ASSESSMENT OF SOIL FERTILITY MANAGEMENT PRACTICES EMPLOYED BY FARMERS IN SELECTED VILLAGES OF JIMMA ZONE, SOUTH WESTERN ETHIOPIA

MSc. THESIS

BY

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Assessment of Soil Fertility Management Practices Employed by Farmers in Selected Villages of Jimma Zone, South Western Ethiopia

By

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A Thesis

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I have completed my thesis research work as per the approved proposal and it has been evaluated and accepted by my advisors. Hence, I hereby kindly request the department to allow me to present the findings of my work and submit the thesis.

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Name and signature of student

We, the thesis advisors, have evaluated the contents of this thesis and found to be satisfactory, executed according to the approved proposal, written according to the standards and format of the University and it is ready to be submitted. Hence, we recommended the thesis to be submitted.

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Decision/suggestion of Department Graduate Council (DGC)

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Chairperson, DGC **Signature** **Date**

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Chairperson, CGS **Signature** **Date**

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DEDICATION

This thesis is dedicated to my lovely mother Jije Tesgera who gave all of her life to her children, hard worker without any fed-up and passed away while I was conducting the study. Although she passed, her goodness and kindness remains in my heart forever. The thesis is also dedicated to my wife Mary Bedassa for her patience, confidence and encouragement during the study and to my child Nuharessif Abebe who was born while I was conducting the study.

DECLARATION

I hereby declare that this thesis entitled Assessment of Soil Fertility Management Practices Employed by Farmers in Selected Villages of Jimma Zone, South Western Ethiopia is my own work and no part of this thesis has been submitted to any other university. All sources of materials used for this thesis have been duly acknowledged.

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BIOGRAPHICAL SKETCH

Abebe Bobo Olana was born on 6th July, 1985 in Gimbie *district*, Western Wollega Zone of Oromia national regional state, Ethiopia. He grew up in rural village of Chuta Soddu *kebele*, and he attained his elementary school from grade 1 to 6th in Chuta elementary and senior school from 1992 to 1997. He continued his grade 7th and 8th at Biftu Gimbie elementary and senior secondary school found in Gimbie town in 1998 and 1999. In 2000 he joined Gimbie comprehensive high school and graduated with grade 10th school leaving exam in 2002. In December, 2002 he joined Agarfa Agricultural TVET College and graduated with a Diploma in Natural Resources. He worked as natural resource management experts for five years. In 2009 he got a chance of upgrading his academic career and joined Jimma University College of Agriculture and Veterinary Medicine, department of Natural Resource Management and graduated with a Bachelor of Science degree in 2011. After two years of services, he joined the same university for his MSc study in agronomy.

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LIST OF ABBREVIATIONS

AFABP	African Fertilizer Agribusiness Partnership
A-GDP	Agricultural Growth Domestic Product
CASCAPE	Capacity building for scaling up of evidence based best practices in agricultural production in Ethiopia
EATA	Ethiopian Agricultural Transformation Agency
FAO	Food and Agricultural Organization
FGD	Focus group discussion
FYM	Farm yard manure
GDP	Growth Domestic Product
IFDC	International Fertilizer Development Centre
IFPRI	International Food Policy Research Institute
ISFM	Integrated Soil Fertility Management
MLE	Maximum likelihood estimator
MOARD	Ministry of Agriculture Development and Rural Development
OLS	Ordinary least square procedures
PIF	Policy and Investment Framework
SNNPR	Southern Nations, Nationalities and Peoples Region
SSA	Sub-Sahara Africa
UNDP	United Nations Development Program
USAID	United States Agency for International Development
VIF	Variance inflation factor

