DETERMINANTS OF PARTICIPATION IN SOIL FERTILITY MANAGEMENT PRACTICES BY SMALLHOLDER FARMERS: THE CASE OF GURAWA AND HAROMAYA DISTRICTS, EAST HARARGE ZONE, OROMIA, ETHIOPIA

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DEDICATION

I dedicate this thesis manuscript to my mother Dama Abu for her tolerance all the challenges for nursing me with affection and love and for Muhammed Kedir for his dedicated partnership in the success of my life.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born in West Arsi Zone of Oromia National Regional State, Heraro town, in September 1981. He attended his primary and junior education at Heraro primary and junior schools and then joined Adaba Secondary School to attend his high school studies. He completed his secondary class in 1999/00 academic year. After completion of his high school education, he joined Ambo College of Agriculture (now Ambo University) in October 2000 and successfully completed his Diploma program in General Agriculture in July 2002. He was employed and served in agricultural and pastoral development offices of different woredas of Oromia National Regional State since 2003. He joined Haramaya University by summer program in 2005 for his bachelor’s degree program. He completed his Bachelor of Science in Agriculture (Agricultural Economics) in September 2009.

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ACRONYMS AND ABBREVIATIONS

DAP	Di-ammonium Phosphate
DA	Development Agent
EEA	Ethiopian Economics Association
EHZADO	East Hararge Zone Agricultural Development Office
EIAR	Ethiopian Institute of Agricultural Research
FYM	Farm Yard Manure
GM	Green Manure
GDADO	Gurawa District Agricultural Development Office
HDADO	Haromaya District Agricultural Development Office
HH	Household
ICRAF	International Center for Research in Agro forestry
IIA	Independence of Irrelevant Alternatives
ISFM	Integrated Soil Fertility Management
LSB	Level Soil Bund
LWS	Lower Water Shade
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MVP	Multivariate Probit
NUE	Nutrient Use Efficiency
SB	Soil Bund
SFMP	Soil Fertility Management Practice
SML	Simulated Maximum Likelihood
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
SUR	Seemingly Unrelated Regression
SWC	Soil and Water Conservation
UWS	Upper Water Shade

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES IN THE APPENDIX

Appendix table **Page**

Determinants of Participation in Soil Fertility Management Practices by Smallholder Farmers: The Case of Gurawa and Haromaya Districts, East Hararge Zone, Oromia, Ethiopia

ABSTRACT

In Ethiopia, agriculture is the main economic activity which employs the majority of its population; however it is known for its low productivity. The depletion of soil fertility is among the main factors that contributed to low performance of the sector. Farmers use different soil fertility management practices to improve the fertility of their soil. To enhance utilization of different soil fertility management practices there is a need to identify determinants of soil fertility management practices by smallholder farmers. Therefore, this study aims at identifying the determinants of soil fertility management practices by smallholder farm households in Gurawa and Haromaya districts, East Hararghe zone, Oromia national regional state. The study used cross sectional data collected from 200 randomly selected sample households from the two districts. Descriptive statistics and econometric models were used to analyze the data. Descriptive statistics were used to identify different soil fertility management practices such as use of inorganic fertilizer, organic inputs and soil erosion control measures at farm level. Multivariate probit model was run to identify factors influencing households' use of different soil fertility management practices. Results of the multivariate probit showed that the likelihood of the household to use fertilizer (DAP), farmyard manure, compost, soil bund and stone bund were 78.25%, 72.43%, 37.68%, 77.22% and 46.04% respectively. The result also showed that the joint probability to use all soil fertility management practices is 6.84% and the joint probability of failure to use all the soil fertility options is only 0.31%. Results of the correlation between the error terms on multivariate probit model indicate that some soil fertility management practices are substitutes or compete (negative sign) for the same scarce resources and some are complements (positive sign). Multivariate probit model results also mirrored that sex, household size, number of plots, plot area, agro-ecology, district, livestock holding, extension contact, average distance of the plot, slope of the plot, off/non farm income, credit and irrigation use have significant effect on use of different soil fertility management practices. These findings hinted to the policy makers the need for formulation and implementation of policies targeting the above mentioned factors to enable framers improve the fertility of their productivity thereby achieving food security at various levels.

Key words: Soil fertility management practices, Soil fertility, Multivariate Probit, Smallholder farmers

1. INTRODUCTION

1.1. Background of the Study

Ethiopia, the country with about 1.12 million square kilometer area of land is one of the most populous countries in Africa with a 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 system due to an adverse combination of agro climatic, demographic, economic and institutional constraints and shocks.

Ethiopian agricultural sector contributes about 41% of the country's GDP, employs 83% of total labour 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 in the economy.

Though agriculture is the corner-stone of Ethiopian economy, its performance has been unsatisfactory and unable to meet the ever increasing demand of the increasing population. This is mainly attributed to the 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 (Kinde, 2005). 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.

Agriculture in Ethiopia 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 and imperfect agricultural market.

Hans-Joachim *et al*. (1996) reported that most of the highland terrain of Ethiopia has slopes of more than 16% and only a fifth is considered free from erosion hazard. Therefore, most of the productive top soils in the highlands have been degraded resulting in chronic food shortages and persistent poverty.

Even though, the application of chemical fertilizer has increased in the country, productivity increase is not as expected. Gete *et al*. (2010) reported that 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. While application rates 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. For example, the nutrient use efficiency (NUE = kg yield per kg nutrient) of maize in Ethiopia is 9-17 kg of grain per kg of applied N, while in Kenya and Tanzania, equivalent NUEs range from 7–36 and 18–43 respectively (Vanlauwe *et al*., 2001). These differences are not driven only by the amount of chemical fertilizer applied; equally, if not more, significant factors include agro-ecology, soil fertility, and physical management practices, as well as the resulting interactions between chemical and physical soil properties.

Soil fertility decline which tackle agricultural productivity performance is an expressed priority for farmers, as well as a concern for the government of Ethiopia and international agencies working in this sector. 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. Even though different soil fertility management practices are undertaken by most of the farmers, the adoption of different soil fertility management practices is different among the farmers and comparatively low. Thus, there is a clear implication on the productivity improvement of crops in the country in general and in the study area in particular. Factors that make the difference and low adoption rate should be known and addressed to intervene it by the concerned bodies. Hence, the identification of soil major soil fertility management practices that are accomplished by the small-holder farmers and factors influencing them in the study areas are critical for intervention by different stakeholders.

1.2. Statement of the Problem

Declining soil fertility obviously becomes an obstacle for sustainable productivity improvement of crops and livestock. Studies show that land degradation is a serious problem in Eastern Africa; more than 14% of its total area suffers from severe to very severe degradation (FAO, 2005). The average annual rate of erosion on cropland is estimated to be 42 tons per hectare per year which is very much exceeding the soil formation rate of 3-7 tons (Gebremedhin and Swinton, 2003; Hurni, 1993 as cited in Behailu, 2009).

The productivity of land is declining because of inappropriate soil fertility management practices and this is causing great challenge in attaining food security in Ethiopia in general and in the study areas in particular. Tweeten (1993) states that the potential of land productivity has been deteriorating from time to time due to runoff, topographic variation, slope, intensive farming and farming on steep slopes and deforestation which results in loss of soil nutrients and its productive capacity. During the past decades nearly uninterrupted civil conflict, increasing population pressure, and severe soil nutrient depletion have steadily lowered land and labour productivity (Beekman and Bulte, 2012). This in turn brings loss in crop yield and results in a vicious cycle of poverty and food insecurity which affects the dimension of human wellbeing.

According to Troeh *et al.* (1980) as cited in Barry and Ejigu (2005), soil is a critically important resource, the efficient management of which is vital for economic growth and development for the production of food, fiber and other necessities. To accommodate the increasing demand for food either production per unit area must be intensified, or more land must be cultivated. The possible option is intensification of the available cultivable land with using appropriate soil fertility management practices and improving other important issues. The practice of continuously cultivating the same land without appropriate and sufficient management to replenish or maintain nutrients, will likely lead to soil degradation and its consequences.

Land degradation poses the greatest long-term threat to human survival in the country and remains one of the greatest challenges facing the ever-growing population and the government (FAO, 2001). Its problem mainly resulting from soil erosion and nutrient depletion can be singled out as one of the most important environmental problems creating an unprecedented threat to food security goals of the country (Mengistu, 2011). Furthermore, Breman (1998) stated that the improvement of soil fertility in smallholder farming systems in semi-arid and sub-humid Africa has been rendered more difficult and complicated due to increasing scarcity of locally-derived nutrient sources and the changing socio-economic environment over the years. Hence, improving soil fertility management among smallholder farmers is widely recognized as a critical aspect in addressing food security and poverty through increasing agricultural productivity and at the same time curbing problems of nutrient depletion (Tchale *et al.*, 2004).

As the main source of economic activity in SSA is agricultural production, declining soil productivity means not only that less food can be grown but also that production of cash crops for export is endangered. Dasgupta (2003) also pointed out that severe soil nutrient depletion is a main element in the vicious cycle of declining yields, decreasing rural incomes, deepening poverty, and increased degradation of the natural resource base. Fairust (2012) reported that the soils in Sub-Saharan Africa are being depleted at annual rates of 10kg/ha for nitrogen, 2kg/ha for phosphorus, and 6kg/ha for potassium. It is therefore essential that production and soils be managed in a sustainable way, so that the present generation is fed and soil conditions are improved to support future generations (FAO, 2001).

Apart from the primary effects of declining per capita food production, poor soil fertility triggers other side effects on-farm such as lack of fodder for livestock production, reduction in fuel wood and high deforestation rates (as farmers are forced to abandon poor soils and encroach on forests which are more fertile).

Improving soil fertility management among smallholder farmers is widely recognized as a critical aspect in addressing food insecurity and poverty, especially in Sub-Saharan Africa, where the majority of the populations in most countries earn their livelihood as smallholder farmers (Donovan and Casey, 1998). Therefore, soil capital, the amount and quality of land one controls is one of the major assets of smallholder farming households depend on to generate food and cash incomes. Therefore, it seems intuitive that smallholders should invest in conserving, even building up, one of their scarcest and most valuable assets.

To address the problems on the participation of use of soil fertility management practices some empirical studies were conducted. 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, studies did not identify factors that determine participation of use of different soil fertility management practices in holistic approach. Hence, there is a need to identity what works as well as what determine to use different soil fertility management practices in the study areas.

There are moves by Ethiopian government to improve soil fertility management system, mitigate the problem of soil erosion and enhance or maintain the production potential of agricultural land especially in using chemical fertilizer and in mobilizing the community to control soil erosion. According to MoFED (2013) report of the 2011/12 fiscal year, 1170.5 thousand tons of chemical fertilizer was supplied during the year and communities have undertaken conservation works such as planting trees, constructing terraces, bunds water harvesting structures etc. on 8.5 million hectares of land throughout the country. Moreover, ATA is also undertaking encouraging duties to improve soil productivity such as developing a digital soil map for Ethiopia (EthioSIS), developing evidence based fertilizer application and recommendations and establishing fertilizer blending plants (ATA, 2014). In addition to these it is important to identify socio-economic and demographic factors that determine participation in using different soil fertility management practices to achieve food self-sufficiency because still productivity increase is not as expected and with the pace of population growth rate. Hence, due attention is needed towards maintaining and improving soil fertility using interdisciplinary approach. Therefore, identifying soil fertility management practices and determinants of its use is helpful for the stakeholders to intervene in the area and contribute towards achieving food security.

This study made an attempt to address the following research questions;

1. What kinds of soil fertility management practices are being employed by the smallholder farmers in the study areas?
2. What are the socio-economic, institutional and demographic factors that determine smallholder farmers' participation and intensity of SFMPs in use?

1.3. Objectives of the Study

The general objective of the study is to assess the existing soil fertility management practices employed by smallholder farmers in Haromaya and Gurawa districts of eastern Hararghe zone.

The specific objectives of the study are to:

1. Identify the different soil fertility management practices used by smallholder farmers in the study areas; and
2. Identify the socio-economic, demographic and institutional factors that determine participation and intensity of soil fertility management practices used by smallholder farmers in the study areas.

1.4. Significance of the Study

The importance of 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. Land intensification is the possible intervention because the sizes of the land is very small, thus the farmers use this land unwisely and cultivate the land continuously for longer period without any rest; this is because land is the main source of food for their family food consumption and income generating means to fulfill their basic needs. Therefore, it is paramount to consider important determinants to use important SFMPs undertaken by smallholder farmers on their farm plot.

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 of the land 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.

1.5. Scope and Limitations of the Study

The study was undertaken in Gurawa and Haromaya districts, East Hararghe zone, Oromia national regional state, with the objective of identifying the soil fertility management practices used by small holder farmers and the determinants of participation and intensity of its use.

The study only reflects farmers' circumstances in a given year and may affect by specific climate of the year. Besides this, Farmers do not keep records; as a result they may face recalling problems of the past events. Thus, they may probably give wrong information during the survey time. In analyzing the determinants of participation in soil fertility management practices and extent of use of them only major soil fertility management practices are taken to ease data analysis and reliability. So, all these limitations were assumed to affect the findings of the study to some extent.

1.6. Organization of the Thesis

This thesis is organized into five chapters. The remaining part is organized as follows. The second chapter deals with review of literature which includes theoretical, analytical, conceptual frameworks and empirical studies on determinants of use of SFMPs. A brief description of the study area and a thorough explanation of the methodologies employed for data collection and analysis were presented in chapter three. Chapter four deals with the results and discussion of descriptive and econometric model used and finally chapter five presents summary, conclusion and recommendations of the study.

2. LITERATURE REVIEW

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, theoretical framework, analytical framework, empirical studies on the determinants of SFMPs and conceptual framework of the study are presented.

2.1. Definition of Soil Fertility and Related Terms

Soil fertility: It is usually seen as equivalent to the capacity of the soil to supply nutrients to the plant. In its broadest sense, soil fertility can be seen as a mixture of soil chemical, physical and biological factors that affect land potential (Wopereis and Maatman, 2002). Soil fertility varies in the landscape due to 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 and Maatman, 2002). Soil fertility is fundamental in determining the productivity of all farming systems. Swift and Palm (2000) however suggest that, it is more helpful to view soil fertility as an ecosystem concept integrating the diverse soil functions, including nutrient supply, which promote plant production.

Integrated soil fertility management: Integrated soil fertility management refers to a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe, 2010).

Land degradation: It is defined as reduction of resource potential, the loss of utility or potential utility resulting in temporary or permanent lowering of current or future productive capacity of land. It has been attributed to one or a combination of natural and human processes that act on the land such as water erosion, wind erosion, a long-term reduction in the amount or diversity of natural vegetation, salinization, or sodification (World Bank, 2007).

2.2. Soil Fertility Management Practices

Fairhurst (2012) classifies soil functions into five basic functions that are important for sustaining livelihoods. These are soil is used as a medium for plant growth, environmental services, habitat for diverse biological organisms, source of raw materials and physical space/platform.

The decline of soil fertility happens due to different reasons. According to Barry and Ejigu (2005), the decline in soil fertility in Ethiopia is mainly caused extra pressure on land due to increased population, decline in the amount of manure available for soil fertility. However, farmers are responding to the decline in soil fertility in numerous ways. Some are changing their social behavior or adapting their farming system, whereas others are reacting through action to improve the soil itself (Barry and Ejigu, 2005).

Soil fertility management can be strongly related to the degree of access to resources (e.g. land, carts, cattle, labor, and cash) (Wopereis and Maatman, 2002). Farmers use different soil fertility management and agronomic practices to respond for the depletion of soil fertility. Barry and Ejigu (2005) and Fairhurst (2012) mentioned the following soil fertility management practices applied by farmers such as; inorganic fertilizers, manuring, crop residues, leaf litter, composting, fallowing, soil conservation practices, alley cropping, rotational cropping with legumes, green manuring, cover crops and etc.

Three common soil fertility management practices practiced in the study areas are use of organic inputs, use of mineral fertilizer and minimizing losses of added nutrients are discussed.

2.2.1. Use of organic inputs

Organic inputs used in soil fertility management commonly consist of livestock manures (farmyard manure), crop residues, woodland litter, household organic refuse, composted plant materials (compost), leaf litter (example *Cordia africana*, *Ficus vasta*, *Erythrina* species etc) alley cropping, rotation with legumes, green manures, cover crops and any plant biomass harvested from within or outside the farm environment for purposes of improving soil productivity (Fairhurst, 2012). Use of manure, locally called *dike*, is the oldest and most widely practiced means of nutrient replenishment in the eastern highlands of Oromia and in Ethiopia in general (Mengistu, 2011). Organic resources have multiple functions in soil, ranging from their influence on nutrient availability to modification of the soil environment in which plants grow.

Organic inputs have several advantages in soil fertility management. They contribute directly towards the build-up of SOM and providing essential plant nutrients. Nutrients are released slowly from organic resources compared with mineral (inorganic) fertilizers, and provide a continuous supply of nutrients over the cropping season. The major disadvantage of organic inputs is their relatively low nutrient contents and therefore required in large quantities. In line with this, Vanlauwe *et al*. (2010) stated that organic inputs applied at realistic levels seldom release sufficient nutrients for optimum crop yield. Therefore, combining organic and mineral inputs has been advocated as a sound management principle for small-holder farming to sustain soil fertility and crop production (Vanlauwe *et al*., 2010). Most organic resources used on farms contain 0.5–2.5g N/kg, or 5–25 g N/kg, compared with >100–460 g N/kg, contained in mineral fertilizer (Fairhurst, 2012).

2.2.2. Use of mineral fertilizer

Fertilizer is a material that contains at least one of the plant nutrients in chemical form that, when applied to the soil, is soluble in the soil solution phase and ‘available’ for plant roots. Some fertilizers such as urea, potassium chloride (KCl) and diammonium phosphate (DAP) are completely soluble in water (Fairhurst, 2012). Use of fertilizers to replenish soil nutrients is one of the major ways of counterbalancing low soil fertility, but the nutrients applied in mineral fertilizers by the smallholder farmers in central Kenya remain low due to insufficient amounts used (Mugwe *et al.*, 2008). Fertilizers could be part of a solution to correct environmental degradation and properly address rising food demands. However, average fertilizer use in Africa is very low (about 8 kg/ha, i.e. only 1/10th of world average) (Wopereis and Maatman, 2002).

2.2.3. Minimizing losses of added nutrients

With good management practices, a significant proportion of nutrients added to the farming system in the form of mineral fertilizers or crop residues and manure can be recycled many times through crops and livestock. Losses of added nutrients can be minimized by water and wind erosion control, reducing the effect of leaching, reducing gaseous losses through denitrification and volatilization and crop residue management. Nutrients added as mineral fertilizer, crop residues and manure as well as soil nutrient stocks may be lost from the farming system or the farm plot through water or wind erosion, leaching or gaseous losses.

