colour and workability (Talawar & Rhoades, 1997). Farmers are well acquainted with these characteristics through their daily observations of soils, and particularly of their surface (Habarurema & Steiner, 1997; Kanté & Defoer, 1994).

Participants of focus group discussions also recognize about the existance of three types of soils in the study area based on possible indicators. And they also stated that farmers use various indicators to make soil management decisions and for subsequent monitoring and assessment in addition to simple classification. However, rather than using just a single indicator to classify soil, they use at least three indicators. Each indicator is described separately, but their significance is combined when making assessment. The following table illustrates some examples of how, and which indicators are used by farmers for different assessment points.

Table 12: Specific indicators used by farmers to answer different questions

Assessment	**Indicators used by farmers**
What is the current level of soil fertility?	Soil colour, crop productivity, soil OM content and water holding capacity
How soil classification can be made?	Soil color, soil water holding capacity
Are changes in soil fertility management needed?	soil colour, crop productivity, Topography , Texture and soil depth
What crop should be grown?	Soil colour, water holding capacity,distance from home

According to farmers response, soils were identified as fertile where it comprise black color, cracks during dry season, good crop performance, high growth of certain plants, presence of plants in a dry environment and low frequency of watering where as infertile soils show red colors, compacted soils, small plant growth, high frequency of watering and presence of rocks and stones.And moderately fertile soils have a character between the two.

With similar to farmers classification Mrema et al. (2003) stated that soil are classified as fertile where it comprises high OM and clay content, adequate supply of growth factors, large supply of plant nutrent, high water holding capacity , high infiltration rate and high biological activity with neutral PH where as infertile soils have low organic matter content, presence of cementing materials (Al,Fe_2o_3 heavy clay)and low biological activity,physical ,chemical and biological limitation ,low PH ,high PH and shallow in depth.

Table 13: Types of soils and their main differences in the study area, according to farmer's perception

Characterstics	Kooticha(Most fertile)	Gombore(Moderately fertile)	Cari(Infertile)
Fertility status	Most fertile	Moderately fertile	Infertile
Colour	Black	Brown	Red
Texture	Heavy Clay	Medium	Low
Depth	Deep	Medium	Shallow
Workability	Average	Average	Difficult
Stoniness	Slight	Moderate	High
Water holding capacity	High	Medium	Low
Degree of erosion	Slight	Moderate	High
Yield	Maximum and most reliable	Medium with a slight risk of crop failure	Low with a high risk of crop failure
Description	During rainy season grasses emerge slowely and generally survive	During rainy season grasses emerge and dry slowely	During rainy season grasses emerge fast and die quickly.
Range of crops	Support a wide variety of crops i.e teff,wheat,bean,	Production is limited to	Low variety of crops
Agricultural use	Intensively cultivated	Some cultivation and also used for pasture	Limited
Frequency of plouging	3 times	3-4 times	>3 times
Limitation	-affected by leaching -affected by pest -high use of fertilizer(with low fertilizer its productivity is low)	- less effective for teff	-erosion, -un able to cope up on the times of drought, -affected by wind, -low suitability to teff
Fertilizers used	UREA and DAP	UREA and DAP in small amount	DAP and UREA

4.4 Farmers soil fertility management practices

Before entering in to discussion of soil fertility management(SFM) undersanding of indigenous knowledge of soil fertility status is important. Farmers in the study area have accumulated indigenous knowledge about their soil resources, its characteristics, limitations, potentials and appropriate management practices. About 87.9% of rich, 80% of medium and 82% of poor group farmers have perceived the existence of soil fertility problem while only 12.1 % of rich, 20% of medium and 18% of poor group respondants were not aware of the existence of soil fertility problems.

In addition to the presence of the problem they rate the level of the problem. About 96% of poor, 55% of medium and 3% of rich group respondant farmers stated that the rate of soil fertility problem is high and the remaining respondants said that the problem is at medium level. Regarding the causes of soil fertility decline, most farmers described soil fertility decline as a consequence of soil erosion, continuous cultivation and lack of manure and chemical fertilizer application (Figure 15).

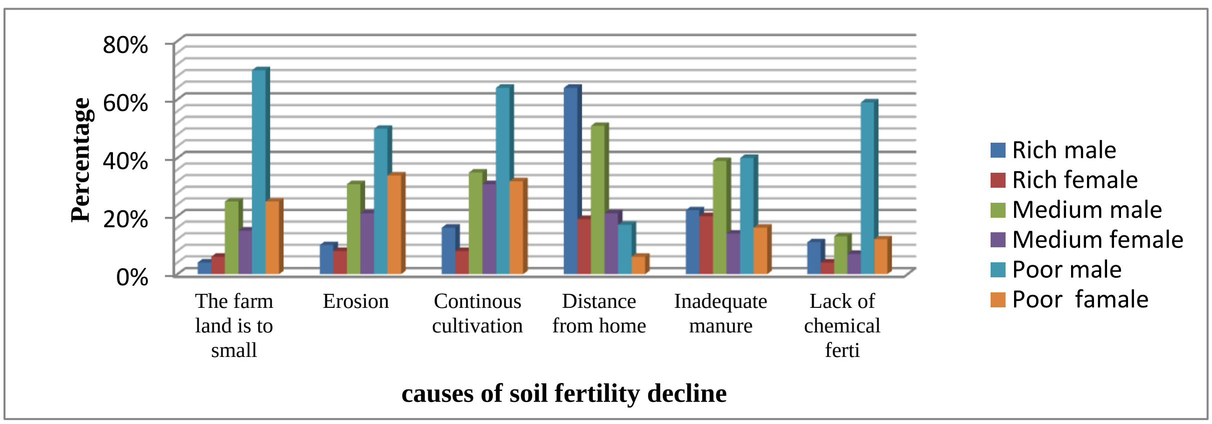

Figure 20. Farmer's perception on major cause of soil fertility decline.

SFM practices followed by most of the farmers in the study area for the different soil types are not different. Only few Kumbursa village farmers reported distinctly different SFM approaches for different soils. Especially for relatively poor soils, additional input of manure and inorganic fertilizers is reported. Different soil fertility management practices such as use of inorganic fertilizers, organic inputs and soil erosion control measures are accomplished by the famers in the study areas to respond to soil fertility depletion.

They were asked to describe about the ways they follow inorder to improve soil fertility status. The result shows that farmers of the three wealth catagory report different soil fertility management practices.The most common practices are outlined in Table 15 below.

Table 15: The management practices of different wealth groups used to maintain/improve soil fertility and agricultural productivity in Kumbursa *village* (percent of households in each group)

Land management practices	**Wealth category**					
	Rich		**Medium**		**Poor**	
	M	**F**	**M**	**F**	**M**	**F**
Inorganic fertilizer	**100**	**100**	**100**	**100**	**100**	**100**
Organic fertilizer	**97.6**	**90.2**	**82.4**	**83.6**	**43.5**	**46.5**
Inter cropping	**16**	**8**	**-**	**10**	**-**	**-**
Crop rotation	**95.4**	**92.1**	**88**	**92.3**	**69.2**	**63.2**

Participants of focus group discussion also stated that farmers of kumbursa *village* uses different types of soil fertility management practices. According to the result from discussion farmers in the study village use chemical fertilizers as a main soil fertility management practices followed by crop rotation and use of organic fertilizer. Crop rotation is commonly practiced with a sequence of cereals with pulses.

With similar to them development agents also stated that farmers use chemical fertilizers (DAP + UREA) for cereal crops production. Pulses are produced without application of fertilizers. But they rarely use animal manure or other organic wastes to improve soil fertility. Discussions with local extension agents (development agents) and focus group proved the progressive increment of fertilizer usage is related to the decline in soil fertility status of the study area.

Field observation also revealed that highest proportion of farmers used inorganic fertilizers as the sole source of improving soil fertility and productivity for cultivated land where cereal crops grow. Relatively, very few farmers tended to use a combination of organic and inorganic fertilizers instead of purely rely on inorganic fertilizers. In agreement to few farmers practice Corbeels *et al*., 2000 stated that farmers need to be familiar with the use of organic fertilizer and mineral fertilizers in a complementary manner one with the other rather than replace each other. However, there was also a major constraint for small scale farming system to use both organic and inorganic fertilizer. The problem becomes high for poor farmers because of expensiveness of chemical fertilizer price and in accessability to inorganic fertilizer attributed by low number of livestock and other causes.

The identification of major soil fertility management practices that are accomplished by the small-holder farmers in the study areas is critical for intervention by different stakeholders. Detail description of the major soil fertility management practices used by farmere were listed here under፡

a) Inorganic fertilizer use

In organic fertilizers have a dominant role in order to increase crop production, but its availability to the majority of the farmer is questionable. There is a wide spread supply limitation which is related to shortage of foreign currency at national level, lack of loan facilities and inefficient distribution system (Anthony, 1990).

All of the interviewed farmers uses inorganic fertilizers as the source of improving soil fertility and productivity for cultivated land where cereal crops grow (Table 15). But the difference is based on the frequency of application. More than 90% of poor farmers from both sex use inorganic fertilizer only once on the time of while sawing. In my opinion the cause for the low rate of mineral fertilizer usage by poor farmers may be the current escalating prices of chemical fertilizers. 72.5% of rich male,62% of rich fimale, 88% of medium male and 96% of medium female respondants use two times on the time of while sawing and and after some times crops are grown. The remaining number of respondants stated that they use inorganic fertilizer three times the one before sawing, the other while sawing and after some times Crops are grown.

Similarly, Laura and Rienke(2004) reported that Chemical fertilizers can be used in various ways and time. Fertilizers may spread over the whole field followed by ploughing of the land; it can be applied in rows next to or below the seed and can be used once the crop has grownup known as top dressing.

Development agents of kumbursa village also stated that wealth category and management practice affectes soil fertility status. This can be explained by the rate of application of inorganic fertilizer, manure, crop residues and response to different agricultural inputs. Rich farmers have a capacity to purchase expensive fertilizer to maintain their soil fertility status and also they have more livestock that contribute to soil fertility through generating more manure (Table 15).

b) Use of organic fertilizer

Organic fertilizers are important constituents in crop production system of the study areas. The organic inputs which are widely used by the farmers in the study areas are manure and compost. On average from both sex groups 53.5 % of rich, 47.4 % of medium and 33.6 % of poor interviewed farmers uses manure to maintain soil fertility status. Manure fermented for a long period of time can offer balanced nitrogen and other macro and micro nutrients (Mark et al., 2007).

However, the use of manure and compost is restricted by the number of livestock the households owned. Those farmers who own more number of livestock (rich farmers) use more manure and compost than those who own less number of livestock (poor farmers). As far as use of organic matter is concerned, in Ethiopia, farmers do not return animal excretion and crop residues to the soil. This is because of low availability of animal dung and farmers use the crop residue and animal dung for feed to animals and fuel respectively.

The results showed that the use of crop residues for livestock feeding were common practices in the study area (Figure 16). Discussion with farmers and extension agents revealed that crop residue from cereals crops (wheat, barley and teff) and legumes (beans and peas) are transported from field to the home compound and stored for animal feed. In addition to this, teff residues are used mainly for fodder, fuel wood and fencing. It leads to soil fertility decline more rapidly in the fields.

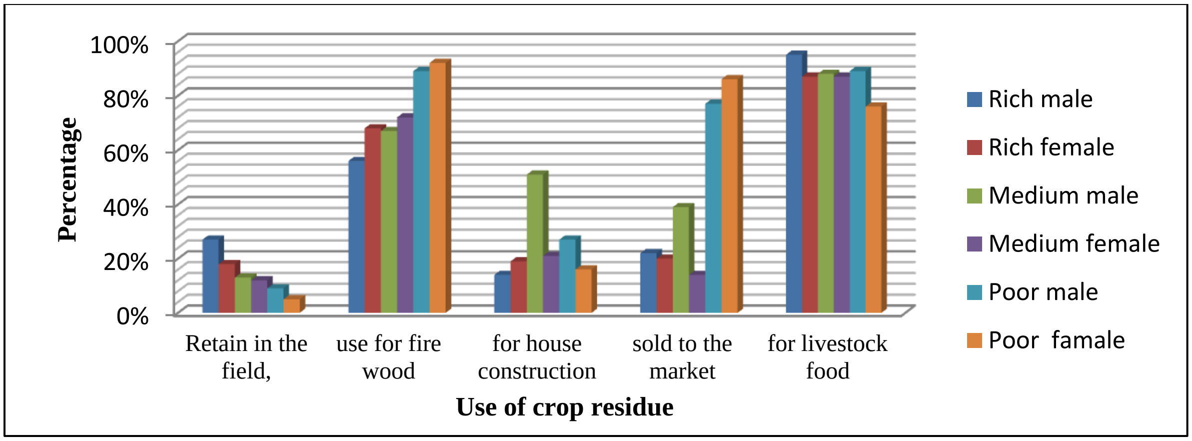

Figure 21. Use of crop residue

Similarly, Barry and Ejigu (2005) reported that the decline in the fertility status of Ethiopian soils is largely caused by extra pressure on land due to increased population, decline in the amount of organic input available for soil fertility.

Field observation confirmed that only few farmers in the region use crop residues to maintain soil fertility. But they are well aware of the advantage of returning crop residues to soil fertility. But, only few farmers around 14% retain most crop residues in their field. This is because crop residues are used as construction material, fuel and source of animal feed. In the study area all crop residues apart from wheat are cut at ground level, and the straw is stored as fodder for livestock.