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ABSTRACT

Soil fertility is one of the most important constraints of crop production in Ethiopia. There is a need to understand soil fertility management practices of farmers and the influence of socioeconomic factors on soil fertility management decisions. The study was conducted during 2014/2015 growing season. This study was conducted to document soil fertility management practices employed by farmers in Gera, Omo Nada and Limu Seka districts of Jimma zone, south western Ethiopia. Data was collected through questionnaire survey, focus group discussion and key informants at kebele level. The majority of farmers reported that crop yields are declining primarily due to declining of soil fertility along with low and erratic rainfalls. Weed infestation, pest and disease damage were also rated as the top most important agronomic factors that cause declining in crop yield. Continuous cropping, soil erosion and low fertilizer applications were the most important factors that are believed to have caused declining of soil fertility. Farmers' main strategies to maintain soil fertility include application of kosii (household refuse or waste) along with farm yard manure and mineral fertilizer applications. The rate of mineral fertilizer applied varied across households. The mean fertilizer application to maize is 88.2 kg DAP and 86.5kg urea per hectare in Gera, 91.1 kg DAP and 90.7 kg urea per hectare in Omo Nada, and 108 kg DAP and 105.7 kg urea per hectare in Limu Seka. Whereas, the mean fertilizer application to tef is 72.4 kg DAP and 17.4 kg urea per hectare in Gera, 70.5 kg of DAP and 13 in Omo Nada, and 75kg DAP and 13.4 urea per hectare in Limu Seka. The application rate to maize is roughly close to the nationally issued blanket recommendation rate of 100 kg DAP and 100 kg urea per hectare whereas to tef is far below. House demographic characteristics (labour supply), annual income and livestock ownership have significantly affected farmers' soil fertility management decisions. Construction of physical soil and water conservation is negatively correlated with headship of the household (male vs female), age, and model vs non-model farmers. On the other hand, household wealth status, family size, education level and farm size positively and significantly affected physical soil and water conservation. Wealth category and extension status of the farmers were negatively and significantly associated to vetiver or row of any other grasses, whereas farm land size and educational status associated positively and significantly. Crop residue management is influenced negatively and significantly by age, wealth category, and extension status, whereas educational status is associated positively and significant. Most commonly, male head households, richer farmers and model farmers are better of in maintaining soil fertility levels of their fields. The opposite is true for female headed, poor and non-model households.

Key words: Nutrient depletion, soil erosion, binary logistic regression, crop rotation, mineral fertilizers

1. INTRODUCTION

Agriculture is the backbone of the Ethiopian economy and special attention is given by the government to spearhead the economic transformation of the country (Urgesa and Amsalu, 2014). The sector is the main economic pillar of the country's economy, and the overall economic growth is highly dependent on the success of the agriculture sector. It represents 42% of the GDP and 85% of the population gains their livelihood directly or indirectly from agriculture (CSA, 2015). About 64% of agricultural value addition comes from crops (Global Forum on Agriculture, 2010).

Soil is the most important resource required for agricultural production **(**Khanif, 2010**)**. The most important constraint limiting crop yield in developing nations, and especially among resource-poor farmers, is declining soil fertility (Khosro and Yousef, 2012). Soil fertility is declining in many parts of Sub-Saharan Africa (SSA) (Stoorvogel *et al*., 1993). In Ethiopia, nutrient depletion is featured as one of the major causes for declining soil fertility (Fassil and Charles, 2009). Soil fertility is declining throughout the country primarily due to reduction in the length of fallow periods, lower levels of fertilizer application, complete removal of crop residues from fields, use of dung as a household fuel, and lack of adequate soil conservation practices (Eyasu, 2002). As a result, there is a growing concern that fertility depletion will seriously limit food security and sustainable agricultural production in Ethiopia (Shiferaw and Holden 2000; Bewket and Sterk, 2002).

Soil erosion is presented as severely depleting existing soil nutrient reserves, while levels of soil organic matter are declining as land is subject to continuous cropping (Lechisa *et al*, 2015). Soil erosion still remains the major challenge that is adversely affecting the agricultural performance of the country; hence, the call for improved land management practices (Woldeamlak, 2003). In terms of soil nutrients and fertility, Ethiopia is one of the countries that experiences highest rates of nutrient depletion in Sub Sahara Africa (Stoorvogel and Smaling, 1993; PIF, 2010). The estimated annual nationwide loss of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer use (PIF, 2010). UNDP (2002a) reported loss of 30kg N /ha and 15-20 kg P /ha annually. A field level investigation in southern Ethiopia found even higher rate of nutrient depletion amounting -102 N and -26 kg K particularly in the distant out fields planted to cereals (Eyasu, 2000). In Jimm Zone, decreasing agricultural productivity per unit area due to soil fertility depletion is becoming a challenge for small holder farmers (Abebayehu *et al*., 2011).