Consequences of more intensive farming and farming on steep slopes are declining fertility and increasing the high incidence of soil loss due to erosion (Shiferaw and Holden, 1998). Soil erosion accounts for the major forms of land degradation in developing countries, and at the same time, it is difficult to isolate and measure its impact on productivity even when the means and resources are available (Ayalneh, 2002). For these problems effective soil and water conservations are the solution.

2.3. Soil Fertility in Ethiopia

Several soil fertility management practices are difficult to undertake because of different factors. Particularly, land shortage and fragmentation have increasingly forced farmers to abandon soil fertility management and agronomic practices in Ethiopia such as fallowing, manuring, terracing, and using crop residues. Farmers need to recognize that organic and mineral fertilizers should be used to complement, and not replace each other (Corbeels *et al.*, 2000).

Some estimates suggest the nutrient contents of the crop residues used as feed are higher than the quantities applied as fertilizers (IAEA, 2001). Top soil erosion is another major problem in almost most parts of the country that cause loss of fertile topsoil. Studies show that about 10-13mm per annum or 137t/ha/year of topsoil loss is happened, driven by the limited use of basic practices and benefits, e.g. minimum tillage and soil and water conservation (Spielman *et al*., 2009).

Important soil fertility management practices become difficult to undertake because of increasing population with limited cultivable land resource. Crop rotation, fallowing and green manuring are largely difficult to implement in densely-populated areas with small farm sizes, and even more so where food supply is insecure (Gete *et al*., 2012).

Encouraging moves are undertaken by the government to maintain soil fertility and to increase the productivity of agricultural crops. However, multiple interventions are needed to address these soil fertility issues including, but not limited to, chemical and organic nutrient sources.

Spielman *et al*. (2011) reported that when measured in terms of quantity imported, fertilizer use in Ethiopia has increased from 250,000 tons in 1995 to 400,000 tons of product in 2008. Successful practices have been developed in food-insecure areas (e.g. Tigray) but are not well spread to the rest of the country. Moreover, ATA is also undertaking encouraging duties to improve soil productivity such as developing a digital soil map for Ethiopia (EthioSIS), developing evidence based fertilizer application and recommendations and establishing fertilizer blending plants (ATA, 2014). To date, EthioSIS has trained 38 soil surveyors to use AfSIS survey methods, and the surveyors have visited 22 sample sites around the country. The teams have collected more than 4000 soil samples, and the samples are now being processed at six processing centers. So far, EthioSIS has accomplished soil fertility survey in **277** woredas in the country, of these, **35** are woredas in Tigray have been completed.

2.4. Indigenous Knowledge of Soil Fertility and Its Management

Indigenous knowledge refers to the perception that farmers have about their natural and social environment, which they use to adopt, adapt and develop technologies to their local context (Teklu and Gezaheny, 2003). Indigenous knowledge of soils is defined as “the knowledge of soil properties and management possessed by people living in a particular environment for some period of time” (Winklerprins, 2002).

Taye and Yifru’s (2010) study on assessment of soil fertility status with depth in wheat growing highlands of southeast Ethiopia found that farmers in the study areas have common criteria to evaluate and identify their soils. They use soil color, texture, water holding capacity, workability and fertilizer requirement as criteria to classify in to different groups.

Corbeels *et al*. (2000) study on farmers knowledge of soil fertility and local management strategies in Tigray of Ethiopia and reported that farmers’ use appearance of some weed species (*Echinips hispidus* and *Xanthium spinosum),* rocky out crops and crop wilting as sign of decline or low soil fertility in Tigray region. The farmers in the Tigray region classified their land into three classes: *reguid meriet* (fertile), *mehakelay meriet* (moderately fertile), and *rekik meriet* (infertile). Farmers in the region distinguish between four different soil types, mainly on the basis of soil colour and texture. 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).

Kebede *et al.* (2013) study on farmers’ perception of the effects of soil and water conservation structures on crop production in southern Ethiopia found that the perception of farmers of soil and water conservation structure on the impact of crop productivity is SWC structures had taken to improve soil fertility and crop yield. The observed effect was immediate, in the opinion of a majority of respondents (74.5%) in the UWS, and took place is not more than a year. But a majority of respondents in the LWS observed a yield increase between one and two years after the construction of structures.

Abebe *et al*. (2011) stated that crop residues are deliberately left by farmers on crop land to increase soil fertility and organic carbon on their study in Damot Sore (Wolaita). The protection of soil by crop residue is widely used in the area by different parts of the community (from rich to poor farmer). In the study area the use of animal dung, ash and household trash to crop land is common practice to improve soil fertility as manuring and it is well manifested in the homestead gardening or at backyards.

According to Barry and Ejigu (2005), based on their study conducted in Wolaita, although 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.

Abush *et al*. (2011) in their study report on subsistence farmers' experience and perception about the soil, and fertilizer use in western Ethiopia stated that most farmers (85.9%) use poor crop yield in climatically good season as a means of knowing the decline in the fertility of the soil.

2.5. Theoretical and Conceptual Framework of the Study

A lot of empirical models have been specified to explain farmers' technology choice decisions. The most commonly used analytical models in adoption studies are based on the attribute theory of Lancaster (1971). These models analyze the rational decision making process in choosing among alternatives characterized by attributes that may be unobserved to the analyst but are assumed to be observed and acted upon by the decision-makers.

As mentioned in various studies use of different soil fertility management practices increase the productivity of farm plots. Thus farmer can increase their return by using different soil fertility management practices in the farm plots. The farmer decision whether to use or not to use different soil fertility management practices is influenced by various factors such as physical, socio-economic, institutional and behavioral. Farmers are rational in their decision making (Bunder *et al*., 1996). They can maximize their utility by using different soil fertility management practices.

In this study, the plot level participation on the use of different soil fertility management practices of subsistence farmer depends on different factors that influence the decision of farmer whether the farmer to participate on different types soil fertility management practices or not. The farmer decision to participate on the use of different soil fertility management practices at the farm plot level is motivated by random utility function is expressed as:

$$U_j = \beta_j X_j + e_j \quad (1)$$

Where U_j is the utility to be obtained from farm plots, X_j is a vector of attributes of the plots and the farm household characteristics, β_j *is* a parameter to be estimated, e_j is the disturbance term and assumed that is distributed normally, and j is the choice of farmer use among different soil fertility management practices in their farm plots, where j =1, 2, 3, ---N. Assume that a farmer drives utility from adopting different soil fertility management practices, from his resource endowment and from household characteristics. Let us assume that the farmer chooses to adopt or not to adopt of any one or more of soil fertility management practices are presented by utility function U_1 and U_0 respectively, i.e.

$$U_1 = (1, z, y) \text{ and } U_0 = (0, z, y) \quad (2)$$

Where, U_1 and U_0 are the farmer utility obtained from the farm plots product due to the choice of adoption and non adoption of soil fertility management practices respectively. Thus, the utility function of farmer subject to the farmer resource endowment constraints (z) and other observable attributes of the farm household can affect the adoption decision of farmers (y).

From the theoretical specification of utility function we assume and an additively separable utility function in the deterministic and stochastic component that can be expressed as:

$$U_1 = U(1, z, y) = D_1 (1, z, y) + e_1 \quad \text{and}$$

$$U_0 = U(0, z, y) = D_0 (0, z, y) + e_0 \quad (3)$$

Where U_j (.) is the utility obtained from farm plot product, D_j (.) is the deterministic part of the utility and e_j is the stochastic component known to the farmer but unobservable to the researcher. The farmer's decision process is modeled using the random utility framework. From the theoretical stand point a farmer is preferring to adopt soil fertility management practices, minus its cost, is at least as great as the return without adopting soil fertility management practices, that is when

$$U_1 (.) > U_0 (.) \quad (4)$$

$$D_1 (1, z\text{-}c; y) + e_1 \geq D_0 (0, z\text{-}c; y) + e_0$$

Thus c is the cost of adoption of soil fertility management practices that includes the implicit and explicit cost to the farmer. The existence of the stochastic component allows us to apply probabilistic distribution about decision behavior. The probability distribution of the adoption and no adoption of soil fertility management practices can be expressed in equation (5) and (6) respectively as follows:

$$P_1 = P \text{ (choice)} = Pr(D_1 (1, z\text{-}c; y)) + e_1 \geq Pr(D_0 (0, z\text{-}c; y)) + e_0 \quad (5)$$

or

$$P_0 = Pr(D_0 (0, z\text{-}c; y)) + e_0 \geq Pr(D_1 (1, z\text{-}c; y)) + e_1 \quad (6)$$

The choice of farmer to adopt the soil fertility management practices in terms of utility function of probability distribution can be expressed as:

$$Pr(\text{choice}) = Pr(U_1) \geq Pr(U_0) \quad (7)$$

In similar manner for multiple choice of alternatives farmer, we assume that there is choice among various alternatives of soil fertility management practices indicated by j= 0, 1, …, N. Let us suppose that the utility of the i^{th} farmer to each alternatives soil fertility management practice(s) is given by U_{ij} , j = 1, 2, …, N. The farmer will choose alternatives j, if it can be given him the highest utility from various soil fertility management practices that is expressed as:

$$U_{ij} = \max\{ U_{io} ---- U_{iN} \} \quad (8)$$

The theoretical framework implies that the decision to chose a given soil fertility management option will not only depend on the marginal benefit and marginal cost criterion, but will also depend on the household's ability to satisfy its own consumption, given the soil fertility management option.

In the case of Ethiopia, soil fertility management practices are a complex issue requiring further investigations as they are influenced by different factors operating at different scales. These factors include government policies, programs, and institutions at many levels. Infrastructure development, agricultural extension, conservation technical assistance programs, and rural credit and savings programs affect awareness, opportunities, and constraints at the village or household level which may further influence land management (Ehui, 2004).

Generally, we can understand that different empirical studies have been carried out to see the direction and magnitude of the effect of different factors on farmer decision behavior regarding use of different SFMPs.

A factor which is found to enhance use of particular soil fertility management practice in one locality at one time may hinder it or an irrelevant factor in another locality. In line with this, Ehui *et al*. (2004) pointed out that, although some known determinants tend to have general applicability; it is difficult to develop a universal model with defined determinants and hypothesis that hold everywhere. This is difficult because the socio economic and ecological distinctiveness of the different sites and the dynamic nature of the determinants, since there is repeated need for analyses under different conditions.

2.6. Analytical Framework of the Study

Statistical challenges of modeling adoption decisions involving packages or bundles of inputs have been addressed in a number of ways over the past few decades, particularly with regard to sustainable farming practices. In early research, despite the recognition that adoption of technology components is multivariate, econometric methods were limited to feasible approaches such as probit, logit and multinomial logit, in which adoption outcomes were redefined to create an order (Kamau *et al*., 2013).

In Kenya, Omamo *et al*. (2002) used a two-stage probit approach to test whether organic and inorganic fertilizers were used as complements or substitutes, assuming a sequential adoption process. Several recent studies about adoption of soil fertility management practices in Eastern and Southern Africa have used a series of single probit or logit equations to model the range of practices independently (Odendo *et al*., 2010; Mugwe *et al*., 2009). Recognizing that parameter estimates based on individual probit models may be biased by cross-practice correlations, Marenya and Barrett (2007) applied a multivariate probit model. Kassie *et al*. (2013) also analyzed the adoption of sustainable agricultural practices in Tanzania using a multivariate probit model, demonstrating the interdependence among choices.

Several studies confirm that farmers use one, several, or complex combinations of practices to address segregated and overlapping constraints in soil fertility. Research has also demonstrated that soil erosion lowers soil fertility through removal of organic matter and nutrients in eroded sediment (Young, 1989 as cited in Kamau *et al*., 2013). The control of erosion is therefore necessary although not sufficient for maintaining soil fertility. Furthermore, the non-separable model of the agricultural household predicts that market failures, imperfections or missing markets for some components or practices may lead to variations in the way they are applied that depend on household endowments. Heterogeneous household endowments may result in substitution or complementary among practices.

Recognizing these features of the empirical context and in concurrence with the recent studies mentioned earlier, multivariate probit (MVP) regression was used to estimate the probabilities that households use one or two mutually exclusive soil fertility management practices. Building on the decision to use inorganic fertilizer (DAP and urea), farmyard manure and soil and stone bunds in the multivariate probit model, SUR models were used to estimate the intensity of the selected soil fertility management practices. The SUR model is suitable for response such as use of fertilizer (DAP), farmyard manure and soil bund where the variable is continuously distributed over positive values.

The factors affecting whether or not a household applied one or more of the soil fertility strategy are not expected to differ from those affecting the amount used for the elements, and thus the independent variables included in the SUR models are those included in the MVP estimation.

Adoption studies based up dichotomous regression models have attempted to explain only the probability of adoption versus non-adoption rather than the extent and intensity of adoption. Knowledge that a farmer is using high yielding variety may not provide much information about farmer behavior because he/she may be using 1 percent or 100 percent of his/her farm for the new technology. Similarly, with respect to adoption of fertilizers, a farmer may be using a small amount or a large amount per hectare area. A strictly dichotomous variable often is not sufficient for examining the extent and intensity of adoption for some problems such as fertilizers (Feder *et al*., 1985).

There is also a broad class of models that have both discrete and continuous parts. One important model in this category is the SUR Model.

Examining the empirical studies in the literature, many researchers have employed the SUR model to intensity of technology use. The advantage of the SUR model is that, it helps to know the intensity of adoption of more than two dependent variables as the same time as MVP model helps to know the factors that affect adoption of technology more than two dependent variables.

2.7. Empirical Studies on the Determinants of SFMPs

Endrias *et al*. (2013) studied the determinants of farmers' decision on soil fertility management options for maize production in southern Ethiopia found that farmers in the study areas apply different soil fertility management practices to produce maize depending on their choice which is a function of several natural, socioeconomic and institutional factors.

They argued that agro-ecological location of the household, extension visit significantly influenced the use of mineral fertilizer at less than one percent significance level. The decision to use crop residue as a soil fertility management option for maize production was positively influenced by farm size at 5 percent level of significance (Endrias *et al*., 2013).

Desta (2012) has studied on the determinants of farmers' land management practices found that educational status, access to extension services and farmers' training have significant positive impact both on terracing and manure application. Age of farmers and livestock holding are also identified to have significant positive influence on manure application. Access to credit is identified to have significant influence on terracing and male headed households are more likely to practice terracing.

Mugwe *et al*. (2008) have analyzed determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya was made analysis using logistic regression and found that the age of the household head negatively influenced adoption implying that younger households had a higher probability of adopting the ISFM technologies than the older households. The farm management positively influenced adoption with households who had both spouses working on-farm full-time having a higher probability of adopting the ISFM technologies than those who had only one of the spouses working on-farm full-time. Ability to hire labour on a seasonal basis in this study positively influenced adoption at the, an implication that households that could afford to hire labour had a higher probability of adopting compared to households who were unable to hire labour.

Kamau *et al*. (2013) through their study on farmer demand for soil fertility management practices in Kenya's grain basket found that renting land is positively and significantly related to use of inorganic fertilizers on all plots and on maize plots. Benefits of chemical fertilizers are captured in the year the fertilizer is applied (Minot *et al*., 2000), although there may be some residual effects in subsequent years. By contrast, there is a lower likelihood of having other soil amendments or soil erosion control measures on land which is rented-in, and particularly on maize plots because such rented land is not accessible to them in the longer term. The number of legume crops is also positively associated with use of soil amendments, but not on the use of inorganic fertilizer suggesting that legumes may be a substitute for inorganic fertilizers rather than a complement or supplement. Results confirm that the effect of season is generally an important consideration in the uptake of soil fertility management practices.

In the same study, they also reported that households are more likely to use inorganic fertilizer on plots planted with maize during the major season, but less likely to use other soil amendments or engage in soil erosion control activities during this season. An increase in the share of off-farm earnings in total household income is positively associated with soil erosion control and use of inorganic fertilizers on maize or any other plot. The effect on erosion control is comparatively high. The result suggests that increasing off-farm income may be an important pathway to investments in ISMPs by smallholder farmers.

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, (types, sources and methods) of data collection, sampling technique and sample size, methods of data analysis and variable definitions and working hypotheses are presented.

3.1. Description of the Study Areas

3.1.1. East Hararge

East Hararge is one of the Zones of Oromia national regional states. Harar town which is the capital city of the zone is 517 km from Addis Ababa to east. East Hararge is bordered on the southwest by the Shebelle river which separates it from Bale, on the west by West Hararghe, on the north by Dire Dawa and on the north and east by the Somali Region (EHZADO, 2011).

Based on the 2013 population projection by the Central Statistical Agency of Ethiopia (CSA), this zone has a total population of 3,059,637, of whom 1,553,937 are men and 1,505,700 women; with an area of 17,935.40 square kilometers in 2013/14. East Hararghe has a population density of 170.6 per square kilometer.

The economic base of the population is mixed agriculture, which is crop and livestock production. The major crops grown in the zone are maize, sorghum, groundnut, sweet potato, *khat*, coffee and haricot bean (EHZADO, 2011).

3.1.2. Haromaya district

Haromaya district is located in Oromia regional state of East Hararge zone. It is located at $9^{0}07$ and $9^{0}31'$ N latitude and $41^{0}52'$and $42^{0}51'$ E longitude. According to planning and program section of Haromaya agricultural development office (2011) the total area of the district is 52,163hectares. Haromaya town, the capital of the district is at distance of 505 km from Addis Ababa to east and about 18 km far from Harar town to west**.** Haromaya is bordered on the south by Kurfa Chele district, on the west by Kersa district, on the north by Dire Dawa, on the east by Kombolcha district, and on the southeast by the Harari Region (HDADO, 2011).

The altitude of this woreda ranges from 1400 to 2340 meters above sea level; the highest points include Dof and Jeldo. The district can get 118 to 866 mm of rainfall annually. The agro-climatic zone of the district is categorized as, midland (59.3%) and lowland (40.7%) (HDADO, 2011). The known river is the Hamaresa; bodies of water include Lake Haromaya. According to planning and program section of Haromaya agricultural development office (2011) of the total area of the district 36.1%, 2.3%, 1.5% and 60.1% is arable or cultivable, pasture, forest, (built-up, degraded or unusable) respectively.

According to the same office, there are 33 farmers associations with 38,547 members. Out of 33 farmers associations 22 have midland agro-ecology and 11 have lowland agro-ecology. Haromaya has 35 kilometers of gravel and 83kms of dry-weather road, for an average road density of 214.5 kilometers per 1000 square kilometers (HDADO, 2011).