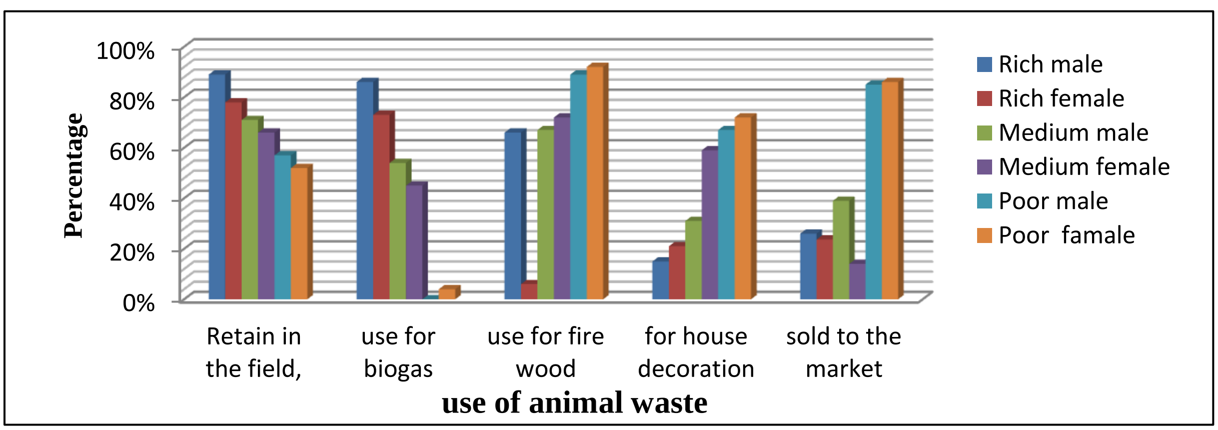

Figure 22: Use of animal waste

Participants of focus group discussion indicated that mulching is not applicable in their field due to unavailability of crop residue and other mulching materials.Thus, poor management and unsafe use of crop residues may have reduced the quality and availability of residues to be used for soil fertility management, especially in cereal based farming systems in the area.

c) Crop rotation

In Kumbursa *village* farmers traditionally rotate the major cereals with pulse. On average more than 83 % of the respondents(93.75% of rich, 90.15% of medium farmers and 66.2% of poor farmers) reported that they practice crop rotation. A relatively high proportion of farmers grow cerials in rotation with pulse. They preferred this sequence of crop rotation; as they believe that soil fertility would be improved when cereals are grown in rotation with pulse. If farmers use legumes in crop rotation the accessibility of nitrogen increases because legumes can fix nitrogen from the atmosphere (Melissa, 2003).

d) Intercropping

Intercropping is another system used in the study area but not widely practiced. Out of interviewed farmers, only 16% of rich male, 8% of rich female and 10 % of medium female respondents practiced intercropping. Intercropping, mainly bean with maize and bean with pea is a deliberate measure to maintain soil fertility. In both cases the emphassis is on legumes crops that helps to enhance soil fertility.

In my opinion intercropping practices in the study area essentially has major practical advantages, for example, mixing legumes with a grain crop especially maize, legumes are nitrogen fixing plants, therefore, by intercropping the two farmers don't even have to apply so much inorganic fertilizer since most of them cannot even afford to buy fertilizers on the recommended rate .

And also grains generally grow tall and slender, while beans stay low and creep over the ground. This combination protects the soil more than a single grain crop would. Grains generally need as much sun as possible, while beans and other legumes grow just as well in the shade. The available sunlight can thus be utilized optimally by both crops. In addition to this if one of the crops fails, for example due to irregular rainfall or disease, then the other crop can often still provide a successful harvest. In this way, the farmer minimises the risks of crop failure.

Intercropping can have a limiting effect on the spread of diseases and pests. Insects or other pests that damage a particular crop can be driven away by substances that another crop produces, or by the other crops attraction of insects that eat the damaging soil organisms or insects.

e) Fallowing

The traditional method of restoring soil productivity is fallowing. Farmers said that yields on farm land decline when they continuously grow crops in each year without any fallow period. Farmers in Kumbursa *village* are well aware of the importance of fallowing for improving soil fertility. But no one from the three groups practiced regular fallowing. The study clearly depicted due to the ever increasing population pressure, long term fallowing was abandoned in all the study area. But, farmers understood the benefit of fallowing to restore soil fertility.

Some of the participant farmers stated that they produce once ayear that longs for three or four months on the other time the land is seasonally fallowed. But this was however, short period for restoration of soil fertility. In reverse to the farmers idea Allan (1965) reported that the fallow period should not be less than eight years on the best soils. Similarly, Mansfield (1973) claimed the required fallow period for the soil recovery was about 15-20 years.

Tillage practices

Interms of labour and energy tilling is the most demanding farming activity. In the study area farmers mainly use oxen to pull the traditional plough or *maresha*. They see ploughing as a way of improving soil productivity. On the times of preparing land there are two main problems that the ox-plough is not very efficient at turning the soil to a suitable depth, and that ploughing requires a lot of time and labour. Mainly it is difficult to plough vertisols, especially during the first tillage after harvest.

In Kumbursa village different groups of farmers by wealth difference have similar idea about the frequence of ploughing needed for each types of soil but they differ on their perception about its importance. They stated that frequence of ploughing is different on different types of soils and differs according to the type of crop.

Table 16: Frequence of ploughing difference based on soil type variation

Types of soil	Frequency of ploughing
Kooticha soil	At least three times
Gombore soil	Three to four times
Cari soil	Three times or more

The field is ploughed a minimum of four times for teff. The first phase of tilling has a particular local name is called *Senteka*.On the other hand, pulses (Peas, beans or lentils) were planted with minimum tillage (often ploughed once). Participants of focus group claimed that increasing frequency of tillage for pulse crops could result in lodging and ultimately got lower yield.

Table 17: Frequence of ploughing difference based on crop variation

Types of crops grown	Frequency of ploughing
Teff	At least four times
Cereal	Three to four times
Pulse	Once

Though, there was only one cropping seasons in the area that starts on June and last for three to four months. Farmers from the three different wealth group have different perception about the importance of frequent tillage. Most of the farmers argued that increasing the frequency of tillage is the most important way of improving soil productivity. The other respondants also argued that in order to conserve moisture reducing frequency of tillage was the best means .

Table 18: perception of different wealth groups farmers towards frequent tillage practice (percent of households in each group)

Argument points	Percent of respondants					
	Rich(%)		Medium(%)		Poor(%)	
	M	F	M	F	M	F
Increasing frequency of tillage is important for better soil fertility	90	85	96	87	76	84
Reducing frequency of tillage is important for better soil fertility	10	15	4	13	24	16

Soil erosion control measures

One of the important activities undertaken by the farmers in the study areas were soil erosion control measures. In the study areas, soil erosion control measures were taken to conserve the top soil from being eroded through water erosion. Farmers in the study area perceive that the use of any crop productivity improvement inputs will become meaningless unless soil erosion control measures are taken on their plots. Soil and stone bunds are common soil erosion control measures practiced by the farmers in the study areas.

Soil bund: Farmers in the study area constructed soil bund on the plots with better soil depth and free from stones and less availability of stones with the help of development agents. Soil bund is preferred in the study areas because *catcha* can be easily grown on it. It makes the activity easy to undertake different cultural practices by the farmers. The amount of soil bund used increases if a plot is used for *catcha* production. This is because as there are no other crops grown in between two soil bunds, the distance between two soil bunds becomes shorter.

Development agents of Kumbursa village complained that, the disadvantage of using soil bund is its requirement for more labor cost for maintenance activity. Soil bund needs maintenance after each season. It can also be damaged by runoff, when the runoff amount is higher and the size of the bund is smaller.

Figure 23 : Soil bund constructed by farmers with the help of development agents

Planting grass strip on bund: Grass strip makes the soil bund stable if it is planted on or under the soil bunds. Farmers in the study areas plant grass strips on bunds and on borders of their plots to produce feed for their livestock and to make the bund stable. *catca* plant is the common type of plant planted on the soil bund by the farmers.

Other soil conservation measures: Planting trees around their homesteads or their farm plots is another soil conservation measure that contributes to minimizing soil erosion. Out of the total sample households, 38% of rich, 26% of medium and 14% of poor group farmers planted trees around their homesteads or plots. At the last Farmers were asked to describe about the constraints they faced on the implementation of various soil fertility management practices they follow inorder to improve soil fertility and crop productivity. The most common constraints are outlined in Table 19 below.

Table 19: the main constraints listed by farmers about the different types of Soil fertility management practices

SFM practice	Constraints
Mulching	As farmers said the practice of mulching highly increses the problem of pests especially on Kotticha soils after the rainy seasons begin. Use of residues for fodder and fuel
Green manure	They said that when they invest time and labour they needs to get obvious benefit like cash and food. But the result of green manure to improve soil fertility is not quick. Land fragmentation and use of manure as fuel.
Fallowing	Problem of Shortage of land.
Crop rotation	They use it (No constraint mentioned).
Inter cropping	Lack of labour at peak seasons such as sowing and harvesting time. If the sowing and harvesting periods of the different crops vary, it is easier to spread the available labour over the entire season avoiding high peaks. Difficult to combat disease, pests and weeds due to its dense concentration.
Terrace	Land ownership, shortage of land.
Compost	It is labour intensive, and not highly effective becauce of organic material scarcity.
Chemical fertilizer	Expensiveness

Similarly, participants of focus group discussion and development agents reported that all the farmers use inorganic fertilizer but its price increases from time to time. So it becames the major constraint to use inorganic fertilizer at the recommended rate.

Concerning agricultural extension services more than 95% of sample respondents from the three wealth category were realized that they have provided with agricultural extension services by the development agents (DAs) and all of the sample house holds replied that there is no any Non-Governmental organizations (NGOs) that supports them in order to improve the fertility level of their soil. In line with this development agents also stated that soil fertility management practice in the area is supported by the integration between local, District ,zonal and national level government institutions. As she seid there is no NGOs in the area that participate in soil fertility management practices.

4.5 Farmers perceived value of soil fertility status for crop yield

Soil fertility is a complex quality of soils that is highly related to crop nutrient management. It is the component of overall productivity of soil that deals with its available nutrient status, and its ability to provide nutrients for crop production out of its own reserves and through external applications.

The survey data show that most farmers in the study area consider soil fertility as a very important aspect of crop production. In addition, a majority of respondant farmers have an excellent grasp of the important nutrient management concepts involving the relationship between soil fertility and crop productivity.

Farmers was asked about the level of importance of soil fertility for their overall crop productivity. A large majority of farmers place a high value for soil fertility. More than 92% of rich, 95% of medium and 98 % of poor farmers stated that soil fertility is responsible in order to get better annual crop yield.They belive that the most fertile soils (Kooticha) by nature can give better crop productivity. Conversely, fewer than 10% of the respondant farmers from each group stated that the level of soil fertility alone can not make them productive interms of crop. They raised the conditions of *Kooticha* soil as example. As they said for all crops the productivity of Kooticha soil becames low with out the application of fertilizer. So they perceives that soil fertility by it self can not increase crop productivity rather other factors have its own impact. This information is significant, because when coupled with recent research data, both researchers and farmers feel that soil fertility is an important component of crop yield. And also in the eye of most farmer respondents soil fertility is at least as important to yield as crop variety selection and pest management.

In general, soil fertility is seen as an increasingly important component of yield.Table 14 shows us about the types of crops that can be effectively grown in different soil type based on farmers perception.

Table 14: Suitability of each type of soil for different crops based on farmers perception

Soil type	**Crops grown**
Kotticha	Effective for Teff, Wheat,Bean and Chick pea
Gombore	Effective for Bean,Barley, pea and Wheat, but less effective for Teff and totally not used for chickpea
Cari	Moderately effective for Pea and Bean but less effective for Teff

Inaddition to the types of crops grown in each types of soil participant farmers also asked to indicate the most important indicators they used in order to determine the relevance of each soil type for crop production. As shown in Table 10 the leading indicators listed by farmers for crop productivity is soil water holding capacity, color and distance from home. In the study area the role of distance from home for soil fertility is an arguable point.

About 90% of the respondant farmers stated that field near to the home have better chance to get inorganic fertilizer that increases its fertility and makes it more productive. The other 10% of the respondent farmers also presented important points. They said that any modificion made by human beings by addition of manure and ashes or polluting materials can make the soil bad/polluted. As they seid this problem is high in the field near to home.

As we see from the result that assesses farmers perception they classify their soils in to three major groups based on their own indication factors. But figure 5 from chapter three indicated that the soil type of the study ares is pellic verti soil. From the foregoing listing of some of the important properties of Vertisols, it is obvious that this type of soils is potentially one of the most productive in semi-arid regions because it possesses one attribute of high moisture-storage capacity that is very important in an environment that has unreliable and heavy rains. The major factors responsible for this in most soils are the high clay content, and the fact that this is usually montmorillonitic. Nevertheless, it is interesting in passing to note that some members still possess the swelling characteristics of Vertisols, whilst containing little "expanding clay" and essentially an illitic/kaolinitic mixture.