Farmers have the experience of the potential and constraints of their soils. In the process of soil fertility evaluation by local farmers from their indigenous perspective, farmers have common criteria to evaluate and identify their soils (Yifru and Taye, 2011). Abush *et al*. (2011) and; Eyasu (2002) reported that low crop yield in good season, change in soil color and thickness, reduced growth and change in crop color, and shift in weed biomass were found to be the most important soil fertility decline indicators of farmers.

Several studies have been undertaken to assess local knowledge about soils. Research in this area has predominantly focused on documenting how farmers classify their soils (Talawar and Rhoades, 1997). Ethiopia is a large country with a wide diversity of socio-economic and agro-climatic conditions and farming systems. The reliable generalized analysis of soil fertility decline, soil fertility management practices and its picture at local level need to be identified (Eyasu, 1998). Less attention has been paid to studying and understanding how soil fertility is managed at farm level, and how various socioeconomic factors influence soil fertility management. Such systems are a source of site-specific ecological information, and provide the key to understanding peoples' socio-cultural conditions (Pawluk *et al*., 1992).

Since farmers are the ultimate decision-makers and managers of their soils, understanding of farmers view and their soil fertility management practices is indispensable for exploring opportunities of improvement. Hence, farmers should be considered as a research partners for any technology generation and dissemination. Regarding soil fertility management, agricultural research and extension agents should base on the farmers' indigenous knowledge for efficient utilization and adoption of soil fertility management technologies (Yifru and Taye, 2011). Farmers' perceptions and their reaction as well as factors influencing investments in soil fertility management vary from place to place and from household to household due to variations in socio-cultural, economic and biophysical conditions (Payton *et al*., 2003; Amsalu and de Graaff, 2007).

The participation of local communities in decision making on soil fertility management is not well developed, rather decisions made at higher level have been implemented at grass root level. As a result, this top-down extension intervention approach has not been well absorbed by the farmers. In order to achieve food security in the country, it is time to shift research towards an approach based on soil fertility management that combines various existing soil fertility management practices that considers local realties. Unless efficient soil fertility management practices are designed and implemented, the productivity of the country's soils remain poor. In order to design and implement intervention actions, there is a lack of proper document of existing soil fertility management practices in the study area. As a result, proper understanding of farmers' soil fertility management practices is crucial. Against this background, the current study was carried out with the overall objective of documenting existing soil fertility management practices employed by farmers disaggregated by wealth group and extension status, and to explore the socioeconomic factors (land and livestock ownership, income, labour availability) that dictate farmers' management decisions at farm level thereby identifying areas of improvement for technical and policy intervention. This will help identify areas for improvement by way of introducing basket of options instead of blanket recommendations since options are not equally open to everyone. The specific objectives are:

- ➢ To identify and document how farmers in different settings manage their soil comparing strategies employed by rich vis-à-vis medium and poor farmers, model *vis-a-vis* non-model
- ➢ To examine how wealth endowment and extension status at household level dictate farmers' decisions on soil fertility management.
- ➢ To identify areas for improvement in farmers' soil fertility management strategies that cause nutrient depletion and need to be rectified through research and extension intervention.

2.LITERATURE REVIEW

2.1. Definition of Conceptual Terms

Soil fertility- soil fertility refers to the ability of the soil to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction in the absence of toxic substances which may inhibit plant growth (John, 2002).

Soil productivity- soil productivity is the ability of a soil to support crop production determined by the entire spectrum of its physical, chemical and biological attributes (http://www.fao.org/3/a-a0443e/a0443e01.pdf.).

Soil fertility decline- soil fertility decline is defined as the decline in chemical soil fertility, or a decrease in the levels of soil organic matter, pH, cation exchange capacity (CEC) and plant nutrients. Soil fertility decline thus includes; nutrient depletion or nutrient decline, nutrient mining, acidification and the loss of organic matter and increase in toxic elements such as Aluminium and Manganese (Alfred, 2006).

Nutrient balance - is defined as the difference between the nutrient inputs entering a farming system and the nutrient outputs leaving the system (OECD, 2016).

Nutrient depletion or nutrient mining means net loss of plant nutrients from the soil or production system due to a negative balance between nutrient inputs and outputs. Typical channels of nutrient depletion are nutrient removal through harvest, leaching, denitrification, fire, soil erosion, and runoff (Drechsel and Gyiele 1999).