Based on the 2013 population projection by the Central Statistical Agency of Ethiopia (CSA), in 2013/14 this district had a total population of 332,985 of whom 169,283 were men and 163,702 were women; 70,077 or 21.05% of its population were urban dwellers with an area of 553.99 square kilometers. Haromaya district has a population density of 638.35 persons per square kilometer.

The economic base of the population of the district is mixed agriculture, which is crop and livestock production. The major crops grown in the district are maize, sorghum, groundnut, sweet potato and haricot bean. *Khat*, fruits and vegetables are important cash crops in the district.

3.1.3. Gurawa district

Gurawa district is located in Oromia regional state of East Hararge zone at about 551 km from Addis Ababa to east and about 75 km far from Harar capital town of the zone. According to the planning and program section of Gurawa agricultural development office (2011) the total area of the district is 136,365.6 hectares. It is located at $8^0$51’ and $9^0$17’ N latitude and $40^0$42’and $42^0$02′E longitude. Gurawa is bordered on the south by Gola Oda and Meyu district, on the west by Bedeno district, on the north by Kurfa Chele district, and on the east by Fedis district. The administrative center of the woreda is Gurawa (GDADO, 2011).

The altitude of this district ranges from 500 to 3230 meters above sea level; Geyle is the highest point; other significant peaks include Mount Gara Muleta. The district can get 550 to 1100 mm of rainfall annually. The agro-climatic zone of the district is categorized as highland (20%), semi-highland (31%) and lowland (49%) (GDADO, 2011). According to planning and program section of Gurawa agricultural development office (2011) of the total area of the district 54.3%, 4.4%, 1.2%, 21.8% and 18.3% is arable or cultivable, pasture, forest, built-up, and degraded or unusable respectively. Gurawa district has 45 farmers’ associations with 34,732 members. Out of 45 farmers’ associations, 10 kebeles have highland agro-ecology, 13 kebeles have midland agro-ecology and 22 kebeles have lowland agro-ecology.

Based on the 2013 population projection by the Central Statistical Agency of Ethiopia (CSA), in 2013/14 this district has a total population of 286,972 of whom 145,163 were men and 141,813 were women; 7778 or 2.71% of its population were urban dwellers with an area of 1109.41 square kilometers. Gurawa district has a population density of 210.44 persons per square kilometer.

The economic base of the population of the district is mixed agriculture, which is crop and livestock production. The major crops grown in the district are maize, sorghum, groundnut, sweet potato and haricot bean. *Khat*, fruits and vegetables are important cash crops. Coffee is also an important cash crop in the district.

Table 1: Summary of the description areas

	Haromaya	Gurawa
Location	**505km** from A.A to East &**12k**m from Harar toWest	**551km** from **AA to** East **& 75km** from Harar to Southwest
Latitude and longitude	$9^0$07' and $9^0$31' N $41^0$52'and $42^0$51′E	8^0 51' and $9^0$17' N $40^0$42'and $42^0$02′E
Total population	306,288	268,916
	51% M and 49%F	50.7%M & 49.3%F
Total area coverage	52,163has	136,365.6has
Annual rainfall	118 to866mm	550 to 1100mm
Major crop	Maize, Sorghum, Haricot bean sweet potato, Veg. and fruits	Maize, Sorghum, Haricot bean sweet potato, Veg. and fruits
Perennial crop	Coffee, *khat*	Coffee, *khat*
Agro-ecology	Midland (59.3 %) and lowland (40.3%)	Highland(20%), midland(31%) and lowland(49%)
Farmer Associations	33	45
Highland kebeles	-	10
Midland kebeles	22	13
Lowland kebeles	11	22

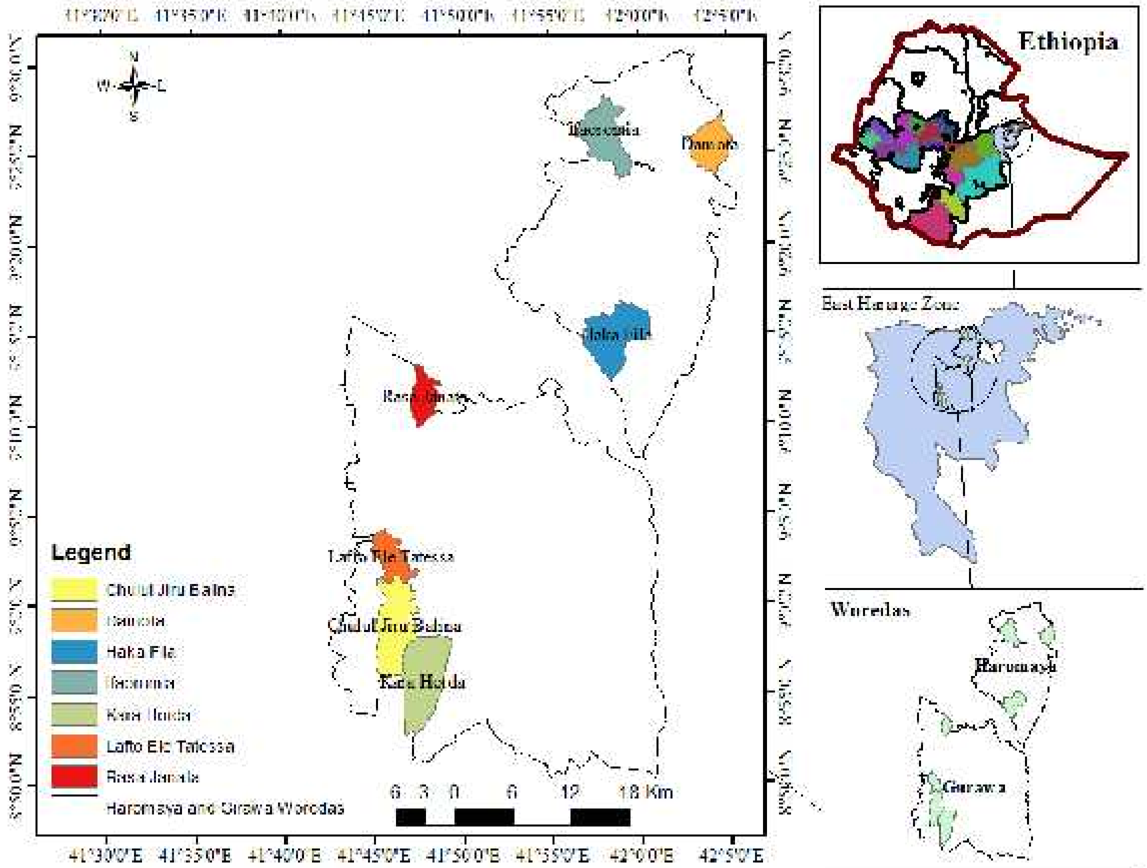

Figure 1: Location of Haromaya and Gurawa districts and selected kebeles
Source: Haromaya and Gurawa districts Agricultural Development Offices

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

The study was based on both primary and secondary data. Primary data were collected from the sample farm households. Secondary data which are relevant for the study were also gathered from governmental and non-governmental sources available in the study areas; so as to backup the primary data. Both published and unpublished documents were used.

Primary data were collected by employing a semi-structured questionnaire modified after an informal survey was conducted. Pre-testing was done and improvement was made based on the feedbacks obtained from the pre-testing exercise. Trained enumerators were used to gather data on different social, economic and institutional variables from sample households.

Focus group discussions and key informants' interview were also made with farmers, development agents, concerned agricultural professionals and administration offices by the researcher.

3.3. Sampling Technique and Sample Size

Haromaya and Gurawa districts were purposively selected for the study because the two districts can represent the highland, midland and lowland areas of the zone and so that multi types of soil fertility management practices are used by smallholder farmers of these districts. To determine the sample kebeles and households, a two stage stratified random sampling procedure was used. Kebeles in the districts are stratified in to their agro-ecologies because of utilizing different soil fertility management practices may differ because of agro-ecological differences. In the first stage, 33 kebeles in the Haromaya district were stratified into two agro-ecologies (midland and lowland). Based on probability proportional to size two kebeles from 22 kebeles of midland and one kebele from 11 kebeles of lowland agro-ecologies were randomly selected. In the same manner, 45 kebeles in Gurawa district were stratified into three agro-ecologies (highland, midland and lowland). Based on probability proportional to size one kebele from 10 kebeles of highland, one kebele from 13 kebeles of midland and two kebeles from 22 kebeles of lowland agro-ecologies were randomly selected. Totally, seven kebeles were selected randomly from the two districts, which are three kebeles from Haromaya and four kebeles from Gurawa district. In the second stage, a total of 200 sample households from the selected kebeles of two districts were taken randomly based on probability proportional to size.

The sample size was determined based on the formula provided by Yamane (1967). To determine the required sample size at 95% confidence level, 0.5 degree of variability and 7% level of precision was used. Therefore, the sample size is;

$$n = \frac{pqZ^2}{e^2} \quad (1)$$

Where n is the sample size, Z is confidence level (α=0.05), p is proportion of the households participating in soil fertility management practices, q = 1-p and e is level of precision.

n = (0.50 x 0.50) $(1.96)^2 / (0.07)^2$ =196

The formula suggests that 196 sample households should be taken. However, 200 sample households were taken for the study.

Table 2: Sample kebeles, agro-ecologies, total households and distribution of sample HHs

Name of district	Name of kebele selected	Agro-ecology	Total household heads	Sample household heads
Haromaya	Damota	Midland	1175	34
	Ifaoromia	Midland	1510	44
	Haka Fila	Lowland	845	25
	Sub total		3530	103
Girawa	Rasajannata	Highland	803	23
	Lafto Elatatessa	Midland	600	18
	Chulul Jirubalina	Lowland	1080	31
	Karra Orda	Lowland	857	25
	Sub total		3340	97
Total			6870	200

Source: Own computation, 2015

3.4. Methods of Data Analysis

To address the objectives of the study, descriptive statistics and econometric methods of data analysis were employed.

3.4.1. Descriptive statistics

In the descriptive part, simple measures of central tendencies and variations, frequency, mean, percentages and standard deviations were used to describe sample household characteristics and soil fertility management practices. In addition t-test and χ^2 –test were used to test if there are significant differences between districts of sample households practicing different soil fertility management practices in terms of different variables.

3.4.2. Specification of the econometric models

In the econometric analyses, a multivariate probit model was used to identify the determinants of soil fertility management practices use of inorganic fertilizer (DAP and urea), farmyard manure, compost, soil bund and stone bund) and finally a SUR model was employed to analyze the intensity of inorganic fertilizer (DAP and urea), farm yard manure and soil bund uses. The use of DAP and urea in Multivariate Probit and SUR model analysis is combined together in both participation and amount used as the application of the two fertilizers are almost the same. The two fertilizers were used by the sample household farmers almost equally in terms of participation and amount used in the study areas.

A. Multivariate Probit model

The dependent variables in the empirical estimation for this study is the choice of soil fertility management practice(s) from set of soil fertility management practices use of inorganic fertilizer (DAP and urea), farmyard manure, compost, soil bund and stone bund). Following Lin *et al*. (2005), the multivariate probit econometric approach is characterized by a set of m binary dependent variables Y_{ij} such that:

$$Y^*_{ij} = X'_{ij}\beta_j + U_{ij} \qquad j = 1, 2, \ldots m \ and \tag{1}$$

$$Y_{ij} = \begin{cases} 1 \text{ if } Y^*_{ij} > 0 \\ 0 \text{ otherwise} \end{cases} \tag{2}$$

Where j = 1, 2, …m denotes the soil fertility management practices used by the farmers; X'_{ij} is a vector of explanatory variables, β_j denotes the vector of parameters to be estimated, and U_{ij} are random terms distributed as multivariate normal distribution with zero mean and unitary variance. It is assumed that a rational i^{th} farmer has a latent variable, Y^*_{ij} which captures the unobserved preferences or demand associated with the j^{th} choice of soil fertility management practice. This latent variable is assumed to be a linear combination of observed household and other characteristics that affect the choice of soil fertility management practice, as well as unobserved characteristics captured by the stochastic error term.

Given the latent nature of the variable Y^*_{ij}, the estimation is based on the observable variable Y_{ij} which indicates whether or not a household adopts a specific soil fertility management practice. Since adoption of several soil fertility management options is possible, the error terms in equation (1) are assumed to jointly follow a multivariate normal distribution, with zero conditional mean and variance normalized to unity. The off-diagonal elements in the covariance matrix represent the unobserved correlation between the stochastic component of the j^{th} and m^{th} type of soil fertility management options. This assumption means that, equation (2) gives a multivariate probit model that jointly represents decision to use a particular soil fertility management option. The specification with non zero off-diagonal elements allows for correlation across error terms of several latent equations, which represent unobserved characteristics that affect choice of different soil fertility management practices.

B. Seemingly unrelated regression (SUR) model

The SUR model is a generalization of multivariate regression using a vectorized parameter model. Following Takada *et al*. (1995) SUR model can be specified in the following ways. Let us consider a system of M SUR equations, such that

$$y_i = X_i\beta_i + u_i, \quad i=1, \ldots, M \tag{1}$$

Where y_i is Tx1 vector of observations on the dependent variable y, X_i is a Txk_i matrix of non stochastic regression, β_i is a kx1 vector of the un known regression coefficients u_i is a Tx1 vector of unobservable disturbances . Equation (1) can be written more compactly as

$$y=X\beta + u \tag{2}$$

where y is an MTx1 vector, X is an MTxK matrix, β is a kx1 vector, u is an MTx1 vector of disturbances. It should be noted that

$$k = \sum_{i=1}^{m} k_i$$

It is assumed that the disturbances are contemporaneously correlated with the mean zero and the variance–covariance matrix given $\Omega = \sum \otimes I$. Where $\otimes$ is the kronecke product operator. I is an identity matrix of order TxT and $\sum=((\sigma_i))$. Such that,

$$E(u_i u_j) = \sigma_{ij} I \qquad i = j$$

$$= \sigma_{ij} \qquad I \neq j \; ; \; i, j=1,\ldots M \qquad (3)$$

3.4.3. Variables Definition and Working Hypotheses

A. Dependent variable

The dependent variables used in this study are use of soil fertility management practices by farm households that are dichotomous and assumes value of 1 if a given soil fertility management practice is used and 0, otherwise.

The soil fertility management practices included in the MVP model as dependent variables are use of five classes of soil fertility inputs. $\mathbf{Y}^*$ is measured using dummy variables with a value of one when soil fertility management practice is used and zero otherwise. These are use of inorganic fertilizer (DAP and Urea) = $\mathbf{Y_1}$; use of farm yard manure= $\mathbf{Y_2}$; use of compost = $\mathbf{Y_3}$**;** use of soil bund=$\mathbf{Y_4}$ and use of stone bund=$\mathbf{Y_5}$.

Use of inorganic fertilizer (DAP and Urea) ($\mathbf{Y_1}$): The commonly used inorganic fertilizer in the study areas are DAP and urea. It assumes a value of one if the farmer uses inorganic fertilizer (DAP and Urea) and zero otherwise.

Use of farmyard manure ($\mathbf{Y_2}$): This refers to whether the farmer uses farmyard manure or not. Farmyard manure is a common organic input used as soil fertility management practices by the farmers in the study areas. It assumes a value of one if the farmer used farmyard manure and zero otherwise.

Use of compost (Y_3): This refers to whether the farmer uses compost or not. Compost is a common organic input used as soil fertility management practices by the farmers in the study areas. It assumes a value of one if the farmer used compost and zero otherwise.

Use of soil bund (Y_4): This refers to whether the farmer uses soil bund or not. Soil bund is a common soil erosion control and moisture conserving measure used as a soil fertility management practice by the farmers in the study areas. It assumes a value of one if the farmer used soil bund and zero otherwise.

Use of stone bund (Y_5): This refers to whether the farmer uses stone bund or not. Stone bund is a common soil erosion control and moisture conserving measure used as soil fertility management practice by the farmers in the study areas. It assumes a value of one if the farmer used stone bund and zero otherwise.

Intensity of use SFMPs refers to the amount of (DAP and Urea) and farm yard manure used in kgs and soil bund constructed in kms were analyzed using the SUR model.

B. Independent variables

The independent variables that are expected to have association with the use of soil fertility management practices were selected based on empirical literature. The following 15 variables are selected based on the available literatures. Out of these variables 11 are continuous, 2 are discrete or categorical and 2 is dummy.

Sex of the household head (SEXHH): This is a dummy variable measured as 0 if the household head is female and 1, otherwise. Since women are the ones who are responsible for the many household domestic activities, they may not accomplish important soil fertility management practices on time and efficiently (Kinde, 2005) as they usually face a shortage of labour and working capital. Therefore, it is hypothesized that male household heads are better users of SFMPs as compared to female household heads.

Age of the household head (AGE): This is a continuous variable referring to the age of the household head in years. This variable is also used as a proxy variable for farming experience. Through experience, farmers may perceive and understand the problem of the decline in the fertility of the soil and use of improved soil fertility management practices. Thus, more experienced farmers in farming are likely to manage their land in a better way than less experienced farmers. On the other hand, as the age of household increases, even though age of the household and perception on land degradation are expected to relate positively, the ability of applying fertilizer and other soil fertility management practices decreases (Fitsum and Holden, 2003). Therefore, it is hypothesized that the effect of age of household head on the use of soil fertility management practices is indeterminate, a priori.

Education of the household head (EDUCAHH): Refers to the education level of the household head which is measured in years of schooling and can be used as a proxy variable for managerial ability. Education may increase households understanding on the causes and impact of soil fertility decline and the increase in the cost of rehabilitation. Education improvements appear to have contributed to several aspects of agricultural intensification (Ervin and Ervin, 1982; Feder *et al*., 1985; Baidu-Forson, 1999). Despite this, more educated households may be less likely to invest inputs or labour intensive land management practice, since the opportunity cost of investing inputs or labour intensive investments and capital may increase through education. Therefore, it is hypothesized that effect of education of household head on use of soil fertility management practices is indeterminate, a priori.

Household size (FMLSIZE): This variable refers to the number of members of the household regardless of age and sex in man equivalent. The existence of large number of family members with limited land resource could affect use of soil fertility management practices positively or negatively. The first assumption is due to the increasing demand for food with limited land resource soil fertility depletion may increase as a result of cultivation of fragile lands, reduced use of fallow, increased tillage, and other potential results of intensification

(Wagayehu and Drake, 2003). The second assumption is that large household size is normally associated with a higher labor endowment which would enable a household with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortage at peak times. This will be measured in man equivalent; to capture the difference in age and sex. Therefore, it is hypothesized that the effect of household sizes on soil fertility management practices is indeterminate, a priori.