The high moisture storage capacity guarantees much safer and more productive cropping; it can assist crops to survive and possibly even to grow during prolonged dry spells, whereas failures would have resulted on soil not so well endowed. This high moisture-storage capacity will also allow crops to continue to grow for several weeks after the rainy season is ended; it may therefore be possible to grow two crops in 1 year.

However, regardless of these advantages, these soils have several disadvantages. Although the first rain infiltrates quickly to considerable depths through large cracks, subsequent infiltration and permeability are very low because of its high clay content and poor structure when wet. Drainage may be a problem and crops may become waterlogged. Poor trafficability of the soil when wet seriously restricts the planting operations. Vertisols are among the most productive soils (Acquaye et al., 1992). These soils are little affected by Leaching. This has been overcome by identifying the above problems and by developing appropriate management innovations that includes both the perception of farmers and the way science gives in order to minimize the problem.

4.6 Farmers Perceptions Based Laboratory Results

Farmers' classification of soil fertility status was compared with analytical data for soil samples collected from the different soil classification classes made by farmers.

4.6.1 Analysis of soil morphological property

4.6.1.1 Soil colour

Color of each soil type classified by farmers was quantified by using Munsell soil color chart, which uses *hue*, *value* and *chroma* indices to describe colours. *Hue* identifies the approximate place of color's in the rainbow (how red or yellow or blue the soil is), *value* identifies how light or dark it is, with values near 0 being white, and *chroma* identifies how much colour there is, from very faded to very intense. The lower the value and chroma, the darker the soil color.

Generally the morphology of Vertisols exhibits a high degree of uniformity. The soils are usually dark in colour. A colour contrast in the soil of my study area is seen from 10YR 2/1 to 10YR 3/1. As all soil samples fell within the 10YR colour hue, they revealed more or less a similar pattern. As already discussed, the interviews with the farmers indicated that soil colour was the most widely used indicator. Generally, the darker soils were considered to be more fertile than the Brown or red ones (Table 20). It can be seen that the soils classified by farmer as fertile had a lower value and chroma, indicating that they were darker in colour.

Table 20 : Farmers perception based soil color result from Munsell soil color chart

Soil classification based on farmers perception	Color given by farmers	Scientific notation by Munsell soil color chart	Description
Fertile soil (*Kooticha*)	Black	10YR 2/1	Black
Moderately fertile soil (*Gombore*)	Brown	10YR 2/2	Very dark brown
Infertile soil(*Cari*)	Red	10YR3/1	Very dark grey

This shows that soils classified by farmers as most fertile, moderately fertile and infertile have Black, Very dark brown and Very dark grey color based on the Munsell soil color chart. The variations in color observed among the three soil types could probably be attributed to differences in clay and organic matter content, parent material and drainage conditions that affect the redoxmorphic reactions in the soil. In line with the findings of this study, Dengiz *et al*. (2012) also indicated that soil color could be related to organic matter, waterlogging, carbonate accumulation and redoximorphic features.

4.6.2 Analysis of soil Physical Properties

In preparation for analysis the composite soil samples were air dried and crushed to pass through a 2 mm sieve in Debre zeit Agricultural research center soil laboratory. All the results recorded from each soil types classified by farmers are listed here under.

4.6.2.1 Soil texture

Soil is comprised of different types of minerals and organic matter, which is typically decaying plant tissues. In this part of a paper the researcher have tried to investigate how different types of soil classification done by farmers differ one from the other based on there particle size distribution. There were significant differences ($P<0.001$) in sand, silt and clay particle size distribution between the three soil groups (fertile, moderately fertile and infertile) (Table 21).

The laboratory analysis results, as presented in Figure 18 and Table 21, indicated that clay is the dominant particle size fraction in all the three groups of soil. Similarly, Berhanu (1985) reported that the Vertisols in Ethiopia generally contain more than 40% clay content in the surface layer. The highest mean sand fraction (23.13) and clay fraction (62.04%) were observed in surface sample of infertile *Cari* soils and sub surface samples of fertile *Kooticha* soils, respectively (Figure 18). This implies that soils classified by farmers as most fertile, moderately fertile and infertile ranks as 1st, 2nd and 3rd in *Clay* content respectively. The representation of various grain size fractions on USDA textural diagram showed that all soils had clayey texture.

Furthermore, both clay and sand fractions showed a consistent pattern with depth. Sand generally decreased and clay increased with depth. On the other hand, the silt content increases in most fertile and moderately fertile soils and decreases in infertile soils with depth. The increasing of clay fraction and decreasing of sand fraction indicates that these have positive relationship with soil fertility. Additionally, The increase in clay content with depth might indicate the presence of eluviation and illuviation processes or simply translocation within the soil horizons.

The result is similar with the work of Atofarati *et al*. (2012) stated that the profile distribution of clay increased with increasing depth and total sand fraction highest in topsoil may be as a result of clay eluviation – illuvation in the soil.

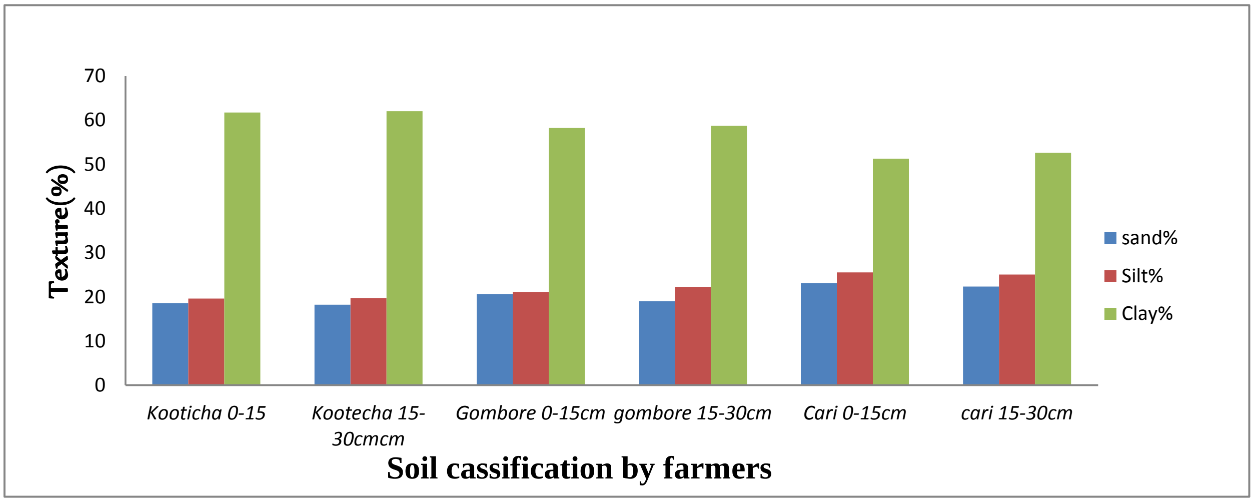

Figure 24. Mean values of soil particle size distribution on soils classified by farmers

There is also a considerable difference in each soil types classified by farmers interms of silt to clay ratio. The highest silt to clay ratio (0.49) was recorded in the surface soil sample of *Cari* (infertile soils) and the lowest (0.317) is from surface soil sample of *kotticha* (fertile soils). This ratio is one of the guides used to assess the rate of weathering and helps to determine the relative stage of development of a given soil.

According to Young (1976), a ratio of silt to clay below 0.15 is considered as low and indicats an advanced stage of weathering and soil development while >0.15 indicates that the soil is young containing easily weatherable minerals. All the three types of soils in the study area has > 0.15 silt to clay ratio. Hence, the soil of the study area is young that contain easily weatherable minerals.

4.6.2.2 Bulk density

There were significant differences (P<0.001) in Bulk density values between the three soil groups (fertile, moderately fertile and infertile) (Table 21). As shown in figure 19 and Table 21 the average BD of the three soil types classified by farmers in the study area was 1.47, 1.42 and 1.31 g/cm^3 *Cari*, *Gombore* and *Kooticha* soils respectively. In all cases the result of BD in kooticha soil is lower than Gombore and cari soils. In my opinion the trend in *kooticha* soil might be related to its high OM and clay content than other soil types classified by farmers.

It also exhibit consistent trend with depth, increases with increasing depth. The reason for the increment with depth could be related to reduce organic matter, aggregation and root penetration compared to the surface layers. Subsurface layers are also subject to the compacting weight of the soil above them. In addition, the surface horizons were under root development effect and relatively higher OM content which could be responsible for the comparatively lower bulk density values. With similar to this the past studies pointed out that bulk density of a soil increases with the increase in depth because of variations in organic matter content, porosity and compaction (Ahmed, 2002; Pravin *et al.*, 2013), BD has inverse relationship with the amount of pore space and soil OM, (Debela *et al.*, 2011).

The result shows that soils classified by farmers as most fertile, moderately fertile and infertile Shows a good, dense and dense range of bulk density based on Landon(1991)rate as shown in Appendix I.

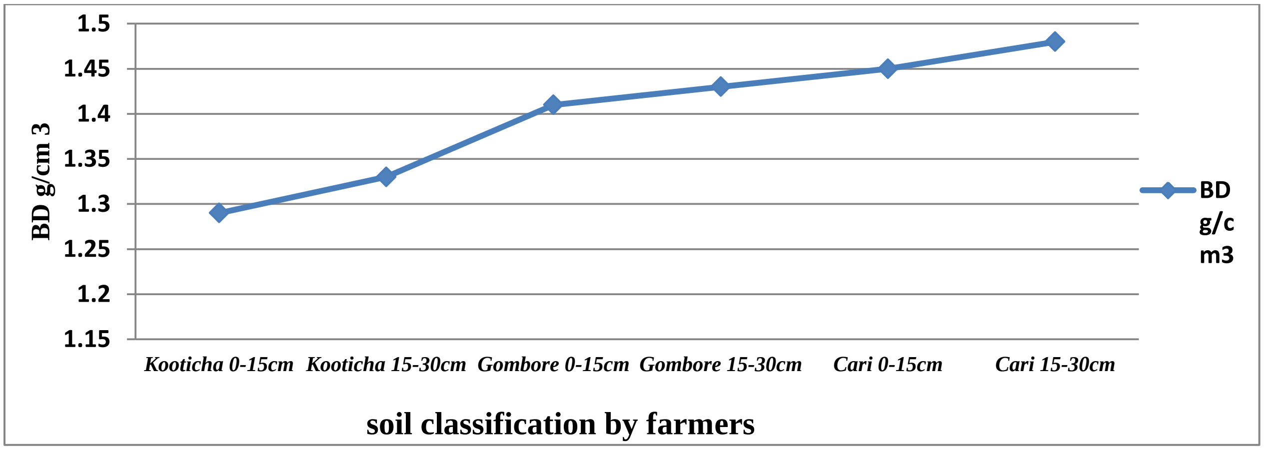

Figure 25. Mean values of soil Bulk density on soil classified by farmers

Table 21:Discriptive statistics of soil physical parameters and farmers perception about soil fertility status

Soil physical Properties	soil type	N	Mean	Std. Deviation	Std. Error	Min.	Max.	F	LSD
sand %	Most fertile	10	18.4150	.28372	.08972	18.14	19.06	131.545	0.000
	Moderately fertile	10	19.8370	.87900	.27797	18.90	21.05		
	Infertile	10	22.7350	.50229	.15884	21.97	23.41		
	Total	30	20.3290	1.91988	.35052	18.14	23.41		
silt %	Most fertile	10	19.6850	.16715	.05286	19.39	20.01	505.282	0.000
	Moderately fertile	10	21.7050	.62072	.19629	21.04	22.40		
	Infertile	10	25.3180	.26515	.08385	24.96	25.62		
	Total	30	22.2360	2.40140	.43843	19.39	25.62		
Clay %	Most fertile	10	61.9010	.16217	.05128	61.67	62.13	1381.514	0.000
	Moderately fertile	10	58.4600	.24558	.07766	58.19	58.73		
	Infertile	10	51.9450	.68455	.21647	51.20	52.72		
	Total	30	57.4353	4.21964	.77040	51.20	62.13		
BD(g/cm3)	Most fertile	10	1.3100	.02828	.00894	1.27	1.37	130.279	0.000
	Moderately fertile	10	1.4200	.01563	.00494	1.39	1.44		
	Infertile	10	1.4640	.02011	.00636	1.43	1.49		
	Total	30	1.3980	.06920	.01263	1.27	1.49		

Lsd: Least significant difference;N:Number of sample;BD:Bulk density;Min:Minimum; Max:Maximum

Table 22:Multiple comparison of soil physical parameters and farmers perception on soil fertility status

Dependent Variable	(I) soil type	(J) soil type	Mean Difference (I-J)	Std. Error	Sig.
sand %	Most fertile	Moderately fertile	-1.42200*	.27147	.000
		Infertile	-4.32000*	.27147	.000
	Moderately fertile	Infertile	-2.89800*	.27147	.000
silt %	Most fertile	Moderately fertile	-2.02000*	.17954	.000
		Infertile	-5.63300*	.17954	.000
	Moderately fertile	Infertile	-3.61300*	.17954	.000
Clay %	Most fertile	Moderately fertile	3.44100*	.19239	.000
		Infertile	9.95600*	.19239	.000
	Moderately fertile	Infertile	6.51500*	.19239	.000
BD(g/cm3)	Most fertile	Moderately fertile	-.11000*	.00983	.000
		Infertile	-.15400*	.00983	.000
	Moderately fertile	Infertile	-.04400*	.00983	.000

4.6.3 Analysis of soil chemical property

4.6.3.1 Soil reaction (pH)

The indicator of soil acidity and basicity is known as soil PH. The pH of a particular soil reflects a certain chemical and mineralogical environment in that soil. For these reasons, soil pH is one of the most important factors affecting soil fertility and so is commonly managed to increase Productivity. The mean pH value were 7.03, 6.85 and 6.7 for *Cari*, *Gombore* and *Kooticha* soils respectively (Table 23, and Figure 20) and was statistically significant ($p<0.001$). Similarly, Berhanu (1985) stated that about 61% of the Vertisols have pH values of 5.5-6.7, 21% have pH values of 6.7-7.3, and 9% have pH values of more than 8.