Integrated soil fertility management (ISFM) - 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. All inputs need to be managed following sound agronomic principles.’ It provides an essential basis for optimizing the use of nutrients within an ISFM framework, and should be part of a holistic evaluation of cropping sustainability (Vanlauwe and Zingore, 2011).

2.2. Declining of Soil Fertility: A major Constraint on Crop Production in Ethiopia

The existence and the extent of soil fertility problem in Ethiopia are accepted without question (Abera and Belachew, 2011). Low soil fertility and soil nutrient imbalances are two of the primary limitations to increase agricultural production in Ethiopia. Dominated by small-scale agricultural producers, Ethiopia is one of the most severely eroded countries in the world. At the national level, full nutrient balance results indicate a depletion rate of 122 kg N/ ha/ year, 13 kg P / ha/ year and 82 kg K / ha/ year (Amare *et al.*, 2005).

The national average for cereals yields is still less than 2t/ha. The figure for pulse crops is generally around 0.8 t/ha. The deficiency of key nutrients such as N, P, K, S, and Zn caused declining of crop yield. An investigation also shows nutrient deficiency of boron and copper in some areas. Other soil productivity related problems include water logging, soil acidity and alkalinity. In addition, farmers' use of fertilizers is at best low (ATA, 2013). Abebe and Endalkachew (2012) reported the deficiency of N, Cu, Zn and 88% of the sampled soils have available phosphorous below the critical level. Abebayehu *et al*. (2011) reported that in Jimma zone, N, P and K added to croplands were much less than nutrients removed out of the system as a result, there is a reduction of agricultural productivity.

2.3. Causes of Soil Fertility Depletion

In the different regions of Ethiopia there are various topographic, agro-climatic, soil and socioeconomic conditions. Soil erosion, continuous cropping, inadequate fertilization, removal of crop residues and burning of cow dung for fuel purpose are the most important causes of soil fertility decline of the country (Belay, 2015). Some of these factors are discussed at some length in the forthcoming sections.

2.3.1.Soil erosion

Soil erosion remains the major challenge that is adversely affecting the agricultural performance of the country; hence, the call for improved land management practices (Woldeamlak, 2003). Compared to other east African countries, Ethiopia experiences the highest rates of soil erosion, with respect to the total available land (ATA, 2013). Most cultivated lands have been affected by erosion thereby reducing agricultural productivity, which in turn results in poor economic growth of the countries (Bekele, 2003). Ultimately, this results in abject poverty and food insecurity among the population. The continued threat to land resources is exacerbated by the need to reduce poverty and poor farming practices, especially among smallholder farmers (Lechisa *et al*., 2015).

Considering the annual rate of soil loss to erosion, USAID (2000) reported figure amounting 12 t/ha/year. The rates can be higher ranging from 250-300 t/ha/year when steep slopes and marginal lands are cultivated. The national average considering all land use types is estimated about 1.5 billion tons leading to destruction of 20, 000 – 30,000 ha of croplands. The average rate of soil loss on crop fields is 42 t/ha/year accompanied with land loss of 25,000 ha/year, of which 45% initiated from cultivated land solely (FAO, 1986; Tamene and Vlek, 2006, cited in Habtamu and Amare (2016)). On the other hand, soil loss in the highlands of Ethiopia was estimated to reach about 200–300 t/ha/year (Bewket, 2003). As indicated in Table 1, Shiferaw and Holden (1999) reported 179 t/ha/year from plot level of cultivated lands. There is a loss of 30,000 hectares annually from water erosion and more than 2 million hectares have already damaged severely (National Review Report, 2002). Such losses heavily reduce the production potential of agricultural land (Sonneveld and Keyzer, 2003).