Number of plots (NUMPLOT): Land fragmentation may undermine farmer's interest in undertaking some types of land management. In dispersed and distant plots, the cost of hauling manure or organic materials may not be worthwhile. The larger the number of parcels of plots a farmer owns and manage, the greater is the amount of time loss in traveling from plots to plots and the lower will be the amount of time left for manuring and soil conservation activities. Thus large number of farm plots is associated with lower level of applying manure and adoption of improved soil and water conservation strategies (Yohannes, 1992; Berhanu and Swinton, 2003). In addition, investments that can be easily damaged by freely roaming livestock or may be subject to theft for distant/dispersed plots because it is difficult to protect them. Therefore, number of plots managed is expected to affect use of SFMPs negatively.

Plot size (PLOTAREA): This is size of the plot of the household used for cultivation of the crop and is measured in hectares. Soil conservation structure may take some area especially that would have been used for cultivation. Farmers who managed larger size plots can allocate some part of the land for soil conservation than those who have smaller farms (Wagayehu and Drake, 2003). On the other hand, large plot size may demand higher labour, capital, and fertilizer. Labour, capital or other constraints may limit the ability of farmers to invest on large plot size area than small plot area. Therefore, the effect of plot size on SFMPs is expected to be indeterminate, a priori.

Distance of the plot from the residence (PLOTDIST): It refers to the average travel time of a given plots from the residence of the household head in minutes. Farmers whose plots are nearer to their residence apply organic matter to substitute soil nutrient loss and soil conservation structure to minimize soil erosion, because the time and energy they spend is lesser for nearer plots than distant plots. Plot distance were expected to detract from investment due to increased transaction cost (Fitsum and Holden, 2003; Berhanu and Swinton, 2003). Therefore distance is more likely to affect use of SFMPs negatively.

Slope of the plot (SLOPE): Slope of the field is the indicator used as a proxy for the erosion potential. It is measured by 1 if the plot is flat (0-5%), 2 if the plot is gentle slope (6-15%) and 3 if the plot is steep (>15%). The land surface configuration that relates to topography is described in terms of slope. The slope of the plot affects soil erosion or soil fertility. Steep slope are subject to more rapid runoff surface water and need large number of soil conservation technology (Ervin and Ervin, 1982; Wagayehu and Drake, 2003). Thus, the slope of the plot is hypothesized to positively affect use of soil fertility management practices.

The agro-ecological location (AGROECO): It is a categorical variable. This variable takes a value of 1 if the area belongs to moisture deficit agro-ecology i.e. lowland (*Gammojji*); it takes a value of 2 if the area belongs to moderate rain receiving agro-ecology i.e. midland (*Baddadare*); and it takes a value of 3 if the area belongs to adequate rain receiving agro-ecology i.e. highland (*Badda*). Agro-ecological locations have influence on usage of soil fertility management practices. Endrias *et al*. (2013) states that agro-ecological location of the household, rated from high altitude areas to low altitude areas in an ascending order, negatively and significantly influence the use of mineral fertilizer. This is because of low extension coverage and farmers' perception of soil fertility management practices. It is, thus, hypothesized that agro-ecology will affect use of SFMPs positively, in an ascending order.

District: Two districts (Haromaya and Gurawa) were the selected for the study. The variable takes a value of zero when the district is Haromaya and it takes a value of one if the district is Gurawa. The use of different soil fertility management practices is different between the two districts. It is assumed that districts with better infrastructure and facility have better opportunity than the district with lesser infrastructure and facilities. Haromaya district has better infrastructure and facility than Gurawa district. Therefore, district is hypothesized that it is negatively affect use of soil fertility management practices.

Livestock holding (TLU): This variable represents the livestock holding of the household in TLU. It was measured by tropical livestock unit using a conversion factor. It is also an indicator of wealth. Those farmers who have large number of livestock may have more animal dung to improve the fertility of the soil and more capital to invest in soil conservation practices. This affects the use of soil fertility measures positively (ILRI, 2000). More specialization into livestock away from cropping may however reduce the economic impact of soil erosion, and/or increase the availability of cow dung to counter the process of nutrient depletion, and thus lower the need for soil conservation (Bekele and Holden, 1998). Moreover, most of the time livestock rearing creates burden on community grazing land. Therefore, it is hypothesized that effect of livestock holding on the use of SFMPs is indeterminate a priori.

Frequency of extension visit (EXTVISIT): It is a continuous variable indicating the frequency of extension contact of the household head with development agent (DAs). It is measured by the number of contacts per year that the household head made with development agents. The farmer's level of access to information from agricultural experts influences the use of soil fertility management practices decision positively. Farmers who have frequent contact with agricultural experts are expected to have easy access to information about problems; potential and performance of agricultural technologies are more likely to adopt new technologies (Wegayahu and Darke, 2003). Therefore it is hypothesized in the present study that access to extension service by farmers and adoption of soil fertility management practices are positively correlated.

Use of irrigation: Use of irrigation increases the opportunity to use different soil fertility management practices. The variable is measured by the frequency of irrigation used in a year. Irrigation increases the application of inorganic and organic fertilizers because it ensures the availability of water at the time of shortage of rainfall. Use of irrigation makes the farmer to earn more income and this will increase their financial capacity to use different soil fertility management practices. Therefore, it is hypothesized that irrigation use will positively influence use of soil fertility management practices.

Credit utilized (CRDTRCUD): It is a continuous variable and it is measured as the amount of credit utilized in Birr by the household. One of the potential constraints to farmer in the adoption of modern technologies and inputs is the shortage of cash. Application of inorganic fertilizer fulfills the NPK demand of the crop and its substitute plants nutrients (NPK) loss by soil erosion, leaching and the uptake of crops. On the contrary, according to Pender *et al*. (2001) and Bekele and Holden (1998), provision of credit for fertilizer has a negative effect on incentive to conserve land and this causes erosion rates to be higher when credit is provided. One may also argue that credit may reduce labour-intensive land management practices. Therefore, the effect of agricultural credit utilization on usage of soil fertility management practices is indeterminate, a priori.

Off/non-farm income (OFFINCOME): This is a continuous variable that measures the amount of off-farm/non-farm income (in Birr) the sample household earned in a year. The net effect of income on investment in land quality is indeterminate on theoretical grounds (Reardon and Vosti, 1995). When the off/non-farm income source is especially from non natural resource conservation activities, it is expected to have negative effect on conservation by creating reliance on this source dominantly. On other hand, off/non-farm income may ease the constraint on liquidity needed for soil fertility management practice investments. Hence, following these arguments, the effect of off-farm/nonfarm income in the study area is, hypothesized to be, indeterminate, a priori.

Table 3: Summary of independent variables and their hypotheses

Variable	**Acronyms**	**Measurement**	**Expected sign**
Age of household head	AGE	Continuous	+/-
Sex of household	SEXHH	Dummy	+
Household size	FMLSIZE	Continuous	-/+
Education of the household	EDUCAHH	Discrete	+/-
Extension visit	EXTVISIT	Continuous	+
Agro-ecology	AGROECO	Categorical	+
District	DISTRICT	Dummy	-
Slope of the plot	SLOPE	Categorical	+
Distance of the plot	PLOTDIST	Continuous	-
Livestock holding	TLU	Continuous	+/-
Off/non-farm income	OFFINCOME	Continuous	+/-
Credit received and utilized	CRDTRCUD	Continuous	+/-
Number of plots	NUMPLOT	Continuous	-
Plot area	PLOTAREA	Continuous	+/-
Use of irrigation	IRRIGUSE	Continuous	+

4. RESULTS AND DISCUSSION

This chapter is mainly concerned with description and interpretation of the findings of the study based on the analysis of the cross sectional data collected using semi-structured questionnaire that was administered to 200 sample households. Under this chapter, the results of descriptive and econometric analysis on the determinants of participation and intensity of soil fertility management practices use along with previous research findings are briefly presented and discussed.

4.1. Descriptive Statistics Results

Before going to presenting and discussing the results obtained from the econometric models, it is important to briefly describe the socio-economic, demographic, institutional variables and soil fertility management activities undertaken using descriptive statistics. This would help to draw a general picture about the study area, SFMPs and sampled households.

4.1.1. Socio-economic and demographic characteristics of sample households

Family size and age composition of sample HH heads: The average family size for the sample households was about 6.52 persons which as lower than the districts average family size of 7.39 persons per household in 2014 population projection of CSA (2013) and ranging between of 2 and 15 persons. The average age of the sample household heads was 40.6 years with a maximum of 67 and a minimum of 22 years. Table 3 also shows that, on average, 2.82 out of 4.74 adult equivalents can provide labor force in man equivalent and actively engage in an economic activity.

The mean comparison tests of the two districts show that, Gurawa has larger family size, adult equivalent and man equivalent than Haromaya district. But there is no significance difference in terms of mean age between the two districts.

Educational level of sample HH heads: Education is an instrument to enhance the quality of labor through improving the managerial skill and the tendency to adopt new technologies.

Therefore, education together with increased experience could enable farmers to better manage their farming activities. From Table 4 below, average education level of the household is 2.56.

Table 4**:** Age, family structure and of sample HHs during the 2013/14 production year

Variable description	**Mean**				t-**statistic**
	Gurawa	**Haromaya**	**Both**	**Std.**	
Age	40.63	40.57	40.60	9.84	0.04
Family size	7.28	5.82	6.52	2.31	4.71***
Adult equivalent	5.18	4.32	4.74	1.45	4.37***
Man equivalent	2.96	2.68	2.82	1.02	1.91*
Education level	2.27	2.82	2.56	2.86	-1.35

Note: *** and * represents significant at 1% and 10% probability level respectively.
Source: Own computation (2015)

Sex and marital status of the sample household heads: Regarding the sex of respondents, about 87% of the sample households were male-headed and the remaining 13% were female headed. Results in Table 5 reveals that 1.5, 92, 3.5 and 3 percents of the sample households were single, married, divorced and widow, respectively.

Table 5**:** Sex and marital status of the sample household heads

Sex and marital status	**Category**	**Name of the district**				**Both**		[illegible]
		Gurawa		Haromaya				
		Freq.	%	Freq.	%	Freq.	%	**statistic**
Sex	Male	87	89.69	87	84.47	174	87	
	Female	10	10.31	16	15.53	26	13	
	Total	97	100	103	100	200	100	1.20
Marital status	Single	0	0	3	2.91	3	1.5	
	Married	94	96.91	90	87.38	184	92	
	Divorced	1	1.03	6	5.83	7	3.5	
	Widow	2	2.06	4	3.88	6	3	
	Total	97	100	103	100	200	100	7.15*

Note: * represents significant at 10% probability level.
Source: Own computation (2015)

The chi-square test shows that there is significance difference between the districts in terms of marital status of the households at 10% significance level.

4.1.2. Farm characteristics

A. Inputs

Farmers in the study areas use different combination of inputs, such as land, fertilizers (organic and/or inorganic), seed (improved and/or local) and labor in the production of crops.

Land: Land is the main factor of production needed by the farmers to make their livelihoods. Farmers use most of their land for crop production or grazing. From Table 6 below the average area of cultivated, homestead, grazing land and forest land by the sample households of the two districts was 0.419, 0.019, 0.017 and 0.015 hectares, respectively. From the same Table, the average land size of the household is 0.4807 hectares. The average number of plots of the sampled households during the survey period was greater than two in number, i.e. 2.45 in average. This indicates that there is land fragmentation in the study areas, with the number of plots ranging from one to five. From Table 5 below on average, the farm plots of the households take 9.52 walking minutes from the residence of the households.

Table 6: Land distribution and farming characteristics of sample households heads

Type of variables	**Mean**			**Std.**	**t- statistic**
	Gurawa	**Haromaya**	**Both**		
Cultivated land (ha)	0.300	0.530	0.419	0.255	-7.32***
Homestead area (ha)	0.009	0.027	0.019	0.039	-3.29***
Grazing land (ha)	0.011	0.022	0.017	0.051	-1.57
Forest land (ha)	0.008	0.021	0.015	0.043	-2.24**
Total farm land (ha)	0.331	0.621	0.481	0.316	-7.31***
Home to plot average distance (minutes)	5.68	13.14	9.521	7.34	-8.31***
Number of plots	2.27	2.60	2.450	1.210	-1.90*
Farming experience	25.61	23.70	24.63	9.008	1.51

Note: ***, ** and * represents significant at 1%, 5% and 10% probability level respectively.
Source: Own computation (2015)

The average farming experience of sample households ranges from 9 to 52, with a mean value of 24.63 years. As indicated in Table 6, the mean comparison tests show that, on average Haromaya district sample households has larger size of cultivated, homestead and forest land than Gurawa district. The mean comparison tests also show that there is no significance difference between the districts in terms of number of plots.

Inorganic and organic fertilizer use: Inorganic and organic fertilizers are the major factors of production that are used in the study areas. The result of the survey indicated that, the majority or more than 78.5% of the sample HHs use inorganic fertilizers both DAP and urea. Regarding organic fertilizer, farmyard manure and compost are the major inputs used by the farmer in the study areas. From Table 7 below, one can see that majority (73%) of the sample households used farm yard manure and 38% of the sample households used compost. Farmers in the study area understood the use of farmyard manure very well; however use of farmyard manure is constrained by mainly availability of farmyard manure i.e. the livestock they owned. As chi-square shows there is no significance difference between the districts in terms of household numbers in using DAP, urea, farmyard manure and compost.

Table 7: Number of sample HHs using of the fertilizer inputs in 2013/14 production year

Fertilizer input	**Gurawa**		**Haromaya**		**Both**		χ^2 - statistic
	Freq.	%	Freq.	%	Freq.	%	
DAP	72	74.23	85	82.52	157	78.5	2.03
Urea	73	73.20	84	85.46	157	78.5	1.17
FYM (Farm yard manure)	66	68.04	80	77.67	146	73	2.34
Compost	42	43.30	34	33.01	76	38	2.24

Note: * represents significant at 10% probability level.
Source: Own computation (2015)

The amount fertilizer (organic and inorganic) used varied from farmer to farmer; as a result of socio-economic, environmental and other factors. Table 8 reveals that, average level of use of fertilizer DAP, urea, farm yard manure and compost used by the sample households in kg is 42.54, 43.34, 1054.45 and 201.95, respectively. Compost is used for increasing the volume of organic input by collecting home waste, farmyard manure, *khat* leaves and crop residues in a well prepared pit. Farmers in the study area perceive that use of farmyard manure or compost with inorganic fertilizer is better than use of them separately because larger volume of farmyard manure or compost is needed as a substitute for the inorganic fertilizer; however the availability of farmyard manure is mainly constrained by the livestock holding. It is shown in Table 10 that the average livestock holding in the study area is 2.48 in tropical livestock unit.

The mean comparison tests show that on average larger amount of DAP and urea are used by sample households in Haromaya district than in Gurawa. In contrast, on average larger amount of compost is used by sample households in Gurawa district than in Haromaya. There is no significance difference in using farmyard manure between the two districts.

Table 8: Use of fertilizer (in Kgs) by the sample HHs in 2013/14 crop year

		Mean				
Input	**Category**	**Gurawa**	**Haromaya**	**Both**	**Std.**	t- **statistic**
Inorganic fertilizer	DAP	28.81	55.46	42.54	32.39	-6.36***
	Urea	29.37	56.50	43.34	33.30	-6.47***
Organic fertilizer	Farm yard manure	974.33	1129.90	1054.45	978.91	-1.12
	Compost	283.81	124.85	201.95	398.17	2.87***

Note: *** represents significant at 1% probability level.
Source: Own computation (2015)

Labor: The result of the survey indicates that the majority (40.5%) of the sample households use family labor. Hired labor is an additional source of labor supply. Results in Table 9 reveal that among the sample households, 26.5% of the sample households use both family and hired labor. Labor exchange was also the additional source of labor supply and it is also another important source of labor to undertake SFMPs and other activities, as 33% of sample households used exchange labor together with family labor. The use of hired labor was low especially in Gurawa district because production is mainly undertaken for consumption whereas it is higher in Haromaya district where most of the farmers grow *khat* for the market. On average, 33% of the sample households use family and exchange labor together.

Table 9: Type of labor used by the sample HHs to undertake various farming operations

Type of labor used	**Gurawa**		**Haromaya**		**Total**		[illegible] – **statistic**
	Freq.	%	Freq.	**value**	Freq.	%	
Family labor	47	48.45	34	33	81	40.5	
Family and hired labor	5	5.15	48	46.6	53	26.5	
Family and exchange labor	45	46.4	21	20.4	66	33	
Total	97	100	103	100	200	100	45.56***

Note: *** represents significant at 1% probability level.
Source: Own computation (2015)

The average wage rate varied between 50 and 70 Birr per day for land preparation, soil and stone bund maintenance, sowing, weeding and harvesting time during the 2013/14 production year. The chi-square test shows that there is significance difference between the two districts in terms of use of labor.

B. Livestock holding

Livestock production is the second important economic activity which was undertaken by the farmers in the study areas following by crop production. Livestock is an important component of additional income and source of organic fertilizer for increasing the production and maintaining soil fertility in the study area. In the study area, livestock management and feeding system was good even though the number of livestock owned is smaller. Zero grazing is practiced by the farmers for small number of animals.

The main constraints in rearing the livestock are shortage of feed and grazing land. The result of the study in Table 10 shows that, the average livestock holding is 2.48 TLU. The mean comparison test shows that there is no significance difference between the districts in terms of livestock holding.

Sample households were asked to answer the question “what is the main problem of livestock production in you respective areas”. Of the total sample households, 88% answered that the main problem of livestock production is shortage of grazing land and animal feed. Again, 12% of the respondents answered that the main problem of livestock production was shortage of grazing land, feed, water and animal diseases. The survey results showed that 95.5% of the respondents used crop residue and their own farm to feed their livestock. Results presented on Table 5 also show that on average sample households owned 0.017 ha of grazing land.

Table 10: Average Livestock holding of the sample respondents in TLU

District	Minimum	Maximum	Mean	Std.	t- statistic
Gurawa	0	5.65	2.59	1.49	
Haromaya	0	5.1	2.37	1.33	
Total	0	5.65	2.48	1.41	1.15

Source: Own computation (2015)

C. Major crops produced and their area coverage

Sorghum and maize are the major crops grown in the study areas. Both crops together covered 76.44% of the cultivated land during 2013/14 cropping year of the main season. *Khat* is another important plant grown in the study areas. It is the main income generating plant in the study areas.