According to the rate set by Tekalegne (1991), the mean PH value of *Gombore*, *Kooticha* and *Cari* soil qualifies for the neutral soil reaction class (pH 6.7-7.3) (Appendix G). This shows that the soil classified by farmers as most fertile, moderately fertile and infertile shows neutral soil reaction class based on Tekalegne(1991) rating , as shown in Appendix G , which is favourable range for availability of most nutrients and activities of microorganisms.

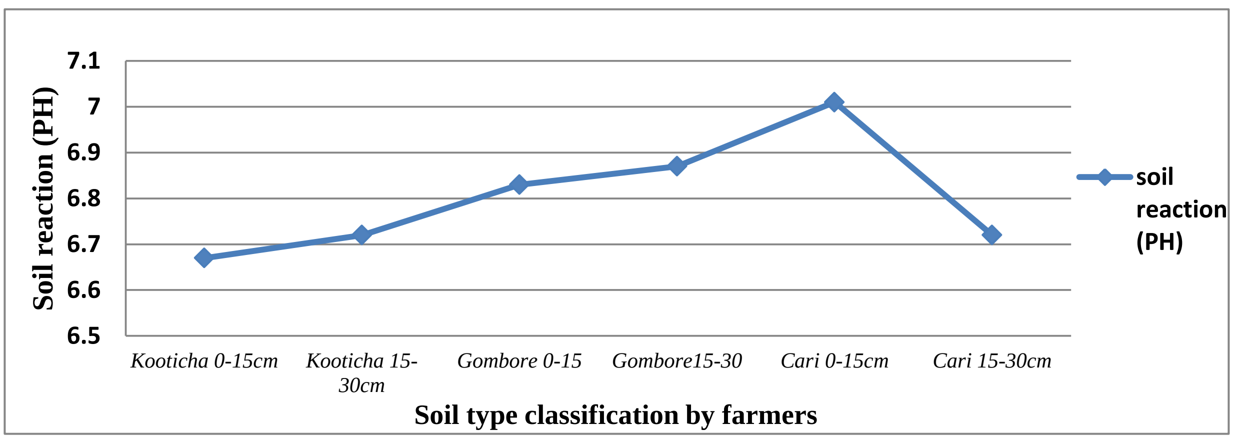

Figure 26. Mean values of soil reaction (PH) on different soil types classified by farmers

The results of soil pH value showed a slightly increasing trend with soil depth in all the three different types of soils classified by farmers.The author stated that this slight increase in soil pH with depth could be due to decreased OM content with depth and subsiquent less H+ ions are released from decreased OM decomposition. And also due to appropriate moisture content and the comparatively high organic matter content near surface profile. Organic matter decomposition can produce carbonic acid, carboxylic acid and inorganic acids (Brady & Weil, 1999) that causes acidic pH in the region where high organic matter content.

4.6.2.4 Soil organic carbon

Organic carbon is one of the most important components of crop yield, crop residue and other organic sources such as manure. The mean SOC content for *Cari, Gombore* and *Kooticha* soil were 1.17, 1.44 and 1.51 respectively (Table 23, and Figure 21) and was statistically significant ($p<0.001$). According to the rate set by Tekalegne (1991), soil having organic carbon of >3 qualify as high, 1.5-3.0 medium, 0.5-1.5 low and <0.5 as very low (Appendix H).Therefore, *Kooticha* soil qualifies for medium OC class (OC 1.5-3.0) and *Gombore* and *Cari* soil qualifies to low OC class (OC 0.5-1.5) (Appendix H).This shows that soils classified as most fertile by farmers has medium level of SOC while moderately fertile and infertile soils are fall under the low class based on Tekalegne(1991) rate. Usually the level of Soil Organic carbon are low in Vertisols, particularly when they are cultivated continuously, as in the case of Ethiopia. This is the case in spite of their dark color, which is thought to be because of the formation of organic matter-smectite complexes. The reasons for the low OC levels observed in the *Cari* soils of the study area could be the removal of crop residues for animal feed and source of energy. Moreover, the practice of organic fertilizers addition such as manure and/or green manure is at a very low level. The OC content variation within the soil type classified by farmers show consistent trend with depth. It decreased consistently with soil depth in all the soil types.

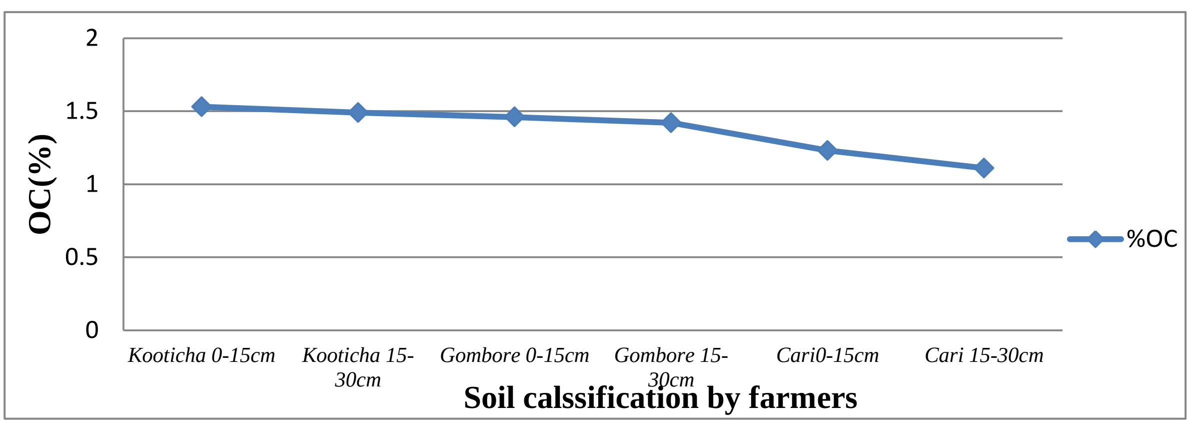

Figure 27. Mean values of OC of different soil tpes classified by farmers

Generally, the value is similar to most cultivated soils of Ethiopia which have low organic matter content which is attributed to land use history such as whole removal of biomass from the field and rapid rate of mineralization (Abayneh, 2001).

4.6.2.5 Total nitrogen

Nitrogen is the most limiting nutrient and critical shortage of this nutrient brings significant grain/biomass yield reduction. Most Ethiopian black or dark grey soils are N-depleted and more than 50% of cultivated lands are N-responsive soils (Yihenew, 2002).

The average TN content for *Cari, Gombore* and *Kooticha* soils were 0.101, 0.124 and 0.131 respectively (Table 23, and Figure 22) and significantly different (P<0.001). According to the rate set by Murphy(1968), soil having TN of >0.25 qualify as very high, 0.15-0.25 as high, 0.10-0.15 medium, <0.10 as low (Appendix J). Therefore, all *Kooticha, Gombore* and *Cari* soil qualifies for medium class (TN 0.10-0.15) (Appendix J). The highest (0.132) and the lowest (0.096) mean TN were observed in surface sample of fertile *Kooticha* soils and sub surface sample of infertile *Cari* soils, respectively (figure.22). This implies that the soil classified by farmers as most fertile, moderately fertile and infertile ranks as 1st, 2nd and 3rd in TN content respectively.

With similar to the variations in OC content, total nitrogen also exhibited some degree of variability among soils with soil depth.This implies that total N content of the soils in the three groups was comparatively higher in the surface horizons and showed a decreasing trend with soil depth. Similarly, Nega (2006) reported that average total N decreased with increasing depth from surface to subsurface soils.

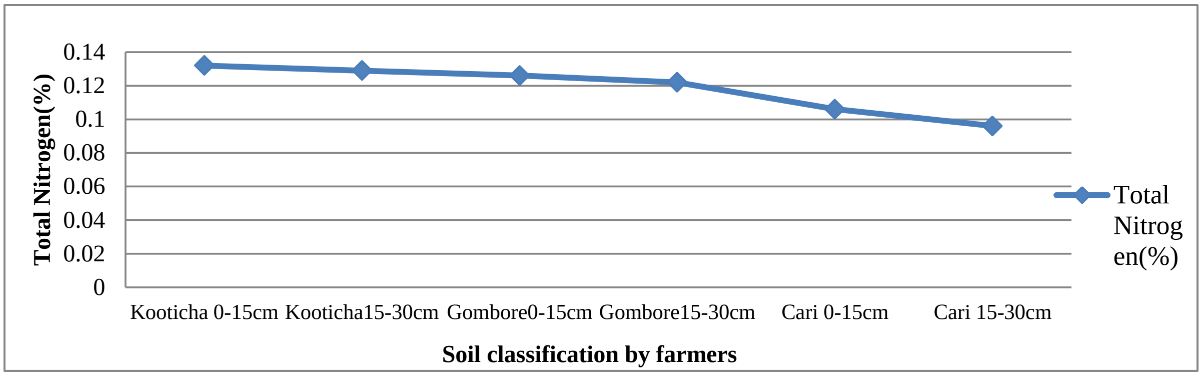

Figure 28. Mean values of Nitrogen on different soil classification of farmers

Similarly Berhanu (1980), stated that total N contents of Vertisols of the Central highlands and Eastern lowlands of Ethiopia varied from 0.08 to 0.22% and the C: N ratio was about 11-18. Furthermore, other research works (Tekalign *et al.*, 1988 ; Mohammed, 2003) conducted in Ethiopia Vertisols also indicate that N is the most deficient nutrient element than any other essential element in these types of soils and has called for the application of inorganic fertilizers and need for a sound management of soil fertility.

4.5.2.7 Carbon to Nitrogen ratios

In line with the trends perceived in soil organic matter and total nitrogen, the carbon to nitrogen ration (C: N) of soils also revealed differences among the three groups of soil and with soil depth (Table 12). The mean carbon to nitrogen (C: N) ratio of 11.58, 11.62 and 11.57 was observed in Cari, Gombore and Kooticha soils respectively. According to the rate established by Landon (1991), C/N ratios >25 as very high, 16-25 as high, 11-15 as medium and <11 as low (Appendix M). Thus, the C/N ratio of all *Cari, Gombore* and *Kooticha* soils falls under medium rate of C/N (Landon, 1991).

Considering the classification made by farmer's higher mean C/N ratio value of 11.64 and 11.60 was found on fertile *Gombore* and infertile cari soils while the lower C/N ratio value of 11.55 was found within the most fertile *kotticha* soil (Figure 23). The highest C/N value in *cari* and *Gombore* soil implies there will be no net mineralization and accumulation of N (Attiwill & Leeper, 1987). They further noted that as decomposition proceeds, carbon is released as CO_2 and the C/N ratio falls.

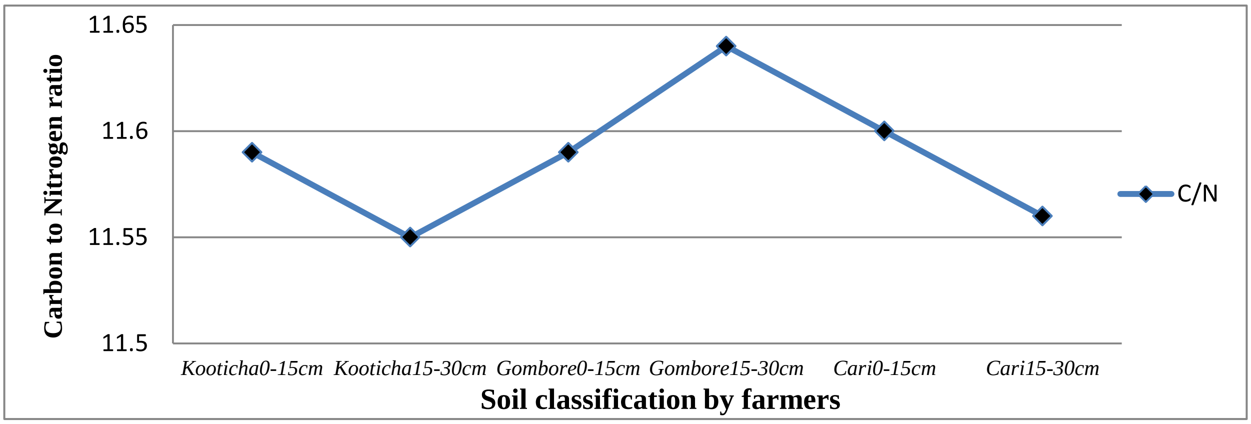

Figure 29. Mean values of C/N ratio of the soil on different soil classification of farmers

The C: N ratio of the three groups of soils exhibit different trend with depth. In both *Kooticha* and *cari* soils it increases with depth but it decreses with depth in Gombore soils. The low carbon to nitrogen (C: N) ratio at the surface layers of *Gombore* soil may be due to the effect of microbial activity and the consequent CO2 evolution than in the subsurface layers. Achalu *et al*. (2012) also reported narrow C: N ratio at the surface soils of cultivated land as a result of enhanced mineralization of OC than N due to better aeration during tillage and increased temperature.