According to Beshir and Awudenegest (2015) the mean annual potential soil loss of the Jimma Zone districts for the year 2001 was 48.1 t/ha and 60.9 t/ha for the year 2013. The authors reported that about 14.3 % of Jimma Zone fall in the very high erosion risk class (over 50 metric ton $ha^{-1}yr^{-1}$) for the year 2001 and 18.1% for the year 2013. About 21% area of the five districts of the Zone (Sekoru, Limu Seka, Dedo, Omo Nada and Tiro Afeta) fallen in to the very high erosion class (over 50 tons/ha/yr) (Beshir and Awudenegest, 2015). Less than 6% areas of Sigmo, Gera, Setema, Mana and Goma have fallen in the very susceptibility class. About 7.6 %, 8.5% and 12.2% areas of Kersa, Seka Chokorsa and Limu Kosa have fallen under a very susceptibility class (Beshir and Awudenegest, 2015). Adeba (2016) reported 31.7 t/ha/year from cultivated land in Tiro Afeta and Dedo districts of Jimma, which was generally higher than the tolerable soil loss of 2-18 t/ ha/year estimated for Ethiopian by Hurni (1985).

Table 1. Rate of soil loss by erosion at national level and in Jimma areas

National average		Jimma area (Districts)		
Rate of soil erosion (t/ha/year)	Author and year	Rate of soil erosion (t/ha/year)	Districts/Place	Author and year
42	Hurn (1993)	1.59-31.7	Tiro Afeta and Dedo	Adeba (2016)
30 – 80	Tekeste and Paul, (1989)	48.1for the year 2001	Jimma Zone	Beshir and Awudenegest, (2015)
12 but can be 250-300 on steep slopes	USAID, 2000	60.9 for the year 2013	Jimma Zone	Beshir and Awudenegest, (2015)

NB- except the report of Beshir and Awudenegest (2015) that includes all land use types the others are estimated for cultivated land.

2.3.2. Continuous cropping and inadequate fertilizer application

The combination of continuous cropping and inadequate fertilizer application are other major causes of declining of soil fertility. Continuous cropping, reduced manure application and removing animal dung for fuel purpose has reduced fertility of the soil (Yohannes, 1994; Tilahun *et al*., 2007). The continuous tilling associated with intensive cultivation has been suggested to facilitate erosion, the level of nutrients and soil physical properties (Patel *et al.*, 2009). Soil management using simple hard plough, *Maresha,* requires repeated passes and cross ploughing caused soil degradation (Bezuayehu *et al*., 2002). These are the major contributors to the loss of nutrients (Bahilu *et al*., 2014). The decline in productivity of the crops could be mainly ascribed to long-term effect of intensive cropping on the same site which gradually disturbed the balanced nutrition of the crops due to higher removal of major and micronutrients without their supplementation in appropriate quantity (Patel *et al.*, 2009).

Fallowing improves soil fertility through improving the micro-biological, chemical and physical condition of soil (Nicola *et al*., 2005). Traditionally, long fallow cycles maintained soil fertility through natural recycling of nutrients but the practice has been largely abandoned with increasing population. As a result of ever increasing population, farmers are forced to cultivate the same land continuously for years without fallow or shifting cultivation. For this reason, soils have been mined of the nutrients and the soils ability to produce high crop yield has declined (Lechisa *et al*., 2015). In many management options, such as keeping grasses in the crop rotation, returning all crop residues to the fields and cultivating no more than necessary for controlling erosion. Whenever possible using cover crops, returning all manures to the soil and adding organic materials are important sources of plant nutrients to improve soil physical and chemical properties (Campbell *et al*., 1996).

The majority of the macronutrient uptake in major cereal crops comes from soil, which is not replenished back into the soil due to the untailored formula and insufficient amount of fertilizer applied (ATA, 2013). Fertilizer use in Ethiopia started with low rates of application which was 100kg DAP and 50 kg Urea per hectare in most places. Then after SG 2000 project and the government's new extension program began recommending that farmers to use 100 kg of urea and 100 kg of DAP per hectare for all cereal crops in most areas (Mulat *et al.*, 1998). The rate of application remains low as compared to global fertilizer rate. The average rate is about 40 kg/ha (total fertilizer in kg used divided by total cultivated land in ha) (Mesfin, 2009).

Poor integrated soil nutrient management practices, ineffective use of locally available nutrient resources, inadequate soil conservation practices and high cost of commercial fertilizers became the cause for unsustainable agricultural production and food insecurity in the Jimma zone (Abebayehu *et al*., 2011).