Table 11: Cropping pattern and share of major crops during the 2013/14 production year

Type of crop	Gurawa		Haromaya		Total	
	Total Area	% share of each crop	Total Area	% share of each crop	Total Area	% share of each crop
Maize	14.22	45.29	15.27	28.76	29.49	34.91
Sorghum	9.38	29.87	25.71	48.43	35.09	41.53
Wheat	1.83	5.83	1.25	2.35	3.08	3.65
Barley	0.44	1.40	0	0.00	0.43	0.52
Groundnut	0.13	0.41	0.81	1.53	0.93	1.11
Vegetables	0.87	2.77	2	3.77	2.87	3.40
Khat	4.53	14.43	8.05	15.16	12.57	14.89
Total	31.40	100.00	53.09	100.00	84.49	100.00

Source: Own computation (2015)

In Table 11 above, it is shown that *khat* covers 14.89% of the total cultivated land. Sorghum is the most preferred crop by the farmers because of its drought tolerance ability of the crop. Out of the total area covered with crops, the share of sorghum was 41.53% of cropped area in 2013/14 crop year. However, maize was the most grown crop in Gurawa district because some parts of the district is highland and maize is said to be better in terms of productivity. In the study areas, landholding size is very small. Results presented in Table 6 above show that, the average land holding of the sample households was 0.4807 hectare and the average size of the cultivated land was 0.4189 hectare. Table 12 presents on average 0.147, 0.175 and 0.063 hectares of land was allocated for maize, sorghum and *khat* production respectively during main season of crop year of the 2013/14 by sample households. It was observed that farmers in the study area undertake different measures to minimize the problem related to shortage of cultivation land. The known activities are intercropping between rows of maize and sorghum and growing vetiver grass on the constructed bunds for their livestock are the common ones. The mean comparison tests show that on average Haromaya district sample households used more area of land for sorghum, groundnut, vegetables and *khat* than Gurawa district sample households. There is no significance difference between the districts in cropping maize and wheat.

Table 12: Average cultivated land under the major crops by sample HHs (2013/14 crop year)

Type of crop	Gurawa		Haromaya		Total		
	Mean (ha)	**Std.**	**Mean (ha)**	**Std.**	**Mean (ha)**	**Std.**	t- **statistic**
Maize	0.146	0.110	0.149	0.147	0.147	0.130	-0.15
Sorghum	0.094	0.085	0.252	0.171	0.175	0.163	-7.80***
Wheat	0.019	0.039	0.012	0.038	0.015	0.039	1.21
Barley	0.005	0.018	0	0	0.002	0.013	2.54**
Groundnut	0.001	0.013	0.008	0.027	0.004	0.021	-2.17**
Vegetables	0.009	0.022	0.019	0.039	0.014	0.033	-2.26**
Khat	0.046	0.044	0.078	0.053	0.063	0.051	-4.71***

Note: *** and ** represents significant at 1% and 5% probability level respectively.
Source: Own computation (2015)

4.1.3. Indigenous knowledge on soil fertility in the study areas

Indigenous knowledge of soil fertility is an important aspect that must be understood before interring into discussion of soil fertility management practices. Farmers in the study area have ample and accumulated indigenous knowledge in using different soil fertility management practices.

They identify their plots soil fertility status using different methods. Sample households were inquired on how they identify the soil fertility status of a plot. Out of the total sample respondents, 58% of them responded that they identify the fertility status of their plots using soil depth, productivity of the plot, type of vegetation grown on the plot and rockiness of the plot as key indicators. Another, 22.5% of the households responded that they identify soil fertility status of their plot using soil depth, productivity, type of vegetation grown and slope of specific location within a plot. Likewise, 19.5% of the households identify the soil fertility status of plots using soil depth, soil texture, productivity of the plot and type of vegetation grown on the plot.

Table 13: Ways of identifying soil fertility status of plots by the sample households

Means of soil fertility identification	Gurawa		Haromaya		Total		χ^2 – statistics
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	
Soil depth, productivity, type of vegetation and rockiness of the plot	89	91.75	27	26.21	116	58	
Soil depth, productivity, type of vegetation and slope of the plot	6	6.19	39	37.87	45	22.5	
Soil depth, soil color, soil texture, productivity and type of vegetation	2	2.06	37	35.92	39	19.5	
Total	97	100	103	100	200	100	88.65***

Note: *** represents significant at 1% probability level.
Source: Own computation (2015)

Farmers in these study areas perceive that plot with better soil depth have better soil fertility and plot with shallow soil depth to have a lower soil fertility status. Moreover, farmers in the study areas perceive that plot with a better yield is considered as fertile and a less productive one is considered as less fertile or infertile soil. In addition, farmers in the study areas perceive that plots on which broad leaved plants grow are considered as fertile.

Farmers in the study areas classify soils based on soil texture, soil color and other properties. On top this, they have their own nomenclature to different types of soils. Sandy soil in the study areas is locally known as *chiracha*. According to the perception of farmers in the study areas, this type of soil have medium fertility and it needs more moisture to give better yield. The other type of soil is *eydachi* which is commonly known as sandy loam. According to the perception of farmers, in the study areas this soil type has better fertility and has no problem of workability. The other type of soil which is known by the farmers in the study area is *kalgabar* soil. This soil type has a mixture of different types of soils such as sandy, sandy loam and clay soil. To the farmers, this is a preferred type of soil for crop production because of its easy workability and fertility status. The other types of soils are *tefara* and *suphe* soils which are similar in their characteristics. Their difference is that *suphe* soil type is more of clay nature and it has a problem of workability during rains period compared to *tefara* soil type.

Table 14: Typology and local nomenclature of soil types in the study areas

Local name	Common name	Color of the soil	Fertility status	Workability
Chiracha	Sandy soil	Light brown	Medium	Medium (Hard to cultivate when there is no rain)
Eydachi	Sandy loam	Brown	Medium	Good
Kalgabar	Mixture of sandy, sandy loam, and clay soil	Brown and black	Fertile	Good
Tefara	Clay loam	Black, brown	Medium	Has a problem when there is excess water
Suphe	Clay soil	Brown and red	Less fertile	It has severe drainage problem

Source: From group discussion by the researcher

4.1.4. Soil fertility management practices

Different kinds of soil fertility management practices are used by the farmers in the study areas. Among the major practices, inorganic fertilizer application, use of organic inputs and soil erosion control measures are the major ones. In this sub-section, the three soil fertility management practices are briefly discussed and presented.

A. Inorganic fertilizer use

DAP and urea fertilizers are the main organic fertilizers applied by the sample households during the 2013/14 main production season. As presented in Table 15, on average 42.54 kg of DAP and 43.34 kg of urea fertilizer were applied during the mentioned cropping season. When we compare the two districts, Haromaya district farmers are better users of the both types of fertilizers as more fertilizer is often applied for growing *khat* and irrigated vegetables. The use of inorganic fertilizers is, however, constrained by the availability of rainfall and price of the fertilizer especially for the farmers living in the lowland areas.

Table 15: Use of inorganic fertilizers by sample HHs during 2013/14 main season (in kg) and (Kg/Ha)

Type of Inputs	**Gurawa**		**Haromaya**		**Total**		
	Mean	**Std.**	**Mean**	**Std.**	**Mean**	**Std.**	t-**statistic**
DAP (kgs/HH)	28.81	21.34	55.46	42.54	42.54	32.39	-6.36***
Urea (Kgs/HH)	29.37	21.25	56.50	36.17	43.34	33.30	-6.47***
DAP (Kgs/HH/Ha)	94.47	73.66	109.07	83.27	101.99	78.90	-1.31
Urea (Kgs/HH/Ha)	95.02	68.95	112.79	86.94	104.17	79.84	-1.52

Note: *** represents significant at 1% probability level.
Source: Own computation (2015)

The use of inorganic fertilizer in kg/ha is higher in the two districts, because farmers use inorganic fertilizers for growing *khat* and vegetables. They use up to three times to grow *khat* in one year. Since the land holding size is small, amount of fertilizer applied by the farmers is higher in kg/ha in the study areas. Results in Table 15 show that, the average use of inorganic fertilizers DAP and Urea by the sample households is 101.99 kg/ha and 104.17 kg/ha, respectively. There is no significance difference in using both DAP and urea in kg/ha between the two districts.

With regards to application of inorganic fertilizers, farmers in the study areas raised a lot of problems. These are higher price of fertilizer, shortage of rainfall and negative impact of fertilizer on the farm land are the major ones. On top of this, farmers were asked to respond to the question “what is the problem of using inorganic fertilizer”. Out of the total sample households, 31% of the households replied that, the problems of using inorganic fertilizer were shortage of rainfall and its price which is too high. Out of the total sample households, 37% of them answered that price of fertilizer was too high.

Table 16: Perceived problems associated with use of inorganic fertilizers by sample HHs.

Problems of using inorganic fertilizers	**Gurawa**		**Haromaya**		**Total**		χ^2 –
	Freq.	%	Freq.	%	Freq.	%	statistic
• Price of fertilizer is too high	39	40.21	35	33.98	74	37	42.71***
• Price of fertilizer is too high and it has negative impact on soil fertility	2	2.06	22	21.36	24	12	
• Price of fertilizer is too high and there is a problem of quality and quantity	1	1.03	14	13.59	15	7.5	
• Price fertilizer is too high, it has negative impact on soil fertility and shortage of rain fall	22	22.68	3	2.91	25	12.5	
• Price of fertilizer is too high and shortage of rain fall	33	34.02	29	28.16	62	31	

Note: *** represents significant at 1% probability level.
Source: Own computation (2015)

B. Use of organic inputs

Organic inputs are important components in crop production in the study areas. The organic inputs which are widely used by the farmers in the study areas are use of farmyard manure and compost. However, the use of farmyard manure and compost is limited by the number of livestock the households owned. Those farmers who own more number of livestock use more farmyard manure and compost than those who own less number of livestock. Results in Table 17 show that, on average 1054.45 kg and 201.95 kg of farmyard manure and compost were used by sample households in the study areas. The mean comparison test shows that there is no significance difference between the districts in using farmyard manure. There is significance difference between the two districts in using compost. That is Gurawa district is more amount of compost user than Haromaya district per household.

As presented in Table 17 below, the average use of organic inputs such as farmyard manure and compost is 2915.56 kg/ha and 690.20 kg/ha per household respectively. The amount is very higher than the amount used per household because of small landholding size in the study areas.

The use of farmyard manure and compost in kg/ha is larger in Gurawa district than in Haromaya district because land holding size in Gurawa is smaller than in Haromaya district. The mean comparison test also approves the above results.

Other soil fertility management practices used by farmers in the study areas are use of crop residues, mulching and planting trees. The use of these soil fertility management practices are limited by the farmers even though they are sustainable for longer period of time than inorganic fertilizers.

Table 17: Quantities of SFMPs used by the sample HHs during the 2013/14 production year

Type of Inputs	Gurawa		Haromaya		Total		t-statistic
	Mean	Std.	Mean	Std.	Mean	Std.	
FYM (kg)	974.33	1052.37	1129.9	902.97	1054.45	978.91	-1.12
Compost(kg)	283.81	490.15	124.85	266.12	201.95	398.17	2.87***
FYM (Kg/Ha)	3438.82	4052.87	2422.80	2221.19	2915.56	3269.44	2.22**
Compost (kg/Ha)	1061.13	1905.15	340.88	865.62	690.20	1505.08	3.48
Soil bund(kms)	0.3344	0.3416	09022	0.5527	0.6268	0.5420	-8.67***
Stone bund (kms)	0.3398	0.2521	0.0953	0.1988	0.2139	0.2567	7.64***
Soil bund (km/Ha)	1.2193	1.2264	2.0297	1.6105	1.6367	1.4899	3.99***
Stone bund (km/Ha)	1.3588	1.2648	0.2479	0.5356	0.7867	1.1084	8.17***

Note: *** and ** represents significant at 1% and 5% probability level respectively.
Source: Own computation (2015)

Use of crop residues: It is believed that leaving crop residues over the cropped land will maintain the nutrient used by the plant. Results presented in Table 18 show that of the total sample households, only 7% use crop residues for soil fertility purposes in addition to animal feed and other uses. Crop residue is mainly used by farmers for animal feed; as 99% of them reported that they use crop residue primarily for animal feed. In addition to animal feed, 72% and 37.5% of households use crop residue for fuel and construction purposes, respectively. As a shortage of grazing land is the main problem of livestock production in the study areas, using crop residue as animal feed is strategy towards minimizing shortage of livestock feed in the areas. As indicted in Table 18, there is no significance difference in using crop residue between the two districts.

Table 18: SFMPs and Agronomic practices used by the sample households

Activity	Gurawa		Haromaya		Total		χ^2 – statistic
	Freq.	%	Freq.	%	Freq.	%	
Use of crop residue	8	8.25	6	5.83	14	7.00	0.45
Use of mulching	0	0.00	8	7.77	8	4.00	7.84***
Planting of trees	22	22.68	55	53.40	77	38.50	19.91***
Use of crop rotation	7	7.22	20	19.42	27	13.50	6.36**
Use of strip cropping	49	50.52	47	45.63	96	48.00	0.48
Use of inter cropping	75	77.32	96	93.20	171	85.50	10.16***
Use of fallowing	9	9.28	13	12.62	22	11.00	0.57
Soil bund	66	68.04	89	86.41	155	77.5	9.66***
Stone bund	67	69.07	24	23.30	91	45.5	42.20***
Contour farming	97	100	101	98.06	198	99	1.90
Planting trees	22	22.68	55	53.40	77	38.5	19.90***
Planting grass strip on soil or stone bund	25	25.77	33	32.04	58	29	0.95
Cutoff drain	49	50.52	48	46.60	97	48.5	0.30
Planting biological soil conservation on soil or stone bund	77	79.38	82	79.61	159	79.5	0.00

Note: *** and ** represents significant at 1% and 5% probability level respectively.
Source: Own computation (2015)

Other Soil fertility management practices: These are use of mulching, and planting of trees. These activities are rarely used by the sample households except for planting trees. Of the total sample households during the survey period only 4% of the sample households reported to use mulching aiming at decreasing evapo-transpiration especially under the *khat* plants. The less availability of crop residue or grass hinders farmers from using mulch for soil fertility management practices.

The other activity which is undertaken by the farmers is planting trees around their plots or homesteads. Trees are planted around their homestead or around their plots; however most of the farmers plant eucalyptus trees around their homestead and their plots. Only small numbers of farmers plant leguminous trees around their farm plots or their homestead areas. Of the sample households, 38.5% of the households planted trees around their homesteads and plots. It is clearly shown that there is significance difference between the two districts in using mulching and planting trees. That is, Haromaya district sample households use both activities than Gurawa district.

C. Agronomic practices used as soil fertility management practices

There are important soil fertility enhancing agronomic practices which are undertaken by the farmers in the study areas. These are crop rotation, strip cropping, intercropping and fallowing. The use of these practices helps to maintain and improve soil fertility. However, use of these activities is constrained by different socio-economic, environmental, physical and other factors. Some of the activities are widely used, while others are rarely used by the farmers in the study areas.

Crop rotation: It is a well known soil fertility management practice that can help maintaining fertility of farm land. It is a good traditional practice that can increase productivity of the land. The use of crop rotation especially with leguminous crops is limited because of different problems. Results presented in Table 18 show that, only 7% of the sample households farmers use crop rotation with leguminous crops. Households were asked to answer the question "what is the problem that makes you not to use crop rotation with leguminous crops". Of the total sample households, 92.5% of the respondents responded that the problem of not using crop rotation with leguminous crop is mainly due to shortage of land, less importance of leguminous crops for food and less productivity of leguminous crops, especially in the lowland parts of the study areas.

The most commonly used crop rotation undertaken in the area is potato followed by maize and then sorghum. Farmers believe that crop rotation is an important strategy to increase productivity of crops that come after potatoes. This is because high amount of inorganic and organic fertilizers used by the farmers for potato production are believed to remain in the soil and increase crop productivity in the coming season. Mean proportion test show that more number of sample household in Haromaya district use crop rotation than Gurawa district.

Use of inter and strip cropping: Using inter and strip cropping are the common practices undertaken in the study areas. The two activities are accomplished to minimize the problem of shortage of cultivated land. *Khat* plant is grown on the soil bunds for home consumption and generation of the much needed liquid cash. Other crops such as maize and sorghum are planted between the soil bund and stone bund. Faba bean, field peas, and *teff* are planted between the rows of maize and sorghum crops. In Table 18 it is explained that, of the total sample households 48% and 85.5% of the respondents use strip and inter cropping, respectively. The use of the leguminous crops in terms of area coverage is very small because the leguminous crops are less drought resistant and less productive compared to maize and sorghum. Again, it is less used as the main component of food in the home. Fallowing is another soil fertility improving strategy practiced in the study areas. However, fallowing is constrained by an acute shortage of land. Given this fact, only 11% of the households were fallowing their plots to rehabilitate their degraded farm plots. Mean proportion test show that more number of sample household in Haromaya district use intercropping than Gurawa district. There is no significance difference between the two districts in using strip cropping and fallowing.

D. Soil erosion control measures

Soil erosion control measures are the important and decisive activities undertaken by the farmers in the study areas because of the land topography is undulating and fragile nature. In the study areas, soil erosion control measures were taken for two main reasons. Firstly, soil erosion control measures are undertaken to conserve the top soil from being eroded through water erosion. Secondly, soil erosion control measures are practiced to conserve rainfall water in moisture stress areas. As most of the land in the study areas is steep slope, soil can easily be eroded with simple runoff water, if not controlled. Farmers in the study area perceive that use of yield enhancing 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: Soil bund is constructed on the plots with better soil depth and free from stones and less availability of stones. Soil bund is preferred in the study areas because *khat* can be easily grown on it. It makes the activity easy to undertake different cultural practices by the farmers where soil bund is used compared to stone bunds. This activity is also undertaken where the steepness of the slope is relatively less. The amount of soil bund used increases if a plot is used for *khat* production. This is because as there are no other crops grown in between two soil bunds, the distance between two soil bunds becomes shorter. It is complained that, the disadvantage of using soil bund is its requirement for more labor cost for maintenance activity compared to stone bund. Soil bund needs maintenance after each season. It can also be damaged by runoff as opposed to stone bund, when the runoff amount is higher and the size of the bund is smaller. Results in Table 17 reveal that, on average 0.6268 kilometers of soil bund was constructed by the sample households. Chi-square test show that on average more amount of soil bund is used by farmers in Haromaya district compared to Gurawa district.