Table 23:Discriptive statistics of soil chemical papameters (PH, OC and TN)and farmers perception about soil fertility status

Soil chemical Propertie	soil type s	N	Mean	Std. Deviation	Std. Error	Min.	Max.	F	Lsd
PH-H2O	Most fertile	10	6.6950	.06346	.02007	6.59	6.80	67.490	0.000
	Moderately fertile	10	6.8500	.03333	.01054	6.79	6.91		
	Infertile	10	7.0300	.08576	.02712	6.93	7.21		
	Total	30	6.8583	.15252	.02785	6.59	7.21		
OC	Most fertile	10	1.5100	.02449	.00775	1.48	1.55	176.174	0.000
	Moderately fertile	10	1.4400	.02494	.00789	1.41	1.48		
	Infertile	10	1.1700	.06532	.02066	1.09	1.25		
	Total	30	1.3733	.15470	.02824	1.09	1.55		
TN	Most fertile	10	.1291	.00296	.00094	.13	.13	115.201	0.000
	Moderately fertile	10	.1233	.00411	.00130	.12	.13		
	Infertile	10	.1011	.00559	.00177	.09	.11		
	Total	30	.1178	.01297	.00237	.09	.13		

LSD: Least significant difference; N: Number of sample; OC: organic carbon; TN:Total nitrogen

Table 24: Multiple comparison of soil chemical parameters (PH, OC and OM) and farmers perception on soil fertility status

Dependent Variable	(I) soil type	(J) soil type	Mean Difference (I-J)	Std. Error	Sig.
PH-H2O	Most fertile	Moderately fertile	-.15500*	.02886	.000
		Infertile	-.33500*	.02886	.000
	Moderately fertile	Infertile	-.18000*	.02886	.000
OC	Most fertile	Moderately fertile	.07000*	.01913	.001
		Infertile	.34000*	.01913	.000
	Moderately fertile	Infertile	.27000*	.01913	.000
TN	Most fertile	Moderately fertile	.00580*	.00195	.006
		Infertile	.02800*	.00195	.000
	Moderately fertile	Infertile	.02220*	.00195	.000

4.5.2.8 Available Phosphorus, Potassium and Na

Phosphorus (P) is a critical element in natural and agricultural ecosystems and its management is basic next to the management of N for the production of healthy plants (Brady & Weil, 2002). The average P of the three soil types in the study area were 5.52, 7.21 and 11.54 for *Cari*, *Gombore* and *Kooticha* soil respectively (Table 25, and Figure 24) and significantly different (P<0.001).

According to the rate set by Olsen *et al* (1954) available P of soil >10 qualify as high, 5-10 $mgkg^{-1}$ as medium and <5 $mgkg^{-1}$ as low. So, the available P of *Gombore* and *Cari* soils falls on medium classes while available P of *Kooticha* soils fall under high available P class of Olsen *et al.* (1954)(Appendix K). In reverse to the result the literature pointed out that most Ethiopian soils including Vertisols are deficient in P when assayed by chemical methods; yet, with the addition of P fertilizers, field crop P responses on these soils, particularly in the central highlands are low, even under improved drainage conditions (Tekalign *et al*., 2002).

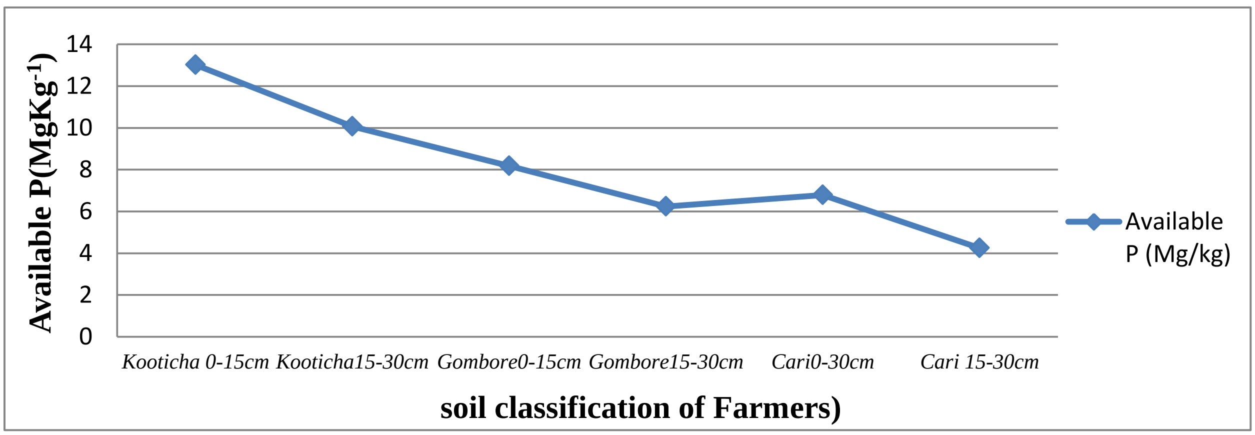

Figure 30. Mean values of available phosphorous (Olsen) of the soil classified by farmers

Figure 24 indicates that regarding farmers perception a soil type classified by them as most fertile contains high available phosphorus based on Olsen *et al.* (1954) classification.

In all soil types available phosphorus content was observed consistently decreased with soil depth. The comparatively higher available phosphorus content in most surface horizons as compared to the subsurface horizons could be attributed to the application of phosphorus containing fertilizers, animal manure and compost by the farmers to improve production as per the information obtained from the farmers, as well as relatively higher OM content in the surface. This is in agreement with the finding of Awdenegest *et al*. (2013) who reported that the higher available phosphorus in the top soil layer of farmland may be related to the application of animal manure, compost, household wastes like ashes and DAP fertilizer for soil fertility management. Girma and Endalkachew (2013) also support this finding by indicating that the high phosphorus in top soil might be attributed to external phosphorus supply, and phosphorus carry over from fertilization.

Soils of the study area also contained available potassium. Available potassium content of the three soil groups also show significant difference at ($P<0.001$). The average K of the three soil types in the study area were 0.395, 0.57 and 1.49 cmol (+) kg^{-1} for *Cari, Gombore* and *Kooticha* soil respectively (Table 25, and Figure 25). Based on Landon (1991), available potassium of soil >0.5 $mgkg^{-1}$ qualify as high, 0.25-0.5 $mgkg^{-1}$ as medium and <0.25 as low values. Regarding to the rate of exchangeable K, FAO (2000) established >1.2 as very high, 0.6-1.2 as high, 0.3-0.6 as medium, 0.2-0.3 as low and <0.2 as very low.

With respect to classification based on farmers perception thus, the K content of *Cari, Gombore and Kooticha* soils falls under the medium and very high range of FAO (2006) respectively as indicated in Appendix L. This implies that the soil type that are perceived as most fertile by farmers and proved by the soil laboratory as composed of high clay content have high K. Similarly Tisdale *et al.,* 1995 pointed out that the greater the proportion of clay mineral high in K, the greater will be the potential K availability in soils.

Surface horizon soil sample of the three groups' available K content was relatively higher than the sub surface samples. Moreover, it showed a decreasing trend with soil depth. The result of this finding agree with the finding of Jobbagy and Jackson (2001) who reported that nutrients strongly cycled by plants, such as K, were more concentrated in the top soil than nutrients usually less limiting for plants.

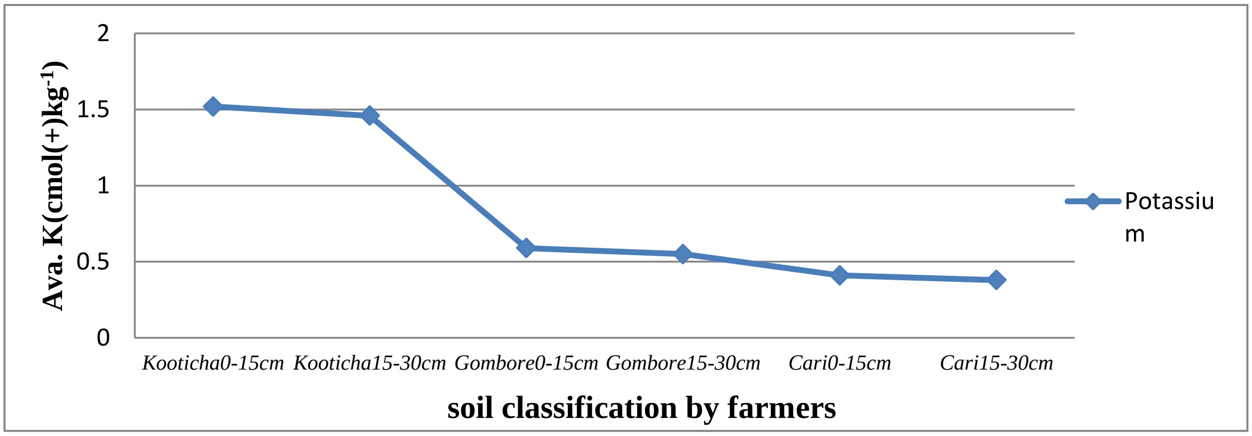

Figure 31. Mean values of available Potassium of the soil classified by farmers

Na content of the three soil groups also show significant difference at (P<0.001).With similar to the other major nutrents the highes values of Na (0.49 cmol (+) kg^{-1} was obtained from *kooticha* soils that perceived as most fertile by farmers while the lowest (0.13 cmol (+) kg^{-1} was registered from the infertile *cari* soils (Table 25 and Figure 26). According to the FAO (2006) rate of classification, Na > 2 stated as very high, 0.7-2 as high, 0.3-0.7 as medium, 0.1-0.3 as low and <0.1 as very low. Thus, the observed exchangeable Na value of the soils that are classified as most fertile by farmer's falls under medium and soils that are classified as moderately fertile and infertile by farmers are fall under low rate of FAO (2006) as indicatd in Appendix N.

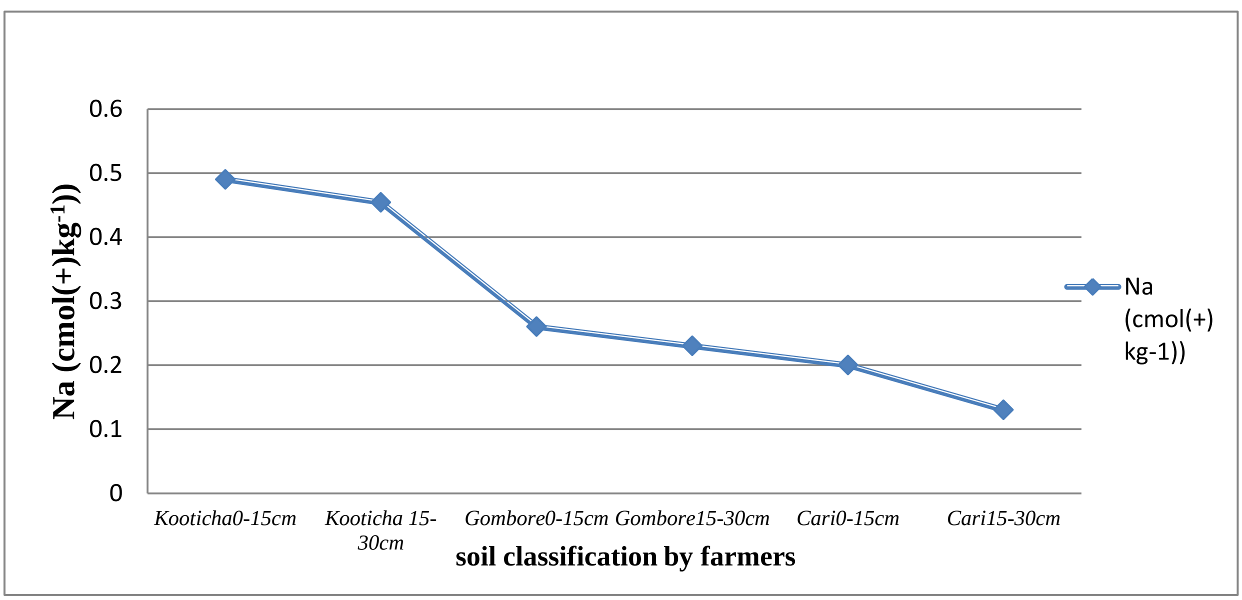

Figure 32. Mean values of exchangable Na of the soil classified by farmer

Table 25: Discriptive statistics of soil chemical papameters (P,Na and K) and farmers perception about soil fertility status