2.3.3. Removal of crop residues

Crop residues contain large quantities of plant nutrients and, if properly managed and returned to the soil from which it was grown, could serve as an effective means of maintaining the organic matter and nutrient levels in soil. The residues of especially grain crops are often regarded as a lower quality resource. However, in the tropics where it is one of the most abundant resources it can play a major role to improve the sustainability of cropping (Tolessa, 2006). When left in the field after grain harvesting, crop residues play a significant role in nutrient cycling, soil and water conservation, maintenance of favorable soil properties, and enhance subsequent crop yields (Unger *et al*., 1991). Other benefits of retaining crop residues on the soil surface include an increase of organic matter and nutrient levels, moderation of soil temperature and increased soil biological activity, all of which are important for sustaining crop production (Powell and Unger, 1997). When all crop residues are used as animal feed or removed for other purposes, the above-mentioned soil related benefits are lost. As a result, sustaining soil productivity becomes more difficult.

Due to the increasing scarcity of traditional fuel wood resources, rural communities have shifted to utilization of crop residues and cattle dung; which otherwise, are resources for soil fertility improvement. The practice of using crop residues and cow dung for fuel has potential for consequently affecting soil nutrient stocks (Kassahun *et al.*, 2013). According to Mesfin (1998) the challenges of soil fertility maintenance in Ethiopia is related to the agronomic practices such as removal of vegetative cover, burning plant residues as practiced under the traditional system of crop production or the annual burning of vegetation on grazing lands.

2.3.4. Understanding of Farmers' Soil Fertility Management Practices

Agricultural extension services in Ethiopia have tended to be top-down and focused on technology transfer approaches (Teklu and Gezahegn, 2003). The technology transfer approach also tended to be top-down and rely almost exclusively on research station based standard recommendations often neglecting taking part in decision making of rural livelihoods and socio-economic diversities at local level (Mekuria, 2015). Long established blanket recommendation rates of 100 kg DAP and 100 kg Urea still apply for cereal crops regardless of soil nutrient reserves, differences in crop need and agro-ecology. In addition to commercial fertilizer application, organic amendments in the form of farm yard manure and green manure or these processed in the form of compost have always been used by Ethiopian smallholder farmers to enhance fertility and soil physical properties (Mesfin, 2009).

For the improvement of soil fertility, both indigenous knowledge and improved soil fertility management should receive considerable attention. Improving farmers' knowledge, and their capacity to observe and experiment, is an essential element in the development of ISFM technologies (Deugd *et al.,* 1998). It is important to build on local systems of knowledge, as they relate to specific locations and are based on experience and understanding of local conditions of production. Many development projects and policies have collapsed because of a failure to understand local practice (Schoonmaker-Freudenberger, 1994).

Kraaling is one of the commonly used soil fertility management approach in most parts of Ethiopia. Kraaling refers to the process of keeping cattle at night and rotating the position of the barn regularly in order to uniformly distribute manure to crop fields. In this case, not only manure, but also urine that is with high N content is distributed. Even though farmers are interested to practice kraaling, herd size is a necessary condition to practice it (Tekilu and Gezahegn, 2003). Cattle spend the nights in the barn and they drop manure and urine in the barn. The barn rotates to new plots after 3 to 7 days depending on the season, crops to be planted and density of the herd. Longer kraaling is exercised during the dry seasons. For heavy feeder crops, such as maize, sorghum and potato, longer kraaling are required. Shorter kraaling is often exercised during the rainy season for *tef* and other small cereals. Since grazing lands including crop stubbles are communal, a farmer with larger herd size benefits more through kraaling. Kraaling avoids the major problems of transportation and distribution of manure, which is one of the major constraints of manure use in the other parts of the country. In East Shoa for instance, use of manure is limited to backyard mainly due to the problems of transportation and distribution as well as its limited availability since it is used as fuel. The other advantage associated with this practice is that crop residues and other herbs can easily be incorporated. Hence, in addition to soil fertility improvement, weed is also well controlled (Tekilu and Gezahegn 2003).

Smallholder farmers cultivate different crops in the home garden as the strategy of livelihood diversification which helps to stabilize their sustenance (Abebe *et al.*, 2010). Since home garden has a mixture of perennial and annual plant species, arranged in a multi-layered vertical structure it plays a great role in soil fertility management. Small holder farmers in south western Ethiopia have experiences of home garden agroforestry for ages (Bishaw, 2009; Abebe *et al.*, 2010). A study undertaken by Zerihun *et al.* (2011) around Jimma reported that about 94% of households have home-garden. Soil fertility management of home-gardens is largely recycling and organic based and home gardens tend to be good in soil fertility (Kumar, 2006).