Stone bund: Stone bund is used on steeper slope and where the availability of stone is not a problem. It is preferred by the farmers because it is stable and needs less maintenance cost as compared to soil bund. It cannot easily get damaged with simple runoff, as well. Stone bund use is constrained by its high labour requirement, difficulty for construction and suitability for rodents. Table 17 depicts that, on average 0.21 kilo meters of stone bund is constructed by the sample respondent households. When we compare the districts, Gurawa district is better than Haromaya district in constructing stone bund because of better availability of stone in Gurawa district. The mean proportion test also approves the above result. The use of stone bund increases where topography is steeper and the stone availability is better.

As presented in Table 17 above, the soil and stone bund constructed by sample households per hectare of land are 1.6367 Km and 0.7867 km, respectively. The use of soil bund is higher in Haromaya than Gurawa district as more soil bund is constructed for growing *khat* and most parts of the cultivated land is not stony. However, the use of stone bund in km/ha is better in Gurawa than Haromaya district due to better availability of stones and steepness of the land in Gurawa district.

The mean comparison tests show that there is significance difference in using soil and stone bunds both in km and km/ha between the two districts. The soil and stone bund constructed by sample households is higher in km/ha than in km per household because of more structures are constructed for *khat* and steep slope plots for maximizing the benefit from plot and control runoff water effectively. The size is larger because of land holding in the study area is very small and farmers construct these structures densely on the plot they have.

Planting grass strip on bund: Grass strip makes the soil bund and stone bund stable if it is planted on or under the stone or 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. Vetiver grass is the common type of grass planted on the soil bund by the sample households. However, it is reported that planting vetiver grass makes the land unsuitable for cultivation; that is, it makes the land difficult to cultivate. Because of its unsuitability, farmers grow vetiver grass along the borders of their plots. As presented in Table 18, 29% of sample households planted grass strip on the bunds. Sample households were asked to respond to the question "what is the problem associated with planting of grass strip on their soil or stone bund". Out of the sample households 37% replied that grass strip decreases the size of the plot, 27.5% said that grass strip decreases the size of the plot and good variety of grass strip is unavailable, and 35.5% reported that grass strip decreases plot size, lack of good variety and scarcity of rain fall are the prevailing problems to plant grass strip. Mean proportion test show that more number of sample households in Haromaya district plant grass strip than Gurawa district.

Cutoff drain: Cutoff drain is another important element used by the farmers to control soil erosion. Cutoff drain is constructed by the farmers for two reasons. Primarily, cutoff drain is constructed to divert runoff from their plot that may cause soil erosion. Secondly, cutoff drain is also constructed to divert runoff to their plot because of shortage of rainfall. This structure helps sustainability of other soil erosion control measures such as soil and stone bunds. It has a problem if it is not constructed carefully and if there is no coordination when cutoff drain is constructed. Some farmers in the study area explain that cutoff drain is sometimes a source of conflict among the farmers.

Constructing cutoff drain need integration and making common waterway is mandatory to receive water coming from different cutoff drains. Results in Table 18 show that 48.5% of the sample households constructed cutoff drain to protect their farm plots. There is no significance difference between the districts in using cutoff drain.

Planting biological soil conservation measures on the bund: Planting biological soil conservation measures on bunds also improves the sustainability of the structures for longer period. Farmers in the study area use *khat* as biological soil conservation measures though the main objective is to maximize earning from farming. As shortage of land is a critical problem, planting of other species other than *khat* is limited.

In addition to scarcity of land, another possible reason is that, *khat* plays conservation role in addition to income generation. Most of the farmers in the study areas i.e. 79.5% of the sample households planted *khat* along the bund in their farm plots. There is no significance difference between the districts in planting biological soil conservation on soil or stone bund.

Other soil conservation measures: Other soil conservation measures which are undertaken by the farmers are contour farming and planting trees. Contour farming contributes more for soil erosion control. Almost all or 99% of the sample households practice contour farming. The activity is very simple, but it is an important measure to reduce soil erosion. However; ignoring this simple principle has its own negative consequence on the farm plot. 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% planted trees around their homesteads or plots. Mean proportion test show that more number of sample households in Haromaya district plant trees than Gurawa district.

4.2. Determinants of Soil Fertility Management Practices

Multivariate probit model was selected to identify the determinants of the use of soil fertility management practices decisions of farmers to maintain or enhance their plots soil fertility. The model was selected based on the justification discussed earlier in the methodology part.

As the fertility of the land has been declining from time to time and this is causing production decline, farmers in the study areas respond to this by using different soil fertility management practices such as use of inorganic fertilizer (DAP and Urea), organic inputs (farmyard manure and compost), soil and stone bunds. These practices help farmers to minimize the loss encountered by the soil fertility depletion; however there are a number of factors which influence household decision to use particular soil fertility management practice(s). This study identifies the most important determinants of decision of various soil fertility management practices using a Multivariate Probit model to provide policy information on which factors to focus and how, so as to encourage farmers to increase their use of different soil fertility management practices. Socio-economic and institutional characteristics are modeled to assess whether they have influence on household choices of the aforementioned soil fertility management options.

The result of the multivariate probit model shows that the likelihood ratio test P (χ^2) (10)>27.976 = 0.0018 of the independence of the disturbance terms (independence of choice of multiple decision in using soil fertility management practices) is strongly rejected, implying that choice of multiple options of soil fertility management practices in the study areas is not mutually independent and supporting the use of multivariate probit model. The binary correlations between the error terms of the five soil fertility management practices are presented in Table 19. Results of the correlation between the error terms on multivariate probit model indicate that some soil fertility management practices are substitutes or compete (negative sign) for the same scarce resources and some are complements (positive sign). The correlation coefficients are statistically different from zero in four of the ten cases, confirming the appropriateness of multivariate probit specification and the choice of soil fertility management practices are not mutually independent.

Results of the multivariate probit model on the determinants of choice of soil fertility management practices using data from cross sectional survey of 200 sample households are presented in Table 19. The result of the correlation coefficients of the error terms are significant on four relations indicating that they are correlated and insignificant for six pairs equations indicating that they are not correlated. The result of correlation coefficients of the error terms indicate that there is substitutability (negative correlation) in three pairs and complementary (positive correlation) in one pair between different soil fertility management options being used by the farmers. The SML estimation results suggested that there was negative and significant interdependence between household decision to use farmyard manure and compost; use of stone bund and farmyard manure; use of soil bund and stone bund. There was positive and significant interdependence between household decision to use inorganic fertilizer (DAP and urea) and stone bund.

The result of multivariate probit model shows that, the likelihood of household to use fertilizer DAP and urea, farmyard manure, compost, soil bund and stone bund were 78.25%, 72.43%, 37.68%, 77.22% and 46.04%, respectively. The result also shows that the joint probability of using all soil fertility management options was only 6.84% and the joint probability of failure to use all of the soil fertility management options was only 0.31%.

Regarding the determinants of soil fertility management practices use, the result suggest that different demographic characteristics of household, socioeconomic and farm characteristics are significant in determining the household decision to choose a given soil fertility management practice(s) (Table 19). The significant variables are discussed as follows.

Table 19: Multivariate Probit simulation result for households SFMPs decision

Explanatory variables	Use of inorganic fertilizer (DAP and urea)	Use of farmyard manure	Use of compost	Use of soil bund	Use of stone bund
	Coefficient (Std. error)	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**	**Coefficient (Std. error)**
Sex*	1.044***(0.381)	0.019(0.329)	0.807**(0.354)	0.339(0.330)	-0.366(0.299)
Age	-0.014(0.017)	-0.007(0.013)	0.014(0.011)	-0.012(0.014)	0.006(0.011)
Education level	-0.001(0.064)	-0.055(0.045)	-0.022(0.042)	-0.088(0.051)	0.017(0.041)
Household size	0.167(0.174)	0.521***(0.138)	-0.061(0.115)	0.553***(0.166)	-0.052(0.115)
Number of plots	-0.105(0.169)	0.254**(0.110)	0.036(0.097)	-0.000(0.120)	0.009(0.095)
Plot area	6.158***(1.491)	0.666(0.569)	-0.498(0.474)	0.229(0.631)	-0.016(0.482)
Average distance of the plots from the residence	-0.009(0.022)	-0.009(0.017)	-0.069***(0.018)	0.029(0.019)	-0.013(0.015)
Slope of the plot* (Flat)					
Gentle	0.312(0.122)	-0.232(0.193)	0.175(0.536)	0.0182(0.089)	-0.325(0.462)
Steep	0.431(0.331)	-0.198(0.223)	0.146(0.213)	0.478**(0.259)	-0.183(0.201)
Agro-ecology* (lowland)					
Midland	0.999**(0.412)	0.491(0.304)	-0.859***(0.285)	0.449(0.315)	-1.092***(0.265)
Highland	0.729(0.584)	0.862*(0.471)	-0.332(0.371)	0.501(0.436)	-0.467(0.363)
District*	-1.053(0.446)	-0.402(0.351)	0.706**(0.332)	-0.332**(0.369)	1.090***(0.309)
Livestock holding	0.205*(0.123)	0.313***(0.095)	0.044(0.084)	0.017(0.091)	0.013(0.076)
Extension visit	0.091(0.071)	0.051(0.055)	0.203***(0.052)	0.187***(0.059)	-0.021(0.048)
Credit utilized (ln)	0.189**(0.094)	-0.063*(0.056)	0.008(0.038)	0.046(0.048)	-0.035(0.035)
Frequency of irrigation use	0.951**(0.451)	0.669*(0.364)	-0.715**(0.317)	0.638*(0.374)	-1.020***(0.312)
Off/non-farm income (ln)	0.174**(0.073)	0.019(0.034)	-0.047(0.030)	0.079*(0.043)	-0.010(0.030)
Constant	-5.218***(1.316)	-1.664**(0.823)	-1.326*(0.720)	-3.421***(0.935)	0.960(0.698)

Table 19: (Continued)

	Use of inorganic fertilizer (DAP)	Use of farmyard manure	Use of compost	Use of soil bund	Use of stone bund
Linear prediction of each equation	1.951	0.849	-0.405	1.099	-0.124
Std .error of each prediction	0.735	0.447	0.406	0.492	0.3386
Marginal success probability for each equation	0.7825	0.7243	0.3768	0.7722	0.4604
Joint probability (success)	0.0684				
Joint probability (failure)	0.0031				
	Coefficient (Std. error)				
Rho21	-0.007(0.211)				
Rho31	-0.044(0.199)				
Rho41	-0.234(0.169)				
Rho51	0.359**(0.183)				
Rho32	-0.337**(0.136)				
Rho42	-0.185(0.182)				
Rho52	-0.406***(0.129)				
Rho43	0.027(0.181)				
Rho53	0.000(0.134)				
Rho54	-0.436***(0.135)				

Note: *** and ** represents significance at 1% and 5% probability level respectively

Number of observations	200
Number of simulations	15
Log likelihood	-410.72
Wald $\chi^2(70)$	225.98
Log likelihood ratio test of $Rh_{ij}=0$, $P> \chi^2 (10) >27.97$	0.0018

Source: MVP model output

Sex of the household: Sex of the household is an important variable to decide use of different soil fertility management practices. The result indicated that, sex positively influences the use of inorganic fertilizers (DAP and urea) at 1% significance level. The result also indicated that sex positively influences the use of compost at 5% significance level. The positive coefficient for sex variable shows that male headed households are more likely to use inorganic fertilizer (DAP and urea) and compost. The possible explanation is that female headed households have cash constraint to buy fertilizer and labour constraints to accomplish compost making. The result is consistent with finding of Endrias *et al*. (2013) and Kamua *et al*. (2013) in relation of sex and use to inorganic fertilizer.

Household size (man equivalent): Household size has significant impact on the use of soil fertility management practices to respond to soil fertility depletion. The model result reveals that, household size has positive and significant impact on the likelihood of using farmyard manure and soil bund as soil fertility management practices both at 1% significance level. The possible reason is that, large household size is normally associated with a higher labor endowment which would enable a household to accomplish various agricultural tasks which are labour intensive such as transporting farmyard manure to the outfield plots and constructing and maintaining soil bunds. Kamua *et al*. (2013) also found that mature adult (24 – 55 years) in the household showed a positive effect on the likelihood that a household uses soil amendments such as manure and compost, implying that family labor of this age group enhances the uptake of other soil amendment practices.

Number of plots: This variable has impact on the use of soil fertility management practices.
The result of the model reveals that number of plots positively affects the use of farmyard manure at 5% significance level. The reason for this is that as number of plot increase the marginal land left for grazing their livestock increases, and it also increases the opportunity of feeding their livestock and planting of grass strip on bunds of their different plots, thus this increases the possibility of having more livestock. The possibility of having more livestock solves the problem of less availability of farmyard manure. The other possible reason is that, shortage of cultivated and grazing land is the main problem because of increased population and

limited cultivable land. Thus, those farmers who have more number of plots do have more incentive than those who have less number of plots to own more livestock. However, Endrias *et al*. (2013) findings show that number of plots negatively affect use of compost at 5% significance level.

Area of plots: Area of plots is the main component of farm and it is an important variable to influence the use of different soil fertility management practices. Area of farm plots positively influence the use of fertilizer (DAP and urea) at 1% significance level. This indicates that farmers with larger plots area are more likely to use fertilizer than those who own smaller plot area. The possible implication is that to use fertilizer a farmer should have a reasonable size of plot area to cover the cost of fertilizers. Farmers with small area of plots fear the risk of shock caused by shortage of rainfall. The findings of Endrias *et al*. (2013) also suggest that the use inorganic fertilizer positively affected by farm size. Kamua *et al*. (2013) also found that the likelihood of using inorganic fertilizer increases with plot size and so does the likelihood of having soil erosion measures taken.

Average distance of the plots from residence of the household: It is an important variable to influence undertaking of different soil fertility management practices. As previously hypothesized, distance of the plot from residence of the household farmers negatively influence the use of soil fertility management practices. The result of the model indicated that, average distance of the plot from home of the residence of the household negatively influence the use of compost at 1% significance level of probability. In other ways, farmers who own farm plots near to their home are more likely to use compost than those farmers who own farm plots at distance from their home. The implication for this is, use of compost is labor intensive and this hinders the undertaking of the activities for plots at distance. Transporting inputs for making compost is labor intensive task for farmers to accomplish the activity. Mengistu (2011) also found that distance of farm plot negatively influence use of manure at 10% significance level.

Average slope of the plots: A change of the slope from flat to steeper positively affects the use of soil bund at 5% significance level. The reason behind is that as the slope of the plot increase from flat to steeper slope farmers are forced to decrease the distance between two bunds, thus this increase the number of bunds per plot. Alternatively when the slope is steeper the effect of runoff to cause soil erosion increases; this makes the farmers to respond by constructing more soil bunds per plot to reduce the effect of runoff. The finding of Yitayal (2003) is also consistent with the result of this finding. He found that the slope positively influence use of improved soil erosion control measures.

Agro-ecology: Agro-ecology is an important variable that makes farmers to select from different soil fertility management practices options. Farmers make choice to use suitable soil fertility management practices that fits to their agro-ecology. The result of the model indicated that, farmers in the midland agro-ecology more likely to use inorganic fertilizer (DAP and urea) than those farmers in the lowland agro-ecology at 5% significance level. The result of the model indicated that, farmers in the highland agro-ecology more likely to use farmyard manure than those farmers in the lowland agro-ecology at 10% significance level. The result of the model indicated that, farmers in the midland agro-ecology less likely to use compost and stone bund than those farmers in the lowland agro-ecology both at 1% significance level. The implication for these is that, farmers in the lowland are challenged by shortage of rainfall than those in the highland parts, they perceive that fertilizer (DAP and Urea) and farmyard manure causes more negative effect when shortage of rainfall occurred. Therefore, their selection is directly inclined to use of compost than fertilizer (DAP and urea) and farmyard manure. Farmers in the lowland perceive that, compost has less effect than farmyard manure and fertilizer when there is no or shortage of rain fall. Endrias *et al*. (2013) also found that, the agro-ecological location of the farm households had statistically significant and negative effect on the farmers' decision to use integrated soil fertility management at 1% level of significance. The multivariate probit model also indicates farmyard manure and compost are substitute or compete for the same resource, i.e. in making compost farmyard manure is the main input that is incorporated with other organic matters.

In the study areas, it was observed that the availability of stone is more in the lowland kebeles than in the midland, therefore farmers in the lowlands area use stone bunds than farmers in the midland areas. The availability of stone bund is more in lowland than the mid and highland areas because of land degradation; that is the top soil is washed by erosion because of steep land topography in the study areas. Endrias *et al*. (2013) also found that agro-ecological location of the household, rated from high altitude areas to low altitude areas in an ascending order, negatively and significantly influenced the use of mineral fertilizer at 1% significance level.

District: Two districts (Haromaya and Gurawa) were the selected districts for the study. The result of the model revealed that Gurawa district have more likely to use compost and stone bund than Haromaya district at 5% and 1% significance level of probability respectively. However, the result of the model revealed that Gurawa district has less likely to use soil bund than Haromaya district at 5% significance level of probability. The implication for this is that compost is more promoted organic inputs in Gurawa district than farmyard manure. Farmers in Gurawa district participate more in using stone bund than Haromaya district farmers as availability of stone is better in Gurawa district than Haromaya district.

Livestock holding: It is an important variable that influences the use of soil fertility management practices. The result of the model showed that livestock holding will increases the probability of using fertilizer (DAP and urea) and farmyard manure as soil fertility management practices at 10% and 1% significance level of probability respectively. In other words those farmers who own more livestock more likely to use fertilizer (DAP and urea) and farmyard manure than those own less number of livestock. The implication for this is that livestock is the main source of income for household next to crop production; this improves the capacity of the farmers to purchase inorganic fertilizer. Moreover livestock is the main source of farmyard manure; thus, those farmers own more livestock use more farmyard manure. Mengistu (2011) also found that livestock holding positively affect use of fertilizer. Kamua *et al*. (2013) also found that livestock holding positively influence the use of soil amendments such as mulching, application of compost, green and farmyard manure, as well as growing of legumes.

Extension contact: Extension contact is an important institutional variable that influences the adoption different technologies. The result of the model indicated that the increase of frequency of extension visit to the farmer increase the probability of using compost and soil bund both at 1% significance level probability. In other expression, farmers who got more extension contact uses compost and soil bund than those who got less number of extension contact. This implies that, making compost is somewhat technically difficult to undertake by the households and thus, those farmers who got technical support uses the activity more. The result is consistent with findings of Yitayal (2003) and Mengistu (2011).