Soil chemical properties	soil type	N	Mean	Std. Deviation	Std. Error	Min.	Max.	F	Lsd
P	Most fertile	10	11.5450	1.55486	.49169	10.05	13.04	55.119	.000
	Moderately fertile	10	7.2100	1.02283	.32345	6.19	8.22		
	Infertile	10	5.5200	1.33900	.42343	4.21	6.81		
	Total	30	8.0917	2.87961	.52574	4.21	13.04		
Na	Most fertile	10	.4710	.02424	.00767	.44	.51	281.110	.000
	Moderately fertile	10	.2450	.02173	.00687	.21	.28		
	Infertile	10	.1650	.04035	.01276	.11	.23		
	Total	30	.2937	.13492	.02463	.11	.51		
K	Most fertile	10	1.4900	.03496	.01106	1.44	1.54	4315.115	.000
	Moderately fertile	10	.5700	.02749	.00869	.53	.61		
	Infertile	10	.3950	.02068	.00654	.36	.43		
	Total	30	.8183	.48926	.08933	.36	1.54		

LSD: Least significant difference; N: Number of sample;

Table 26:Multiple comparison of soil chemical parameters (P,Na and K) and farmers perception about soil fertility status

Dependent Variable	(I) soil type	(J) soil type	Mean Difference (I-J)	Std. Error	Sig.
P	Most fertile	Moderately fertile	4.33500*	.59198	.000
		Infertile	6.02500*	.59198	.000
	Moderately fertile	Infertile	1.69000*	.59198	.008
Na	Most fertile	Moderately fertile	.22600*	.01339	.000
		Infertile	.30600*	.01339	.000
	Moderately fertile	Infertile	.08000*	.01339	.000
K	Most fertile	Moderately fertile	.92000*	.01266	.000
		Infertile	1.09500*	.01266	.000
	Moderately fertile	Infertile	.17500*	.01266	.000

CHAPTER FIVE

Summery, Conclusion, Recommendation and Research implications

5.1 Summary

Farmers knowledge of soil fertility status has come to be seen as essential in understanding the local realities of farmer and may be critical for the success or failure of agricultural development. In light to this the main objective of this study was to assess farmer's perception of soil fertility status, classification, management practices and compare them with the scientific practice in kumbursa *village*. The study area is located in Ada'a District, Eastern shewa zone of Oromia regional state at a coordinates of 8^0 32' 30"- 8^o 57' 30" North & 38^o 47' 30"E- 39^o 12' 30" East with an altitudinal ranges of 1800 to 2400 masl, receiving an average annual rainfall of 839.69 mm and minimum and maximum temperatures of 16.79 and 19.78 ^oC, respectively.

It was search to analyze differences in the physical and chemical properties of each soil types classified by farmers. In order to achieve the general objectives this study formulated the following specific objectives:

- To assess farmers' perception and experience to define status of soil fertility;
- To Identify the major indicators given by farmers to classify status of soil fertility;
- To assess farmers' major soil fertility management practices;
- To document farmers perceived value of soil fertility for crop yield;
- To examine interaction effects of farmers'perception and soil depth on selected soil physical properties;and
- To examine interaction effects of farmers'perception and soil depth on selected soil chemical properties.

In line with the above objectives, survey methodology was employed. The main source of data for this research was farmers in the village. Before collecting the actual data, the researcher carried out a general visual field survey of the area to have a general understanding of the study area. Global Positioning System readings were used to identify the geographical locations and the coordinate system where data was taken. Data collection process in this study consists of questionnaire and FGD with selected farmers. The sample size considered was 83(30% of the total population) respondents selected from the three wealth category through stratified proportional sampling (Rich, medium and poor). To analyze data, both descriptive (mean and standard deviation) and inferential (one way ANOVA) statistics methods were employed.

Through the data analyses and discussions, the researcher came up with the following major findings:-

- Farmers in the study area had a good knowledge about the status of soil fertility. They notified their soils based on their experience of the potential and constraints of their own soil as they cultivated their land for several decades. Mainly soil color, crop productivity, soil drainage, soil water holding capacity and texture were used as criteria to differentiate different soils in the study area. Generally, these are characteristics they can see, feel, or smell in their fields, and are based on their own experiences in cultivating the fields. From all indicators the most important is soil colour. Soil that is black in colour (Kooticha) viewed as the most fertile.
- Almost all farmers perceive that the fertility level of their soil becames decreases from time to time. The use of these dynamic concepts suggests that, farmers consider soil fertility decline as part of a wide complex of interacting constraints that they face on the implimentation of important soil fertility management practices and yield decline as resulting from these interactions.
- Farmers also suggested about how to manage their soils to sustain the productivity level. However, factors like shortage of land, absence of alternative source of energy or shortage of fuel wood were affecting their decision to practice the different traditional soil management methods.
- Considering the three soil groups (fertile, moderately fertile and infertile), the higher mean values of K (1.46 cmol(+) kg-1), Na (0.49 cmol(+) kg-1), total nitrogen (0.132 %), Available Phosphorous (13.02 ppm), organic carbon (1.53%) and neutral pH-H2O (6.67) were observed within the good (*Koötticha*) soils while the highest mean value of sand particle (22.34% in the surface and 23.13% in the subsurface) was observed on infertile *Cari* soils. Thus these all results showed that there was no difference between both perceptions of farmers and scientific practices. Except pH all other physicochemical properties showed decreasing trend with increasing depth.

5.2 Conclusions

Based on the findings of the study, the following conclusions are drawn.

- In the study area farmers have a well-developed knowledge system about their soils, nutrient provision through decomposition of plant organic litter, and nutrient loss and cycling processes. This knowledge system is made up of experiences and phenomena that they can visualize and information retained from colleague farmers and extension officers. So inorder to explore better opportunity for soil fertility understanding farmers view and their soil fertility management is indispensable.
- Apart from local perceptions of soil fertility processes, socio-economic factors such as monetary value of various management techniques heavily influence which techniques farmers implement.
- There is overlap between farmers' and researchers' soil fertility knowledge for there to be useful dialogue as the basis for developing a sustainable approach to managing soil fertility.
- Though farmers' knowledge and perceptions of soil fertility are purely qualitative, they tended to match the scientific assessment of fertile or infertile soils. There were nevertheless some fundamental differences. Whereas scientific frameworks tend to be based on inherent soil characteristics that can be quantified independently of the context, the local approach integrates complex soil–plant–water relations and interactions in terms of factors such as soil colour, yield levels, growth rates and workability, and water holding capacity in the wider ecological context.
- Similarly, their classification and indicators rely on soil characteristics that they can experience, so that the names they give to soils do not necessarily correlate to the scientific classification. Researchers, on the other hand, are usually more interested in the way the soil was formed, or in things that they can measure and which are not always visible (e.g. soil N content).
- Use of inorganic fertilizers (DAP and urea), organic inputs (compost) and soil erosion control measure (soil bunds) were common soil fertility management practices which were practiced by most of the farmers.
- The use of farmyard manure in the area is constrained by shortage of livestock holding.Thus it needs more attention in solving livestock feed shortage.

- Farmers in the study area use important agronomic practices such as crop rotation and inter cropping along with soil fertility management practices.
- There is also a strong correspondence between farmers' assessment of soil fertility status and the measured soil physical and chemical characteristics. Fields that were described by farmers as fertile have significantelly higher values of percentage of organic matter, total nitrogen, available phosphorus, and potassium, and neutral pH.
- And in all soil samples from various depths, the parameters such as NPK and soil organic carbon decreses with depth. The main reasons behind these reductions are low organic matter input and low microbial activitywith increasing depth.

5.3. Recommendations

On the basis of the practical field observations, findings and conclusions drawn so far the following recommendations are put forward፡-

- The agricultural ministries, local agricultural extension staff and NGOs, universities and agricultural research institutions and local governments can play an important role to fill gaps (difference on understanding of soil fertility status)between farmers and scientific knowledge.
- Appropriate policy formulation and implementation is needed which enables farmers to reduce the impact of soil fertility depletion as this is expected to result in low productivity which hinders achieving of food security.Understanding of these factors would contribute to design of appropriate strategies to achieve better utilization of soil in the soil fertility management system in the study areas and other similar areas of the district ,zone and the region.
- Intervention is required to solve problems of alternative source of energy or shortage of fuel wood that forces farmers to use crop residue and dung as asource of energy rather it is important to improve the soil fertility level.
- Farmers should be considered as a research partners for any technology generation regarding soil fertility management. Agricultural research and extension should also be based on the farmers' indigenous knowledge for efficient utilization and adoption of soil management technologies. Therefore, studies relating the farmers' indigenous soil management and classification knowledge to that based on modern research are paramount important in the future.

- Special attention should be focused on the development of farmers' skills for preparation and use of organic manures. The extension workers of the on-going soil fertility management project may insist to work.
- Large number of farmers in the study areas are not better in undertaking varieties of soil fertility management activities to respond to soil fertility depletion challenges. Therefore, those activities which are only applied by few farmers are very essential (like: crop rotation, and intercropping), and shall get detail assessment of their opportunity and should be expanded to other farmers.
- Wealth and sex of a household positively influences the use different soil fertility management practices. This means that rich and male headed households are more effective than female headed households in utilizing different soil fertility management practices. Therefore, due attention should be given to poor and medium female headed households in building their asset to make them effective participation in utilizing different soil fertility management practices.
- Livestock holding positively influence use of organic fertilizer especially farmyard manure. Since the main problem of livestock production is shortage of grazing land and feed, attention should be given in animal forages development that are easily suitable in different agroecologies. These may lead to an opportunity of increasing livestock holding so that farmyard manure usage by households is increased. Increasing livestock holding may also improve means of generating additional income, so that they can easily purchase inorganic fertilizer too.

Generally,both farmers and researchers have similar objectives, namely to ensure that the soil resources are sufficient to meet the needs of present day farmers and also the farmers of the future. Therefore, recognizing both perceptions of soil fertility is important. For this to occur, researchers need to understand and use indigenous knowledge systems, which need to be viewed, not as opposing, but rather as complimentary to their own way of thinking. Researchers can also provide the breadth of understanding of soil biophysical processes gained from experiences world-wide, whereas farmers can provide the context-specific knowledge required to adapt this understanding to local biophysical and socio-economic conditions. Local agricultural extension staff can play an important role in enhancing this essential link between the two worlds.

5.4 Research Implications

The results of this study suggest the following implication for further research፡-

- Future studies should put into consideration a wider geographic reach; extend the study to all other districts in Ethiopia, since the largest population in Ethiopia depends on agriculture as their main source of livelihoods.
- Since this investigation involved a survey instrument consisting of Questionnaire , Focus group discussion, direct observation and interview methods and tried to test only some of soil physical and chemical properrties (texture,BD,OC,OM,TN,P,K,PH and Na) further investigation would be good if conducted by including secondary major and minor soil nutrents.
- There is much to be gained from communicating with farmers. The comparison of evaluation criteria described in this report is a preliminary search for common ground shared by the soil scientist and the farmer. Attention was focused on conventional scientific indicators such as texture, and soil depth but farmers often have unique criteria for soil evaluation that were not considered here. More work is needed to appreciate the value of taste, aroma, and other properties in soil evaluation. Soil surveyors in all development projects should record farmers' evaluations of field sites, investigate their criteria for site evaluation, and request their assistance in soil mapping.
- Finally, in my opinion further studies should be carried out to carefully monitor and assess how farmers continue using and adapting scientific technologies and need to evaluate the influence of social support and social networks on farmer in spread and adopt of SFMTs in rural situations.

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ADDIS ABABA UNIVERSITY
Graduate Studies
College of Social sciences
Department of Geography and Environmental studies
February ,2017

Information sheet for respondant farmers about this study

ASSESSMENT OF FARMER' PERCEPTION ON SOIL FERTILITY STATUS,CLASSIFICATION, MANAGEMENT PRACTICES AND COMPARISON TO SCIENTIFIC PRACTICES IN KUMBURSA VILLAGE, ADA'A DISTRICT, CENTRAL HIGHLAND, ETHIOPIA

Dear participants,

My name is Amelework Kindihun. I am a master's student in Addis Ababa University; Geography and Environmental studies department (Land resource management stream).This questionnaire is designed to gather information for a study on assessment of farmer's perception on soil fertility with different management practices in small holding farms of kumbursa village. For this study i need 83 househods of different wealth group(Rich,Midium and Poor). I invited you to take part in this study about your perception on soil fertility.This study examines the various factors that came from your daily experiance and helps you and other persons to classify your soil.The study will compere your perception on soil fertility level with the scientific view.

To achieve this purpose and to deeply investigate the case, your response to the questions given below has a crucial value. I hope that the research outcomes contribute to the improvement in soil management practices. Therefore, you are kindly requested to read the questions carefully and give accurate and real data. The response that you reply will not be used for any other purposes other than this research work, so be free and give your honest and genuine response.

What will be expected of participants involved in this study?

You will be interviewed for 30-40 minutes by the researcher.The questioinnaire will be made up of alist of simple questions and will ask you about your family characterstics(family size,age distribution,number of livestock,land holding size), your perception on your soil fertility level and some details about the management practices you implimented for better of your soil.During this assessment period, feel free to ask any question about what you don't understand.

N.B. 1.The response you give will not have any negative impact on you.

2. Please respond in feeling free what you thinking is correct.

Thank you in advance for your Cooperation!