2.4.Socioeconomic Factors that Dictate Soil Fertility Management Decisions

Survey conducted by Yitayal *et al*. (2004) in Dedo district, Jimma zone showed that a host of factors influences farmers' conservation decision and extent of use of both improved and traditional soil conservation measures. The level of formal education in the household is an important variable affecting the probability and intensity of using improved soil conservation technologies. This underscores the importance of human capital development in increasing the probability and intensity of using soil conservation technologies (Yitayal *et al*., 2004). According to Kidane *et al*. (2014) education level of household is positively and significantly associated with use of stone bund and soil bund. This could be attributed to the fact that household heads with relatively better formal education are more likely to use appropriate SWC practices and they also able anticipate the consequences of soil erosion than non-educated farmers. In addition, they have better understanding of their environment and risk associated with cultivation of marginal lands.

According to Lechisa *et al.* (2015) shortages of livestock per house have led to a decline in traditional soil fertility management practices. This will have substantial effects on soil fertility, unless farmers use other measures to add nutrients to their soils. Household use of inorganic fertilizers however is determined by their capacity to meet the increasing inorganic fertilizer prices. However, over the years, fertilizer prices have become costly for smallholder farmers, making it difficult for farmers to apply the recommended rate, annually at the appropriate time. Therefore, farmers continue to cultivate on the same plots year after year leading to continued decline in soil fertility production. This indicated that economic status of the farmers can limit them to apply inorganic fertilizers (Lechisa *et al*., 2015).

Age of household head has also an influence on soil fertility management practices (Yitayal, 2004). Million and Kassa (2004) and Derajew *et al*. (2013) reported the negative association of age with physical soil and water conservation. Older farmers may be reluctant to adopt technologies easily than young farmers. Younger farmers were found to exert more effort on improved soil conservation methods. Thus, the effect of age of the farmer on conservation decision to use soil conservation technologies may be positive or negative (Lapar and Pandey, 1999; Bekele and Derake, 2003). Mugwe *et al*. (2009) reported that age of the household head negatively influenced adoption of soil fertility management at 5% probability level implying that younger households had a higher probability of adopting the soil fertility management technologies than the older households.

According to Million and Kassa (2004) farm land size has a positive and significant influence on the farmers' decision to adopt physical soil conservation measures. Since larger farms are associated with greater wealth and increased availability of capital, which increase the probability of investment in soil conservation measures. Adoption of soil conservation measures is significantly and positively associated with the number of economically active family members. Due to the fact that large number of active agricultural workers are more likely to invest in soil conservation measures, which are known to be labor intensive. The number of economically active family members, farm size, family size; wealth status of the farmer influences the adoption of physical soil and water conservation measures (Million and Kassa, 2004).

According to Endrias *et al*. (2013) a change in sex of household head from male to female reduces the probability to use integrated soil fertility management by 19%. Sex of the household head negatively influenced the use of mineral fertilizer at less than one percent level of significance. Thus, female-headed households are less likely to use mineral fertilizers, as compared to male-headed households. This could be due to the low risk bearing capacity of female-headed households, resulting from their meagre resource positions and cash constraints they face to purchase mineral fertilizer. The use of farmyard manure was highly influenced by the sex of the household head at less than one percent level of significance. The negative relationship between the probability of farmyard manure use and the sex of the household head suggests that female-headed households had lesser labor required to transport farmyard manure for maize production which is usually located in the outfield. This limited labor supply was a major production constraint of female-headed households. Furthermore, farmyard manure use is restricted to the availability of livestock. As a result, the low livestock holding of female-headed households inhibited their use of farmyard manure (Endrias *et al.*, 2013).

2.5. Soil Fertility Management Practices and Policies in Ethiopia

According to ATA (2013) massive land rehabilitation and natural resource conservation efforts (sustainable land management), scaling up best practices such as; improved vertisol management, acid soil management, compost use by farmers, introduction and testing of new fertilizers, integrated soil fertility management practices, soil fertility mapping of agricultural lands and blended fertilizer program are on progress. Manure is an important input for maintaining and enhancing soil fertility. The use of animal dung, ash and household trash to crop land is common practice to improve soil fertility.