Irrigation use frequency: It is an important variable that influence the use of various types of soil fertility management practices. The results of the model indicated that, the frequency of use of irrigation influence positively the probability of using fertilizers (DAP and urea) at 5% significance level of probability. This implies that those farmers who use irrigation more frequently use more amount of fertilizer than those use irrigation less frequently in a year. The implication for this is fertilizer application require enough amount of required water for growth. Therefore, those farmers who have access of irrigation to use irrigation several times are secured of water required for growth of crops, vegetables and *khat* and use more fertilizer. The findings of Fanus and Minjuan (2012) and Tsegaye and Berger (2006) are similar in relation to irrigation use and use of inorganic fertilizer. The result for farmyard manure is also similar to fertilizers DAP and urea use. The use of irrigation increases the probability of using farmyard manure at 10% significance level of probability by farmer households. The reason is also similar to that of fertilizer DAP and urea.

The result of the model suggests that use of irrigation decreases the probability of using compost at 5% significance level. In other words those farmers who have more accessibility of irrigation are less likely to use compost. The implication for this is that, those farmers who did not use farmyard manure use compost. It also indicated in the model that compost and farmyard manure has substitute or competing inputs. Therefore, those farmers who have no access of irrigation use compost because less effect on crop growth than farmyard manure during shortage of rainfalls.

The result of the model also shows that use of irrigation increases the probability of using soil bund at 10% significance level and decrease the probability of using stone bund at 1% significance level. The possible implication for this is that, soil bund is easier than stone bund in application of irrigation. It also implies that, those farmers who use soil bunds are more accessible for irrigation facility than those who use stone bund. Moreover these activities are used for the same objectives; that is, they can substitute each other.

Credit utilized by the household: The result of the model indicated that the credit utilized by the household increase the probability of using the fertilizers (DAP and urea) at 5% significance level. This indicates that, the use of credit increase the financial capacity of the farmer, thus it is used for purchasing fertilizer. It was also observed that those farmers who got credit were selected from the community because of their low financial capacity and credit was given for them to increase their financial ability to purchase fertilizer. Endrias *et al*. (2013) also found that farmers who have got access to sufficient credit are more likely to apply integrated soil fertility management than those who have no or limited access.

The result of the model also suggested that the credit utilized negatively influence the use of farmyard manure at 10% significance level. In other expressions, those farmers who use more credit are less likely to use farmyard manure than those who did not used credit. Farmers who have better sources of income and fertilizer inputs such as livestock have less probability to use credit for purchasing or using soil fertility management practices. Those farmers who have problem of serious cash constraint use credit and purchase fertilizer. Moreover the farmers use the two inputs in substitute each other.

Off/non farm income: Off/non-farm income is an important variable that can influence the use of different soil fertility management practices. The result of the model reveals that, off/non-farm income increases the probability of using fertilizer (DAP and urea) and soil bund at 5% and 10% significance level of probability respectively. This implies that those farmers who have engaged in non-farm income have possibility to increase their financial capacity, so that they can easily purchase commercial fertilizer and hire labor to construct and maintain soil bunds. Kamua *et al.*

(2013) also found that, off/non-farm income positively influence use of inorganic fertilizer and soil erosion control at 5% and 10% significant level of probability. The result of Odendo *et al*. (2010) is inconsistent with this finding. The result of their findings show that, off-farm income is negatively and significantly affect use of fertilizer and farmyard manure at 5% and 10% significant level of probability respectively.

4.3. Intensity of Use of DAP and Urea, Farmyard Manure and Soil Bund

SUR model measures the extent of use with respect to a unit change of an independent variable on the expected value (mean proportion) of the dependent variable. It presents the effect of marginal changes in explanatory variable on the intensity of use of selected soil fertility management practices among the users of the activity. Factors which are significantly influence the decision to use in the multivariate probit model simulation are also significant in the SUR model regression except some of the explanatory variables which are weakly significant in the multivariate probit model are insignificant in the SUR model. In interpretation of intensity only the variable commonly significant in both multivariate and SUR model was interpreted and discussed. Three of the soil fertility management practices such as inorganic fertilizers (DAP and urea), farmyard manure, and soil bund are selected because they are practiced by majority of the households. They are also selected from each of three main soil fertility management practices such as inorganic fertilizer use, organic input use and soil erosion control measures. The intensity of use three soil fertility management practices such as inorganic fertilizers (DAP and urea), farmyard manure, and soil bund which were undertaken by majority of the farmers are indicated on the Table 20 below.

Assumption for SUR model is similar to OLS estimation. Post estimation tests were performed for heteroskedasticity, multi-collinearity and omitted variable problems for SURE model using linear regression separately for three dependent variables equations. The tests of the results show that there are no problems for these assumptions for all the three equations. The results of the three tests are presented on table 20.

Use of inorganic fertilizer (DAP and Urea): The SUR model indicated that, on average male headed household used 30.64 Kg of inorganic fertilizer more than female headed household at 1% significance level sample keeping other things constant. The result is consistent with Kamua *et al*. (2013). Kamua *et al*. (2013) reported that being male headed household increase use of Nitrogen and Phosphorus fertilizer by 4.986 kg/acre and 5.267 kg/acre respectively. The SUR model also suggested that with an increase of 1 hectare of farm plot area, on average the use of inorganic fertilizer will be increased by 151.86 kg at 1% significance level keeping other things constant. This result is also similar with Endrias *et al*. (2013. The intensity of use inorganic fertilizer increases by 21.65 kg when agro-ecology changes from lowland to midland at 1% significance level keeping other things constant. The intensity of use of inorganic fertilizer increases by 16.54 kg when the use of irrigation increases by one time in a year among the users at 10% significance level keeping other things constant. The intensity of use of inorganic fertilizer increases by 1.61 kg when the farmer's non/off-farm income increases by 1% at 5% significance level keeping other things constant. This result is inconsistent with Kamua (2013).

Use of farmyard manure: The SUR model result model indicated that, with an increase of household size by one man equivalent the use of farmyard manure increase by 78.7% at 1% significance level keeping other factors constant. The use of farmyard manure increased by 43.9% when number of plot increases by one at 5% significance level by keeping other factors constant. Use of farmyard manure increases by 145.7% when agro-ecology changes from lowland to highland at 5% significance level of probability keeping other factors constant. The use of farmyard manure increase by 66.5% when livestock holding increases by 1TLU at 1% significance level by keeping other factors constant. The intensity of use of farmyard manure will increase by 95.2% when the use of irrigation increases by one time in a year at 10% significance level keeping other things constant.

Use of soil bund: Use of soil bund increases by 0.099 km when household size increased by one man equivalent at 1% significance level, keeping other factors constant. The construction of soil bund increases by 0.089 km when plot slope changes from flat to steep slope. The intensity of use of soil bund will increase by 0.05 km when frequency of extension contact increases by one at 1% significance level, keeping other factors constant. This result is also similar with Desta (2012) and Yitayal (2004). The intensity of use of soil bund will increase by 0.023 km when frequency of use of irrigation increases by one time at 5% significance level by keeping other factors constant.

Table 20: Intensity of use of Fertilizer (DAP and urea), FYM and Soil Bund on explanatory variables

Explanatory variables	**Use of soil fertility management practices**		
	Use of inorganic fertilizer (Kgs)	Use of farmyard manure(ln)	Use of soil bund (Km)
	Coefficient (S.E)	Coefficient (S.E)	Coefficients (S.E)
Sex*	30.642***(8.745)	-0.003(0.568)	0.18(0.09)
Age	0.058(0.323)	-0.018(0.021)	0.001(0.003)
Education level	0.602(1.121)	-0.021(0.073)	-0.009(0.011)
Household size	3.048(3.123)	0.787***(0.203)	0.099***(0.03)
Number of plots	-1.690(2.691)	0.439**(0.175)	0.075(0.03)
Plot area	151.863***(13.911)	1.156(0.904)	0.047(0.136)
Average distance of the plots from the residence	-0.405(0.462)	-0.028(0.030)	-0.003(0.004)
Slope of the plot (Flat)*			
Gentle	3.456(2.328)	0.001(0.246)	0.024(0.467)
Steep	1.345(0.357)	0.092(0.377)	0.089**(0.641)
Agro-ecology*(lowland)			
Midland	21.654***(7.345)	1.622(0.477)	0.033(0.071)
Highland	6.197(10.261)	1.457**(0.667)	-0.098(0.10)
District*	-11.616(8.601)	0.590(0.559)	-0.034(0.084)
Livestock holding	2.939(2.252)	0.665***(0.146)	-0.02(0.02)
Extension visit	2.034(1.371)	-0.092(0.089)	0.05***(0.01)
Credit utilized (ln)	1.125(1.061)	-0.103(0.069)	0.009(0.013)
Frequency of irrigation use	16.535*(8.713)	0.952*(0.566)	0.023**(0.010)
Off/non-farm income (ln)	1.612**(0.809)	0.038(0.053)	0.006(0.008)
Constant	-52.360(19.424)***	0.761(1.263)	-0.432**(0.189)
Observations	105	105	105
R^2 (%)	63.90%	52.32	50.57
LR ([illegible])	354.05	105.64	204.64
Ramsey test (omitted Variable test) (F-Value)	1.08	2.15	1.57
Hettest (chi2(1))	2.06	0.79	2.02
Average VIF	1.68	1.68	1.68

Note: ***, ** and * are significance of probability at 1%, 5% and 10* respectively
Source: SUR Model regression result

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary and Conclusions

Agricultural development in Ethiopia is hampered by many factors; among which soil fertility depletion is the major one, which is threatening the overall sustainability of agricultural production of the country. As soil is the base of agriculture, the livelihood of the major parts of the population is depending on soil. However, the system of utilization of soil resource has many problems. The unwise use of this resource contributes to the challenge of achieving the food security gap of the country. In Ethiopia the topography of the land is also another factor that accelerates the soil fertility depletion and land degradation. This and other social and economical factors contribute to low agricultural production of the farmers which result in vicious cycle of poverty for the farmers. To tackle the soil fertility depletion of their farm plot, farmers respond by undertaking different soil fertility management practices. However, several factors such as socio-economic, environmental and institutional factors influence the use of several soil fertility management practices. Therefore, identifying factors that influence use of these soil fertility management practices will facilitate to design appropriate policies to solve the problems at grass root level. In relation to this, this study attempted to identify the determinants of soil fertility management practices use in Gurawa and Haromaya districts of East Hararge zone of Oromia national regional state of Ethiopia.

For this study, data collected from a total of 200 sampled household heads were used. Descriptive statistics were used to assess soil fertility management practices which were undertaken by small-holder farmers in the study areas. Use of inorganic fertilizers (DAP and urea), organic inputs (FYM and compost) and soil erosion control measure (soil and stone bunds) were common soil fertility management practices which were practiced by most of the farmers. The results in descriptive statistics showed that about 78.5% of the farmers used DAP and urea fertilizers. On average, 42.54kg and 43.34kg of DAP and urea fertilizers were used by the sample households respectively. The descriptive statistics also shows that about 73% and 38% of the sampled household farmers used farmyard manure and compost respectively. On average

1054.45kg and 201.95kg of farmyard manure and compost were used by the sampled household farmers.

In addition to farmyard manure and compost farmers in the study areas were undertaken different activities which were used as soil fertility management practices. Of the total sample households about 85.5%, 48%, 37.5%, 13.15% and 7% of the farmers used intercropping, strip cropping, planting of trees, crop rotation and crop residue as SFMPs respectively.

Farmers in the study areas are also known for undertaking different soil erosion control measures. Among soil erosion control measures soil and stone bunds are the common ones. Descriptive statistics showed that about 77.5% and 45.5% of the sampled household farmers were used soil and stone bund respectively. On average 0.6268km and 0.2139km of soil and stone bunds were constructed on their farm plots by the sampled household farmers respectively. Of the total sample households, 79.5%, 48.5% and 29% used planting of biological soil conservation plants on soil/stone bunds, cutoff drain and planting grass strip on the soil bunds respectively.

The study identified the determinants of household's use of different soil fertility management practices using Multivariate Probit model. The model allows for the simultaneous identification of the all soil fertility management options used in the model, thus limiting potential problems of correlation between the error terms. The correlation between the error terms of different equations were significant indicating that various soil fertility management options tend to be used by household in a complementary or substitute fashion. For instance use of farmyard manure and compost are substitute, the farmer better select one of the activity which is very useful for soil fertility management.

The result of Multivariate Probit shows that the likelihood of the household to use fertilizer (DAP and Urea), farmyard manure, compost, soil bund and stone bund were 78.39%, 72.31%, 37.53%, 77.16% and 46.10% respectively. The result also shows that the joint probability of using all soil fertility management practices is 6.81% and the joint probability failure to use all the soil fertility options is only 0.36%. Multivariate Probit model result also confirm that sex, family size, number of plots, plot area, agro-ecology, district, livestock holding, extension contact, average distance of the plot, slope of the plot, off/non farm income, credit utilized and use of irrigation by the households have significant impact on use of different soil fertility management practices.

As a conclusion, in the study areas farmers use multiple varieties of soil fertility management practices. In participating of using of SFMPs farmers are different because of socio-economic and demographic characteristics of household heads. The level of participation of mainly used SFMPS was also different. Therefore multiple interventions are needed on significant factors such as sex of the household heads, agro-ecology, livestock holding, irrigation use, extension contact and credit of households by concerned stakeholders. Farmers in the study areas use important agronomic practices such as crop rotation, inter cropping and strip cropping along with soil fertility management practices to decline acute land shortage of land holding and to maximize the benefits from farm plot they own. Farmers in the study areas use farmyard manure intensively; however its use is constrained by shortage of livestock holding. Thus it needs more attention in solving livestock feed shortage. Multivariate probit model shows there are interdependence of the activities so that optimum usage the activities such as farmyard manure and compost should be assessed.

5.2. Recommendations

Analysis of cross-sectional survey data based on 200 sample households in Gurawa and Haromaya districts in 2014/15 showed that farmers use different soil fertility management practices and the extent of use of selected soil fertility management practices are influenced by different factors such as, social, economic, institutional and physical factors.

The results of the study provide information to policy makers and extension workers on how to improve farm level soil fertility management options and identify the determinants of soil fertility management practices. This could contribute to reduce the effects of soil fertility depletion and soil degradation and generally help agricultural production development. These findings address the need for appropriate policy formulation and implementation 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 of the country.

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 zone and the region. On the basis of the survey results the following points were suggested.

- Farmers in the study areas are 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 and which are very essential (use of grass strip, crop rotation, intercropping and strip cropping), a detail assessment of their opportunity should be made and expanded to other parts of similar agro-ecologies of the country.

- Sex of a household head positively and significantly influences the use different of soil fertility management practices. This means that male headed households are more effective than female headed households in utilizing different soil fertility management practices. Therefore, due attention should be given to female headed households in building their asset to make them effective participation in utilizing different soil fertility management practices.

- Agro-ecology ranging from highland to lowland negatively and significantly influence use of fertilizer DAP, farmyard manure and soil bund at significant level. Therefore, more attention should be given for lowland remote areas through improving basic infrastructures, irrigation facility, extension services, adopting drought resistant variety crops to increase their utilization of different soil fertility management practices.

- Livestock holding positively and significantly influence use of 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 agro-ecologies. 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.

- Extension frequency positively and significantly influence use of soil bund and compost, therefore attention should be given to improve extension service by increasing coverage and number of extension workers so that the use of the soil fertility management will be improved at farm level.

- Use of irrigation positively influence the use of fertilizer (DAP and urea), farmyard manure and soil bund. Therefore, development of irrigation schemes plays critical role to improve utilization different soil fertility management practices. All the possible opportunities should be used to increase irrigation coverage so that to better apply different soil fertility management that results in improved agricultural production.

- The use of grass strip for soil conservation measures as well as for livestock feed is constrained by shortage of rainfall, unsuitability of grass strip types which are used by the farmers. So, better variety of grass strip which is suitable in the different agro-ecologies should be adopted and distributed to the farmers.

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7. APPENDICES

Appendix Table 1: Crop production by Sample Households the districts

Type of crop	Gurawa		Haramaya		Total	
	Production in(00)kg	Production Share (%)	Production in (00)kg	Production Share (%)	Production in (00)kg	Production Share (%)
Maize	532	49.33	623	30.96	1155	37.37
Sorghum	244.5	22.67	824.5	40.98	1069	34.59
Teff	98.5	9.13	0	0.00	98.5	3.19
Wheat	83	7.70	18.25	0.91	101.25	3.28
Barley	10	0.93	0	0.00	10	0.32
G.nut	0.5	0.05	23	1.14	23.5	0.76
Coffee	16.15	-	0	-	16.15	-
Vegetables	110	10.20	523.3	26.01	633.3	20.49
Khat	17.78	-	70.03	-	87.81	-

Source: Own computation (2015)

Appendix Table 2: Conversion factors used to estimate tropical livestock unit (TLU) equivalents

Animal Category	TLU
Calf	0.25
Donkey (young)	0.35
Weaned Calf	0.34
Camel	1.25
Heifer	0.75
Sheep and Goat (adult)	0.13
Cow and Ox	1
Sheep and Goat (young)	0.06
Horse	1.1
Chicken	0.013
Donkey (adult)	0.7

Source: Storck *et al*. (1991)

Appendix Table 3: Conversion factor for computation of man and adult equivalent

Age group (years)	Man-equivalent		Adult-equivalent	
	Male	Female	Male	Female
<10	0	0	0.6	0.6
11 – 13	0.2	0.2	0.9	0.8
14 – 16	0.5	0.4	1	0.75
17 – 50	1.0	0.8	1	0.75
>50	0.7	0.5	1	0.7

Source: Storck *et al*. (1991)

Questionnaires

TITLE "DETERMINANTS OF SOIL FERTILITY MANAGEMENT PRACTICES USE BY SMALLHOLDER FARMER HOUSEHOLDS: THE CASE OF GURAWA AND HAROMAYA DISTRICTS EAST HARARGE ZONE, OROMIA REGION, ETHIOPIA"

1. General information

1.1. Name of the enumerator ___________________Signature ______ Date _______

1.2. Questionnaire number ____________________

1.3. Respondent's name __________________ Sex _____ Age _____ Signature _____

1.4. Address:(1)Woreda ________ (3) Farmers Association:_________ (4) Village ______

2. Household characteristics

2.1. Marital status (1) Single (2) Married (3) Divorced (4) Widow

2.2. How many families' members do you have at this time? ______

2.3. Religion: 1.Muslim 2.Orthodox 3.Catholic 4.Protestant 5. Other______

2.4. Educational level of the household head 1.Illiterate 2. Formal education (____ grade) 3. Other___________________________

2.5. Years of experience in farming__________________

2.6. Number of family members and structure

S/No.	Name of family member	Age	Sex 0=if female, and 1=male	Kinship (a)	Educational level
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

Code a1)Father of family 2)Mother of family 3)Children 4)Relatives 5)Other, specify