Respondent code

ASSESSMENT OF FARMER PERCEPTION ON SOIL FERTILITY STATUS, CLASSIFICATION MANAGEMENT PRACTICES AND COMPARISON TO SCIENTIFIC PRACTICE: IN KUMBURSA VILLAGE ADA'A DISTRICT, CENTRAL HIGHLAND, ETHIOPIA

Consent form between farmers and researchers for filling the questionery

Please put ✓or ×in the box

1.I verify that i have understood the information sheet for the study. I have had the chance to consider the information, ask questions and have had these answered satisfactorily. ☐

2.I agree to completing ashort questionnaire about my age,all about family characterstics,my perception on soil fertility and details of approperate soil fertility management practices comes in the area. ☐

3.Iunderstand that my participation is voulentery and the data will use for this study only. ☐

4.Igive permission for taking soil samples from my plot if my farm land is selecteed. ☐

________________	________________	________________
Name of respondants	**Date**	**Signature**
________________	________________	________________
Witness	**Date**	**Signature**
________________	________________	________________
Name of Researcher	**Date**	**Signatur**

Appendices:

Appendix A: House Hold Survey Questionnaire

February,2017

Addis Ababa University

Graduate Studies

College of Social sciences

Department of Geography and Environmental studies

A Questionnaire to be completed by Farmers of Ada'a District, Ude peasant Association, kumbursa *village*.

Read the questions and use tick mark (√) or circle your choice

Part one. FARM HOUSEHOLD CHARACTERISTICS

1) General information

1.1. Name of the enumerator ___________________Signature ______ Date _______

1.2. Questionnaire number ____________________

1.3. Respondent's Sex _____ Age _____ Signature _____

1.4 Name of the kebele---------- Location: District--------Zone----------

Gps coordinates at/near the farm of respondant

A.Latitude_________________Longitude________________c.Altitude____________

2) Socio-economic and demographic characteristices

2.1 Sex of respondants: 01) Male ---------02) Female----------------

2.2 Educational Level of the respondants:

(01) Can not read and write (02) Read and write (03) Elementary School (04) Secondary (7-8) (05) Secondary high school (9-12) (06) Diploma (or equivalent)

2.3 Marital status: 01) married 02) single 03) divorced 04) widowed 05) Widower

2.4 Household Family Size: total number of families with age and sex category:

NO	Age	Male	Female	Total
1	0-5			
2	5-15			
3	15-30			
4	30-60			
5	60+			
Total				

3.For how long have you been here? A.<10 Years B.10-20Years C.20-30Years D. >30 Years

4.Total land size.Hectar............/Timad...........

5.What kind of crops do you produce? A)Vegetables B)Fruits C)Cereals D)Grains E)Oil seeds F.If any other,pleas specify...

6.What type and amount of animals do you own?

Animal type	Number of animal
1.Cows	
2.Oxen	
3.Heifers	
4.Calve	
5.Sheep	
6.Goats	
7.Horses	
8.Donkeys	
9.Hens	
10.Others	

7.For what purpose do you use the animal waste? Multiple responses are possible.

1)retain in the field 2)For house decoration 3)sold to market 4) For Biogas 4)Used as afire wood 5)If any,please specify.....................

8. How many growing cycles do you have per year?

1)One 2)Two 3)Three 4)More than three

9.How many months does each growing cycle last?

1)One 2)Two 3)Three 4)Four 5)more than three

10.Would you use one land in all of the growing seasons? 1)Yes 2)No

11.If your answer for question number 16 is No,Why..

12.For what purpose do you use the crop residues? Multiple responses are possible.

1)retain in the field 3)For construction of house 5)sold to market

2)Used as afire wood 4)Feed for livestock 6)If any,please specify.............

13.What you use to plough the land?

1)Oxen 2)Tractor 3)If any,please specify...

14.How many times you till the land before planting cereals?

1)once 2)twice 3)three times 4) Other.........................

15.Is there Extension workers in your district? A.Yes B.No

16.If your answer for question number 21 is yes,what they support you to improve the fertility level of your soil?

A. soil management techniques (ditch) B. providing improved seeds

C providing training how to prapared compost D.Other.......................................

17.Is there NGO's in your district? 1)Yes 2)No

18.If your answer for question number 17 is yes,what they support you in order to improve the fertility status of your soil...

19.What are the serious peroblems to your soil fertility status?Multiple answers are posible

A.The farm land is too small C.Erosion E.Water logging

B.Poor soil fertility D.Distance from home F.If any other,specify....

Part two:-Questions related to farmers perception on soil fertility status.

2.1.How do you explain the fertility level of your farm land?

A)Less fertile B)Moderately fertile C)Most fertile

2.2. How do you describe the development of your soil fertility level?

A.Declined significantly B.Declined somewhat C.Remained the same

D.Improved somewhat E.Improved significantly

2.3. How do you determine soil fertility status?

a) Do you use visual inspection? If yes, how?..

b) Do you use physical measurements? If yes, how?.....................................

c) Do you use crop performance (i.e. growth rate or output in terms of yield)………………………

Part Three:-Questions related with the most common soil fertility management methods that farmers apply to upgrade the soil.

3.1 How do you see the rate of soil fertility problem on your farm?

A. High B. Medium C. Low D. I don't know

3.2 If your answer to question number one is high, how do you treat it? Multiple responses are possible.

A.Use of inorganic fertilizer C.Green manure E.Cover crop

B.Use of organic fertilizer D.Fallowing F.Intercropping

G. Crop rotation H.If any other, please specify...........................

3.3 How many times do you use chemical fertilizers in one agricultural season? Use the table below to answer the question and use (√) to answer frequency of fertilizer application and time of application shall be identified by saying **before sawing, while sawing and after sometimes crops gro**

	Frequency of applcation	Times of applic tion
Once		
Twice		
Three times		

3.4 What are the major challenges that you face towards using chemical fertilizers?

A. Expensiveness B. Shortage of supply

C. Lack of credit D. Lack of awareness

3.5 Do you think that using chemical fertilizer alone can solve soil fertility problem?

A. Yes B. No C. I don't know

3.6 If your answer to question number 3.5 is No. what other things shall be done to

Improve soil fertility? ---

3.7 How often do you plough one agricultural season?
A. 1 times B. Up to three times C. From four to 8 times D. > Eight times

Types of crop	Frequency of ploughing
Teff	
Other Cereals	
Oil seeds	
Fruit and Vegetables	

3.8 Problems related to use of organic inputs

Use of organic inpusts	Less available	Difficult to transport	Used for other purpose	Less effect in increasing productivity	Need further process and Need more labor	Negative impact on next crop season	If any other please specify
Manure							
Use of Crop residue							
Compost							
Mulching							

3.9 Problems related to use of soil erosion control practices

Use of soil erosion control	Difficult to plough and turn the oxen	Take Labor force	Difficult to construct	Drainage problem	Decrese th e size of the farm land	If any other please specify
Soil bund						
Terracing						
Construction of check dam						
Contour farming						
Grass strips						
Wind break						

Part Four: Soil Classification

4.1. Do you classify your soils? Yes…………No…………

4.2. If yes, which of the following soil properties do you Consider?

Table 1

Parameters	Rank of soil properties based on importance								
	1^{st} rank	2^{nd} rank	3^{rd} rank	4^{th} rank	5^{th} rank	6^{th} rank	7^{th} rank	8^{th} rank	9^{th} ran k
Organic matter roots/residue									
Soil drainage infiltration									
Soil depth									
Water holding capacity									
Soil color									
Topography									
Soil texture									
Soil Erosion									
Crop condition									

4.3. If yes, how do you classify them based on color, fertility and depth? Fill the table below based on the given clue:

Fertility less fertile, moderate, fertile

Color Black, red, gray…….

Depth, deep, moderate, shallow

Local name of the soil	Color	Fertility status	Depth

4.4. Rank the classification categories in order of importance for the following factors. The factors are production, soil fertility and land degradation.

Soil Fertility					
Rank	Very important	Important	Undecided	Least important	Not important
Soil color					
Topography					
Soil Drainage					
Soil Texture					
Distance from home					
Soil Depth					
Soil Degradation					
Soil color					
Topography					
Soil Drainage					
Soil Texture					
Distance from home					
Soil Depth					
Production					
Soil color					
Topography					
Soil Drainage					
Soil Texture					
Distance from home					
Soil Depth					

Part Five: Crop production

5.1. Is crop production determined by soil type? If yes, which soils are good for which crops and Why?.....................................

5.2. Soil description

(a) How would you determine soil characteristics relevant for crop production

- Soil Depth…………………….…………………………………………..………………
- Color………………………………………………………………………………..….

(b) How do you then decide on which crop to plant…………………

*What else can you tell me about the property that you think is significant for soil fertility? Or what other concerns or problems have you experienced with regard to soil fertility**?**

Thank you for your cooperation!

Appendix B. Questions for Focus Group discussions (FGD)

1.Do you see any change in the soil fertility status of the agricultural land in your village?

1)Yes 2)No . If yes, describe the changes....................

2. What indicators do you use to evaluate changes in soil fertility status in your village?

3. How do you respond to the declining soil fertility (e.g., application of manure, minera fertilizer, etc)

4.How many types of soils do you recognize in your kebele?

5.Can you name them (use local naming)/

6.On what basis do you distinguish these soil types (document their criteria of classification)/

7.Can you describe these soils according to their properties (use the table below)

Local names of the soil	Soil colour	Fertility status	Workability,problems,etc
1.			
2.			
3.			

8.How do you manage the soils according to their properties (allocation of crops and inputs according to soil type) (use the table below)

Local names of the soil	Major crops grown	Soil fertility management practices

9.Do you think that the change in soil fertility level have negative effects on your livelihood?
A)Yes B)No If Yes, Please explain it_______________________________

10.What are the major causes for the changes on the fertility level of soil?

11. Have you ever involved in community based soil fertility management practices in your Keble?
A)Yes B)No

Thank you for your cooperation!!

Appendix C. Interview Questions for Key informant (with experts)

Dear Experts of agriculture in Ada'a District,

This questionnaire is designed to gather information on farmers perception about soil fertility status, classification and management practices and to compeare with scientific practices in small holder's farming systems of Kumbursa *villag*. I hope that the research outcomes will contribute to better management of soil fertility. Please note that your responses will be kept confidential, and only aggregated results from the whole survey will be used for the purpose of the study.

Yours faithfully

Amelework Kindihun

1. Name ----------------------------------Position/profession------------------------------------

2. Is there any form of soil fertility level change in your *Kebele*? A)yes B)No

If Yes, please explain it____

3. What are the roles of institutions like NGOs in facilitating the management of soil fertility in yourKebele? ____.

4. Is there an integration between government agencies of local , Zonal, regional and national Soil fertility management programs? A)Yes B)No If, not why? ________________________.

5. Do local communities take part in making decisions with regard to appropriate soil fertility management methods and how to apply it? A.Yes B.No

If yes, how, please explain it........................... If not why Please explain it..............................

6. What are the major soil fertility management practices undertake by small holder farmers in your village?A. Inorganic fertilizer use B. Organic inputs C.Green manure

D.Cover crop E.Fallowing F.Intercropping G.If any,please specify__

7. What are the factors hinders soil ertility management practices?_______________________.

8. Are there any programs which facilitate improvement of soil fertility management practices other than government sectors? A)Yes B)No If yes what are they?

Thank you for your cooperation!!!

Appendix D. Monthly and yearly total rainfall (mm) at the study area (1965-2016)

Year	Jan	Feb	Mar	Apr.	May.	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Mean
1965	27.7	0	55.3	19.2	0	25.4	237	114.4	75.2	50.3	0	0	604.5	50.3
1966	0	95.6	10	113.2	0	72.4	167	354.6	88.3	26.6	0	0	928	72.3
1967	0	0	42.3	17.4	98.7	58.2	246.7	213.5	91.5	18.2	96.6	0	883.1	73.5
1968	3.6	98.6	6.3	105.5	0	77	145.8	96.5	142	0	4.5	0	679.8	56.6
1969	19.8	67.8	3.6	62.5	68.5	137.9	189.9	230.2	76.4	0	4	0	893.3	74.4
1970	43.2	39.4	43	29.6	32.7	36.3	261	261.8	94.7	13.3	0	0	855	71.2
1971	1.4	0	7.8	22.7	80.6	133.4	203.6	255.8	91.6	1.6	0	0	798.5	66.5
1972	0	136.7	52.8	50.3	31.9	77.5	209.4	181.4	74.6	4.5	12.2	4.2	835.5	69.6
1973	0	0	0	3.2	43.3	78.1	214.6	182.8	127.8	27.8	0	0	647.6	53.9
1974	0	19.4	130.9	0	62.1	84.2	215	160.1	148	0	0	0.4	820.1	68.3
1975	0	1.7	10.6	67.3	32.5	154.2	270	171.1	77.1	19.4	0	0.8	804.7	67
1976	0	0.2	44.9	106	83.5	85.5	239.3	236.4	81.3	3.2	52.4	3	935.7	77.9
1977	55.8	0.2	44.9	127.7	48.5	91.6	216.4	103.9	79.9	112.7	3.9	0	885.5	73.7
1978	2.4	18.8	10	82.9	48.5	91.6	239.3	215.1	81.3	3.2	0	0	793.1	66
1979	49.7	5.5	75.8	8.8	97.1	63.4	236.6	136.9	68.8	11.6	0	0	752.2	72.6
1980	26.1	13.2	25.3	11.9	47.9	65.7	252.7	195.9	49	19.5	0.9	0	728.1	60.7

1981	0	31.9	229.2	76.1	26.2	36	227.4	171.3	122.5	0	0	3.3	926.9	77.2
1982	17.8	60.5	51	31.1	0	84	121.3	157.1	72.9	121.9	21.9	0	739.5	61.6
1983	0	13	40.8	41.7	149.6	122.7	113.4	327.8	59.5	19	0	0.7	877.5	73.1
1984	0	11	38.6	0	131.6	91.9	242	213	84.4	0	0	0	806.7	67.2
1985	0	0	10.2	83.6	70.3	44.5	324	286.7	79.5	2.2	0	0	903.2	75.2
1986	0	23.6	51.7	141.6	72.4	166.8	142	152.5	90.1	3.2	0	0	844.7	70.3
1987	0	25.6	221.9	97.2	182.2	74.2	93.4	159.5	36.2	4.2	0	0	895.4	74.6
1988	8.3	37.6	2.1	52.9	22.8	121.8	155.3	245	190.4	16.7	0	0	852.9	71
1989	0	24.3	80.2	99.4	3.4	61.9	222.5	202.5	103.3	27.4	0	12.1	836.7	69.7
1990	0	143.9	60.5	75.7	28.1	61.8	208.6	146	141.6	0.5	0	0	966.7	72.2
1991	0.3	37.6	54.3	7.9	1.9	47.2	169.7	191.5	50.1	4.6	0	7.2	572.3	47.6
1992	11	98.5	4.7	37	9.9	78.7	289.5	251	118.9	23.8	6.7	0.9	940.6	78.3
1993	1.8	52.8	0	96.9	37.6	177.7	184	213.2	117.7	3.2	0	0.2	825.2	68.7
1994	0	0	17.5	53.6	69.5	95.9	257.5	158.7	107.6	0	14	0	774.3	64.5
1995	0	18.3	10.8	75.7	9.2	41.4	208	185.8	100.6	0	0	0	652.8	54.4
1996	32	0	70.5	38.8	70	206.6	298.2	173.4	53.2	0	5.2	0	949.9	79.1
1997	43.1	0	13.8	54.1	3.1	71.6	223.2	184.8	52	42.7	16.3	0	704.7	58.7
1998	15.4	56	16.2	54.5	60.7	77.9	198.5	322.8	91.1	73.1	0	0	966.2	80.5

1999	0	0	28.3	1	15	134.3	236.6	279.6	54.1	59.6	0	0	808.5	67.3
2000	0	9.1	20.5	49.2	69.3	52.1	185.3	210.1	115.7	26.2	37.2	2.2	767.7	63.9
2001	0	9.1	172.4	25	106.1	55	308.2	116.8	48.2	2.1	0	0	842.9	70.2
1002	8.4	7.6	43.2	33.3	20.6	161.7	214.8	166.6	76.2	0.3	0	12.9	745.6	62.1
2003	26.8	52.9	58.1	53.7	12.3	84.8	295.7	347.4	45.2	0	0.1	56.5	1033.5	86.1
2004	22.2	6.7	52.8	89.3	25.5	141.1	168.8	224.5	76.3	12.4	6.8	0	826.4	68.8
2005	34.7	0	95.5	83.4	57.4	103.3	179.9	138.2	129.3	0	6.7	0	828.4	69
2006	2.1	52.9	76	63.8	83.9	121.3	239.5	142.2	97.9	61.9	0	11.9	953.4	79.4
2007	9.7	8.7	32.2	48.6	65.5	68	210.7	173.1	174.9	11.3	3.3	0	806	67.1
2008	0	0	0	50.4	51.4	74.8	173.7	249.2	144.6	7.1	60.8	0	812	67.6
2009	20.2	0	82	60.4	76.8	64.9	178.8	152.9	70.4	45.3	1	7.6	760.3	63.3
2010	0	34.5	71.7	139.8	24.6	111	155.9	104.1	174.9	12.4	6.7	0	835.6	69.6
2011	0.2	0	106.3	17	112.5	29.2	134.6	241.7	82.6	0	0	0	724.1	60.3
2012	0	0	26.2	53.8	18	71.4	197.4	256.5	103	0	0	0	726.3	60.5
2013	0	0	41.1	78.3	56.9	121.2	219.7	141	64.1	16	0	0	738.3	61.5
2014	22.2	6.7	52.8	89.3	25.5	141.1	168.8	224.5	76.3	12.4	6	0	826.4	68.8
2015	0	0.2	25.4	37	38.7	48.6	102.1	103.3	93.6	11.5	0	0	460.4	38.4
2016	1.8	9.3	23	24	32.5	52.9	111.8	104.7	78.2	12.4	0.3	0	450.9	37.6
Mean	10.09	26.07	49.89	57.71	52.6	90.7	217.1	200.04	96.4	20.3	15.72	3.07	839.69	19.15

Appendix E. Monthly and yearly total Temperature of the study area (1965-2016)

Years	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Mean
1965	15.6	14.5	17.2	18.4	17.6	17.1	14.3	14.1	14.6	14.7	14.5	14.3	186.9	15.5
1966	15.4	14.7	16.2	16.6	19	17.9	16	15.9	16.4	17.2	14.3	15	194.9	16.2
1967	16.6	16.9	17.2	16.9	16.6	16.5	13.8	12.8	13.1	13.7	12.9	13.1	180.1	15
1968	13	12.5	13.3	12.9	14.6	14	13	14.5	15.6	16.8	16.3	15.6	172.1	14.3
1969	16.2	15.7	15.9	16.1	15.8	15.2	15	15.2	16	15.7	15.8	14	186.6	15.5
1970	15.6	16.5	14.5	16.3	17.7	16.6	15.8	15.7	16.4	16.8	16	15.9	193.8	16
1971	15.5	16.5	16	16.7	17.6	16.3	15.5	15.8	16.5	17.6	16.3	15.7	194	16.1
1972	17	16	16.9	16.8	17.5	16.9	16.2	17	17.3	17.3	18	16.8	203.7	16.9
1973	17.4	20.4	18	18.4	18.2	15.4	19.1	19.1	17.8	16.3	15.4	13	208.3	17.3
1974	20.1	20.5	19.2	20.9	20.4	19	18.1	18.1	17.7	18.4	16.4	16.6	225.4	18.7
1975	16.6	20.7	22	20.4	20.5	19.9	18.4	17.6	18.3	16.3	15.7	16.2	222.6	18.5
1976	16.4	19.3	19.3	18.9	17.6	19.6	20	19.1	18.3	17.8	17.2	16.5	220	18.3
1977	18.6	19.5	19.3	19.1	19.6	20.1	18.8	17.3	16.7	18.5	15.9	15.2	218.6	18.2
1978	17.9	18.2	18	19	19.1	19.3	18.7	18.9	19.1	17.9	17.3	15.1	218.5	18.2
1979	14	15.1	17.8	18.9	18.6	18.1	16.6	18.8	18.3	17.9	17	18.1	209.2	17.4
1980	18		21.6	21.7	21.6	20.4	18.9	18.8	18.6	17.6	17	15.9	230.3	19.1
1981	18.1	18.9	19.8	19.3	19.8	20.2	18.8	18.3	18.4	16.4	16	15.9	219.9	18.3
1982	17.9	19.3	19.3	20	20.4	19.4	18.5	18.1	17.6	16.4	17	17	221.4	18.4
1983	16.8	19.6	21.4	21.7	21	19.8	19.8	18.3	18.7	17.5	14.9	15.5	224.8	18.7
1984	16	16.3	19.9	21.2	20.6	19.5	15.7	18.7	18.3	16.5	17.1	16.5	216.3	18
1985	17.6	15.6	21.2	20.1	20	19.5	17.5	18	17.9	16.7	16.4	16.4	216.9	18
1986	16.5	19.9	19.7	20.5	20.3	19.1	20.2	19.3	17	17	17	17.3	222.6	18.5
1987	18.1	19.2	20.5	19.5	20.2	19.7	18.8	19	19.4	18.7	17.1	17.5	229.1	10.9
1988	18.6	20.6	21	20.8	21	20.1	18.8	18.6	18.4	17.2	14.5	15.6	225.2	18.7
1989	16	17.9	19.8	19.5	19.4	19.5	18.8	18.7	18.3	16.6	16.1	17.8	218.4	18.2

1990	17.1	20	19.1	19.4	19.9	19.3	19	18.9	18.6	16.7	16.8	16.1	220.9	18.4
1991	18.7	19.6	20.4	20.8	21.5	21	18.8	18.6	18.7	18.6	16.4	16.2	229.3	19.5
1992	18	19.4	21	21.2	21.9	20.2	18.5	18.4	17.8	17.3	16.2	17.4	227.3	18.9
1993	17.8	18.2	18.9	20.5	20	19.3	18.9	18.8	18.7	17.6	16.4	16.2	221.3	18.4
1994	17.4	19	20.9	21.3	21.5	20	19.1	18.4	18	17	16.9	16.1	225.6	18.8
1995	17.1	19.7	20.4	20.8	21.7	20.5	18.7	18.8	17.8	17.7	16.5	18.6	228.3	19
1996	18.6	19.5	21.1	20.5	20.3	18.7	18.7	19.8	18.8	17.3	16.3	16.3	227.4	18.9
1997	18.5	19.7	21	20.4	21.7	20.8	19.4	19	19.5	19	18.6	21	240.6	20
1998	18.6	20.6	21.3	22.2	21.6	21.8	19.5	21.9	19	18.4	16.7	15.1	236.7	19.7
1999	17.3	18.2	19.8	21.1	21	19.9	19.9	19.1	18.8	17.6	15.3	15.5	223.5	18.6
2000	16.7	17.5	19.5	22.2	20.7	18.9	18.8	18.1	18.6	17.2	16.4	16	220.6	18.3
2001	16.9	18.8	19.8	19.9	19.8	18.6	18.9	18.8	18.9	17.3	16.4	15.6	187.1	18.7
2002	17.3	19.9	19.6	20.9	21.1	20.6	20.6	18.6	19.7	17.4	16.6	16.7	229	19
2003	16.8	19.6	21.4	21.7	21	19.8	19.8	18.3	18.7	17.5	14.9	15.5	224.8	18.7
2004	15.4	14.7	16.2	16.6	19	17.9	16	15.9	16.4	17.2	14.3	15	194.9	16.2
2005	16.6	16.9	17.1	16.5	20.1	19.3	18.3	19.1	20	17.2	16.6	16.2	163.3	18.1
2006	17.3	19.9	19.6	24.3	20.5	19.5	18.7	18.5	17	18.6	17.6	17	228.5	19
2007	18.3	19.6	20.4	19.9	17.3	20.3	19.3	18.8	19.7	17.6	16.9	16.8	225.9	18.8
2008	18.3	18.9	19.7	22	21.5	20.3	19.6	18.7	19.8	18	15.9	15.6	228.3	19
2009	17.3	18.7	21.5	19.9	21.4	21.5	20.3	19.8	19.3	17.9	16.4	17.4	231.9	19.3
2010	17.3	19.9	19.6	20.9	21.1	20.6	20.6	18.6	19.7	17.4	16.6	16.7	229	19
2011	15.7	18.7	19.9	20.9	19.1	19.4	20.2	19.9	19.9	17	17.7	16.4	224.8	18.7
2012	16.7	17.8	19.5	20.4	19.3	20.9	19.2	18.5	19	16.5	16.8	16.3	221.4	18.4
2013	17.2	18.4	21.6	20.9	20.2	20.1	18.7	18.9	18.7	21	18.2	30.1	244	20.3

Appendix F. Soil sampling (for Bulk density)

Appendix G. Soil pH rating for 1: 2.5 soil to water ratio suspension

pH value	**Ratings**
< 4.5	Very strongly acid
4.5-5.2	Strongly acid
5.3-5.9	Moderately acid
6.0-6.6	Slightly acid
6.7-7.3	Neutral
7.4-8.0	Moderately alkaline
> 8.0	Strongly alkaline

Source: Tekalign (1991)

Appendix H. Soil Organic Matter (OM) and Organic Carbon(OC) rating

Rating or class	OC(%)	OM(%)
Very low	<0.50	<0.86
Low	0.5-1.5	0.89-2.59
Medium/Moderate	1.5-3.0	2.59-5.17
High	>3.00	>5.17

Source:Tekalign(1991

Appendix I. Rating for bulk density

Bulk density(g/cc)	Rating
1.2	Good
1.4	Dense
1.6	Very dense

Source: Landon (1991)

Appendix J. Rating of soil total Nitrogen values

Rating	Total N(%)
Low	<0.10
Medium	0.10-0.15
High	0.15-0.25
Very high	>0.25

Source:Murphy(1968)

Appendix K : Rating of soil total phosphorus(TP)

Rating or class	Total P (mg kg^{-1})
Low	<5
Medium	5-10
High	>10

Source: Olsen et al. (1954)

Appendix L: Rating of soil total Potassium (TK)

Rating/class	Total K(cmol(+)kg^{-1})
Low	<0.25
Medium	0.25-0.5
High	>0.5

Source:Landon (1991)

Appendix M: Rating of soil carbon to nitrogen ratio (C:N)

Rating/class	Total K(cmol(+)kg^{-1})
Low	<11
Medium	11-15
High	16-25
Very high	>25

Source:Landon (1991)

Appendix N : Rating of soil exchangable sodium (Na)

Rating/class	Total K(cmol(+)kg^{-1})
Very low	<0.1
Low	0.1-0.3
Medium	0.3-0.7
High	0.7-2
Very high	>2

Source:Fao,2006