2.7. Responsibility of the household head in the society (1) Kebele's executive member (2) Religious leader (3) Edir and other social committee member (4) Ordinary member (5) Kebele's justice committee (6) Kebele's development committee (7) other, please specify

____

3. Type of land use

No	Type of land use	Area in hectare
1	Cultivated land	
2	Fallow land	
3	Grazing land	
4	Home stead area	
5	Forest (bush land)	
6	Others	

4. Description of farm plots

4.1. How many farm plots do you have? ________________

4.2. Farm plots description in specific

No.	**Description of farm plots**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**
1	Area of the Plot (ha)							
2	Types of crops grown on the year 2005/06EC (1) Teff 2) Wheat 3) maize 4) Sorghum (5) Haricot bean (5)Others___________							
3	Distance from home (walking minutes)							
4	Slope: 1if it is flat (0-5%), 2 if it is gentle (6-10%), 3 if it is medium steep (11-15%), 4 if it is steep (16-20) and 5 if it is very steep/mountainous (>20%).							
5	Plot fertility: 1) low 2) medium 3) high							
6	Color of the soil 1) red 2) black 3) brown							
7	Degree of erosion problem on the plot (1) low (2)medium (3) high							
8	Number of years since the plot is used							
9	Irrigated or not irrigated (0) if No and (1) if Yes							
10	If the answer for the question number 9 is “yes” how many times do you irrigate your plot?							
11	Number of cropping season							

5. Soil fertility management practices used on the farm plots

5.1. Types of soil fertility management used on specific plots

No.	Soil fertility management practices used on the plot	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7
	A. Have you used inorganic fertilizer in 2005/06 EC? (0) if "**No**" and (1) if "**Yes**"							
1	Have you used DAP on your plots in 2005/06EC? (0) If "**No**" and put in (Kg)if "**Yes**"							
2	Have you used Urea on your plots? (0) If "**No**" and put in (Kg) amount used in 2005/06EC if "**Yes**"							
3	Others (Kg)							
	B. Have used organic inputs on your plots? (**0**) if "**No**" and (**1**) if "**Yes**".							
1	Have you used farm yard manure in 2005/06EC? (**0**)if "**No"** put amount used in (Kg) if "**Yes**"							
2	Have you used compost in the year 2005/06EC? (**0**)If "**No**" and put amount used in (Kg) if "**Yes**"							
3	Do you use crop residue for soil fertility purpose? (**0)** if "**No**" and (**1**) if "**Yes**"							
4	Do you use crop rotation with leguminous crops on your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
5	Do you use mulching for soil fertility purpose? (**0**) if "**No**" and (**1**) if "**Yes".**							
6	Do you use green manuring? (**0**) if "**No**" and (**1**) if "**Yes".**							
7	Do you use strip cropping with leguminous crops on your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
8	Do you use intercropping with leguminous crops? (**0**) if "**No**" and (**1**) if "**Yes".**							
9	Do you use planting trees or alley cropping in/ around your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
10	Do you use fallowing**?** (1) if yes and if (0)No							
	C. Do use of soil erosion control on your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
1	Have you constructed level soil bund in your plots? (**0**) if "**No**" put in (Km) if "**Yes**".							
2	Have you constructed terracing? (**0**) if "**No**" put in (Km) if "**Yes**".							
3	Do you use Contour farming? (**0**) if "**No**" and (**1**) if "**Yes".**							

No.	**Soil fertility management practices used on the plot**	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**
4	Have you planted trees for wind break around your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
5	Have you planted grass strips on soil bunds or terracing? (**0**) if "**No**" and (**1**) if "**Yes".**							
6	Have you constructed cutoff drain to protect your plots? (**0**) if "**No**" and (**1**) if "**Yes".**							
7	Have you constructed check dam? (**0**) if "**No**" and (**1**) if "**Yes".**							
8	Have you constructed gabions? (**0**) if "**No**" and (**1**) if "**Yes".**							
9	Have you planted biological soil conservation on stone/ soil bund/terracing other than grass strips? (**0**) if "**No**" and (**1**) if "**Yes".**							
10	Who constructed the structures? (1) family labor (2) hired labor (3) community participation labor (4) Labor exchange (5) food-for -work (6) other specify_______							

5.2. Problems related to use of inorganic fertilizers

Inorganic fertilizer use	Price of fertilizer is too high	It is not provided on time	It has negative effect on plot	Problem of accessibility at nearest place	Quality and quantity problem	Specify if any other_______
DAP						
Urea						
Other						

5.2.1. Did you use inorganic fertilizer as per the recommendation rate? (**0**) if "**No**" and (**1**) if "**Yes".**

5.2.2. What is trend of inorganic fertilizer application? (1) Increased (2) Decreased (3)Remain the same (4) No comment

5.2.3. If the answer for question 5.2.1 is no, what are the reasons that affect your fertilizer use? (1) Shortage of supply (2) High cost of fertilizer (3) Transportation problem (4) Low prices of products (5) Lack of credit (6) Other if any specify

____

____

____

5.3. Problems related to use of organic inputs

Organic input use	Difficult to transport	Less availability	Less effect in increasing productivity	Used for other purposes	Negative impact on next crop season	Need further process & need more labour	Other _____
Use of farm yard manure							
Use of compost							
Use crop residue							
Mulching							

Problem related to use of organic inputs

Organic input use	Shortage of land	Less importance of leguminous crops for food	It need more labor cropping together	Leguminous have less price	Leguminous are less productive	Others problems ________
Crop rotation						
Use of green manure						
Inter cropping with leguminous crops						

Problem related to use of organic inputs (rank 1 for the worst category and 2 for less worst and so on)

Organic input use	Shortage of land	Less availability leguminous trees seed verities and seedlings	Uneasy during cultivation of land	Makes shade for crops	Others
Afforastation of leguminous trees					
Agro-forestry					

5.3.1. In general for what purpose, did you us farm yard manure? (1) Fuel (2) Soil fertility (3) for sell (4) No used yet (5) Other____________

5.3.2. For what purpose do you use crop residue? (1) for animal feed (2) For fuel (3)For construction (4) For bedding(5) For soil fertility (6) Others ___________________

5.3.3. What percentage of farm yard manure did you use for compost preparation? (1) 25 (2) 33 (3) 50 (4) 75 (5) all

5.3.4. What is your experience to improve soil fertility culturally? (1) Soil burning (2) Mulching (3) compost manure (4) Green Manuring (5) Crop rotation (6) Fallow (7) Fertilizer (8) Any other, please specify ______________________

5.3.5. If you use crop rotation, specify the rotation sequence and the crops used.

1) Rotation of seasonal sequence________,____________,__________________

2) Rotation of three years sequence ___________ ,______________, ____________

5.4. Problems related to use of soil erosion control practices

Use of soil erosion control	It will be residence for rodents	Decrease the size of the plots	Difficult to plough and turn the oxen	Take high labour force	Difficult to construct	problem related to drainage	Other ______
Level soil bund (Km)							
Terracing (Km)							
Contour farming							
Wind break							
Grass strips							
Cutoff drain							
Construction of check dam							
Construction of gabions							

5.5. What are the serious problems in your plots at present/in rank/?

Plot number	The plot is too small	Very poor soil fertility	Affected by erosion	Too far from homestead	Water logging	Difficult to plow	Shortage of moisture	Steep slope	Any other
1									
2									
3									
4									
5									

6. Agro-ecology

6.1. In what agro-ecology do you live? 1) highland (Badda) 2)Mid highland (badda dare) 3) Lowland (Gammojji)

6.2. What are the main problems in using the soil fertility management practices in general regarding agro-ecology? 1) ___________________ 2)_____________

7. Livestock holding

7.1. Livestock and poultry owned by the household

Sr. No.	Types of livestock	Number of livestock at the time of interview in the house of the respondent	Major sources of feed
1	Cow		
2	Calf		
3	Bull		
4	Heifer		
5	Oxen		
6	Sheep		
7	Goat		
8	Horse		
9	Donkey		
10	Camel		
11	Mule		
12	Chicken		
13	Honeybee 1) Traditional		
14	2) Modern		
15	Any other		

7.2. Problem related to livestock husbandry (1) Shortage in grazing land (2) Disease (3) Shortage of feed (4) Shortage of water (5) Supplementary feed (6) Clinic (7)Guard (8) Specify if there is any others ___________________________

7.3. Major sources of feed (1) Communal grazing land (2) Fallow alnd (3) Crop product (4) Purchasing (5) From own farm (6) Any other __________________

7.4. Major types of feed (1) Grazing (2) Hay (3) Straw 4) Maize and Sorghum residue (5) Atela (6) Cut-and-carry (7) any other, please specify _________________________

8. Institutional support

8.1. Did you get any practical training with regard to soil fertility management? (**0**) if "**No**" and (**1**) if "**Yes".**

8.2. If yes how many times you get training in the year of 2005/2006EC? ______

8.3. On what title you get training?________________, ________________, ________________, ______________, _______________,

8.4. Do you believe the training given is sufficient (**0**) if "**No**" and (**1**) if "**Yes".**

8.5. Do you have extension contact? (**0**) if "**No**" and (**1**) if "**Yes".**

8.6. If yes, who provides the extension service? (1) Development agent (DAs) (2) NGOs _ (3) Any others, please specify ____

8.7. On which area the advice was given? 1. Crop Husbandry 2. Crop diversification 3. Animal husbandry 4.Marketing 5.Irrigation development 6. Post harvest 7. Soil fertility management practices use 8. Other (Specify)_______

8.8. How many times did you contact DAS the year 2005/06EC?___________

8.9. How often does the extension worker visit you?
(1)Weekly (2) Fortnightly (3) Monthly (4) Quarterly (5) other, specify____________

8.10. Do you have any sources of credit? (**0**) if "**No**" and (**1**) if "**Yes".**

8.11. Did you use credit for your farming activity? (**0**) if "**No**" and (**1**) if "**Yes".**

8.12. For what purpose did you ask credit? (1) To purchase fertilizer (2) Other soil fertility management (3) To purchase improved seed (4) For sheep production and fattening (5) Oxen fattening (6)Any other, please specify ___________________________

8.13. When did you repay credit? (1) Any time (2) At the time of harvest (3) At the end of the budget year (4) Based on the credit type _______

8.14. Did you use credit for soil and water conservation? (**0**) if "**No**" and (**1**) if "**Yes".**

8.15. If no, why? (1) Source of credit (2) Interest rate (3)Absence of collateral (4) distance from credit source (5) Inconvenient term of agreement (6) No credit for this purpose (7) any other, please specify ___________________

8.16. Credit received and utilized after 2005Ec by the households

No	**Purpose**		**Amount received**	**Amount utilized**	**Source**
1	Fertilizer	DAP/urea			
2	Seed				
3	Fattening				
4	Livestock production				
5	Organic input use				
6	For soil erosion control activities				
7	Others				

9. Plot ownership characteristics

9.1. Plot ownership characteristics and ways of acquisition

Plot No	Acquisition of the plot (tenure) (a)	Year of acquisition E.C.	For how Long
1			
2			
3			
4			

(a) Acquisition (tenure) (1) Own plot/Government (2) Rent-in (3) Sharecropping in (4) Gift from some for some times(5)inherit from family or any otherbody (5) Others ____________________

9.2. Did you rent-out any of your plots? (**0**) if "**No**" and (**1**) if "**Yes".**

9.3. For what reason did you rent-out land? ____

9.4. What is the term of agreement for rented-out plot? (1) In cash (2) In kind (3) any other, please specify ______________________________________

9.5. If it is in kind, in what percent and to which plot?

	Polt___	Plot____	Plot____	Plot_____
Crop type				
Terms of agreement (a)				

Code a: - (1) 50:50 (2) 33:67 (3) 25:75 (4) Any other, please specify

9.6. How did you get the size of the land in after land distribution? (1) Increased (2) Decreased (3) Remain the same

9.7. If there is change, state the reason. (1) Decrease because the land is given to other (2) given to other as a gift (3) increase due to land redistribution or by other means (4) specify if there is any other ____________________________________

9.8. How many parcels plot do you rent-in? ______ and its total area ______

9.9. How many parcels plot do you sharecropped in? ______ and its total area ______

9.10. For which plots did you give labour and time more? (1) own (2) sharecropped in (3)rent-in (3) No difference

9.11. If there is difference, what is the reason?____________________________

10. Sources of Income

10.1. Annual income from agricultural production of 2005/06EC

A. Perennial crops and annual income of 2005/06EC

No	Type of perennial crop	Number of trees/ hectare	Unit of measure ment	Amount produced	Quantity sold (if any)	Unit price	Total value

B. Annual crops produced and annual income

No	Type of annual crop	Area (ha)	Quantity produced (qt)	Quantity sold (in qt.), if any	Unit price	Total Value

C. Livestock and poultry owned and annual income of 2005/06EC from the sale of them

No.	Type of livestock owned	Quantities	Livestock /product sold	Total income	Remark
1	Cow				
2	Calf				
3	Bull				
4	Heifer				
5	Oxen				
6	Sheep				
7	Goat				
8	Donkey				
	Types of poultry				
9	Chicken				
10	Hen				
11	Honeybee				
12	Any other				

10.2. Do you or your family member work on non/off- farm activities? (**0**) if "**No**" and (**1**) if "**Yes".**

10.3. If the answer to question 10.2 is yes, fill in the following table for the year 2005/06EC.

No	Type of off-farm (nonfarm) activity	Family members working 1)men 2)women 3)children	Total income obtained in 2005/06EC year (birr)
1	Pity trade		
2	Pottery		
3	Weaving		
4	Leather making		
5	Wood work		
6	Selling of fire wood		
7	Labor hire out		
8	Any other		

11. Marketing information

11.1. What is the distance of the local market from your house (walking minute)? ______

11.2. What is the distance of the main market from your house (walking minute)? _______

11.3. From where do you get marketing information?

1. From neighbor 2. DAs 3. Media 4) others ___________

12. Labor Availability

12.1. Do you have labour shortage for your farm activities? (**0**) if "**No**" and (**1**) if "**Yes".**

12.2. If Yes, when? ___________________________. For which activities? ____

12.3. If the answer to question to 12.1 is yes, how do you solve labour shortage? (1) Hiring labour (2) By cooperating with other farmers (Debo/Jigie) (3) if any other please specify ____

12.4. What is the average wage during 2005/06EC cropping season? (In kind ______________ in cash ____________________).

12.5. On which farm activities, do your female family members participate? (1) __________ (2) ________________ (3) _____________________ (4) ________________________

12.6. On which activities children (fewer 14 year) participate on farm activity. (1) __________ (2)______________(3) ___________________(4) ____________________

13. Perception of soil fertility of the household

13.1. Soil fertility identification by house hold

13.1.1. How do you identify soil fertility of your plot?

1) Soil depth 2) soil colour 3) soil texture 4) Productivity of the plot 5) Vegetation on the plot grows 6) slope of the plot 7) rockiness of the plot 8) specify if there is other_____________________________

13.1.2. Identify your plot and indicate the fertility level of your plot

Plot number	Degraded and out of use for crop production	Not fertile but still used for crop production	Less fertile	Moderately Fertile	Highly fertile
1					
2					
3					
4					
5					
6					
7					

13.2. What are the causes for degrade plots problems? 1)Soil erosion 2) soil fertility depletion 3) Unnecessary weed infestation 4)Less water holding capacity 5)Water lodging problem 6)Specify if there is any other _______________________________________

13.3. Did you perceive the presence of fertility decline on your plots? (**0**) if "**No**" and (**1**) if **"Yes".**

13.4. If the answer for question 13.3 is yes, what is the major cause of nutrient depletion (rank)? (1) Intensive cultivation (2) Absence or low inorganic fertilizer application (3) absence of fallow (4) Small amount or absence of organic input use (5) absence of crop rotation (6) Any other, please specify __________________________

13.5. Perception in the trend of soil depth

Trend	Plot number							
	1	2	3	4	5	6	7	8
Remain constant								
Increase								
Decrease								
No perception								

13.6. What do you think the consequences of soil fertility decline (rank)? (1) Land productivity (yield) decrease (2) Change in type of crops grown (3) Land preparation becomes difficult (4) reduced farm size (5) Poverty (6) land become out of cultivation (7) Migration (8) Others, please specify __________

13.7. Which soil fertility management practices are more effective in increasing yield of crop in the short run?

1) Use of inorganic fertilizer 2)use of organic inputs 3)use of soil erosion control 4) use inorganic fertilizer and inorganic together 5)use inorganic fertilizer and soil erosion control together 6)use organic inputs and use of soil erosion control together 7)combination of three options together

13.8. Which soil fertility management practices are more effective in increasing yield of crop in the long run?

1)Use of inorganic fertilizer 2)use of organic inputs 3)use of soil erosion control 4) use inorganic fertilizer and inorganic together 5)use inorganic fertilizer and soil erosion control together 6)use organic inputs and use of soil erosion control together 7)combination of three options together

Thank you for your cooperation!!!

Focus group discussion for farmers

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

   1.1. If yes, describe the changes now compared in the past

	Status in the past	**Status in present time**
1		
2		
3		
4		
5		

2. What indicators do you use to evaluate changes in soil fertility status? List soil fertility indicator plants?

   ____
   ____
   ____
   ____

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

   ____
   ____
   ____
   ____

4. Describe how changes in soil fertility affected crop yields – compare yields of major crops now and in the past (use table below)?

Major crop	Yield in the past (25 years ago) (q/ha)	Yield at present (last season) (Q/ha)	Reasons for the change?

5. **Farmers description and management of soils**
    5.1. How many types of soils do you recognize in your kebele?
    5.2. Can you name them (use local naming)/
    5.3. On what basis do you distinguish these soil types (document their criteria of classification)/
    5.4. Can describe these soils according to their properties (use the table below)

Local name of soil	Soil colour	Fertility status	Workability, problems, etc
a			
b			
c			
d			

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

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

Thank you for your cooperation!!!

Key informant interviews with woreda experts and stockholders

1. What are the major soil fertility management practices undertake by small holder farmers in your district?
    a. Inorganic fertilizer use
    ____
    b. Organic inputs
    ____
    ____
    c. Soil erosion control measures
    ____
    ____

1.1. Which soil fertility management practices are more effective in increasing crop yield your district in?
____
____

2. What factors hinders to use soil fertility management practices?
____
____
3. What are the major constraints and problems of soil fertility management practices use?
____
____
4. What measures was taken to solve the problems?
____
____
5. Are there any programs which facilitate improvement of soil fertility management practices other government sectors? If yes what are they?
____
____

5.1. On what activity the program works?
____

Thank you for your cooperation!!!