In 2010, the Ethiopian government launched a land restoration program that aimed to double agricultural productivity through improving the management of natural resources and agricultural lands (Wolde *et al*., 2016). Following the launch of the program, the regional bureaus of agriculture, district offices of agriculture, and other local administrative bodies mobilized farmers to carry out soil and water conservation (SWC) measures on priority watershed. Since 2010, more than 15 million people have contributed free labour equivalent of US$750 million each year. Physical and biological SWC measures have been introduced in more than 3,000 watersheds managed by local communities (Wolde *et al*., 2016). According to the Gera district agricultural development office 10, 826 ha of land covered by physical soil and water conservation practices and planted by 998, 718 seedlings. Similarly, according to the districts agricultural development office, in Omo Nada and Limu Seka 12, 270 and 15, 020 ha of land covered by physical soil and water conservation practices and planted by 862, 923 and 714, 369 seedlings respectively.

In 2008, an agreement was signed with donors to implement the sustainable land management (SLM) program in six regional states; Amhara, Oromia, SNNPR, Tigray, Gambella and Benishangul Gumuz. SLM is one of the major conservation initiatives of the Ethiopian government, which is primarily intended to combat land degradation, protect natural resources and restore soil fertility in the country. In addition to these different projects and NGOs are participating on soil fertility managements. In 2012, the government started to implement mass watershed management practices with the participation of the communities that promote soil fertility management of the country (Akililu, 2015).

Hence, poverty reduction and achieving food security is among the prime policy agenda of the Ethiopian government, the government strongly believes in the potentials of raising the productivity of smallholder agriculture through intensive use of inputs (mainly improved seeds and fertilizers), and agricultural extension services. National policies emphasize on these key objectives and the strategies are intended to realize them. However, a key question in this regard is to what extent existing policies and strategies have focused on abating soil degradation and enhancing soil fertility (Akililu, 2015). Emphasis has been given to increased soil fertility amendments and reversing soil degradation. Increased use of chemical fertilizers and compost are the most important strategies planned to maintain soil fertility. Over the past years, the country has been investing in the establishment of soil testing centres and laboratories. A number of soil laboratories have been established in most of the regions in addition to the national soil laboratory (Akililu, 2015).

3.METHODS OF THE STUDY

3.1.Description of the Study Area

The study was carried out in Gera, Omo Nada and Limu Seka districts in Jimma zone of Oromia regional state, south western Ethiopia in the 2014/15 crop season. The study covered two *kebeles* per district and 232 households. These were Ganji Chala and Wanja Kersa of Gera district, Doyo Yaya and Nada Bidaru of Omo Nada district, and Seka and Dora of Limu Seka district. The districts and the *kebeles* were purposively selected following the intervention sites of CASCAPE project under Jimma University. Figure 1 presents the location map of the districts within the Jimma zone. Gera district is bordered by Goma and Ginbo districts to the south, by the Sigmo district to the west, and Gumay district to the north (CASCAPE, 2014). Geographically, it is located $7^0$40'N 36^0 15'E latitude and longitudes (Wikipedia, 2014). According to Gera district agriculture development office, the district covers an area of approximately 112,212 ha and comprises 24 *kebele*.

Limu Seka district is situated 109 km and 455 km from Jimma town and Addis Ababa respectively. It is bordered by Yaanfa district to the west, Limu Genet to the north, Noono Benja district to the south and Choora Botori district to the east (CASCAPE, 2014). Geographically, it is located $8^0$20'N 37^0 00'E latitude and longitudes (Wikipedia, 2014). According to Limu Seka district agricultural development office, the district covers an area of approximately 169,400 ha and divided into 19 *kebeles* (CASCAPE, 2014). Omo Nada is bordered by Gojeb River to the south which separates it from the Southern Nations, Nationalities and Peoples Region (SNNPR), by Dedo to the west, by Kersa to the northwest, by Tiro Afeta to the north, by Sokoru to the north, and by the Omo river to the east which separates it from the SNNPR. Geographically, it is located 30'N 37^0 15' latitude and longitudes. According to the district agricultural office, Omo Nada covers an area of 165,602.66 ha.

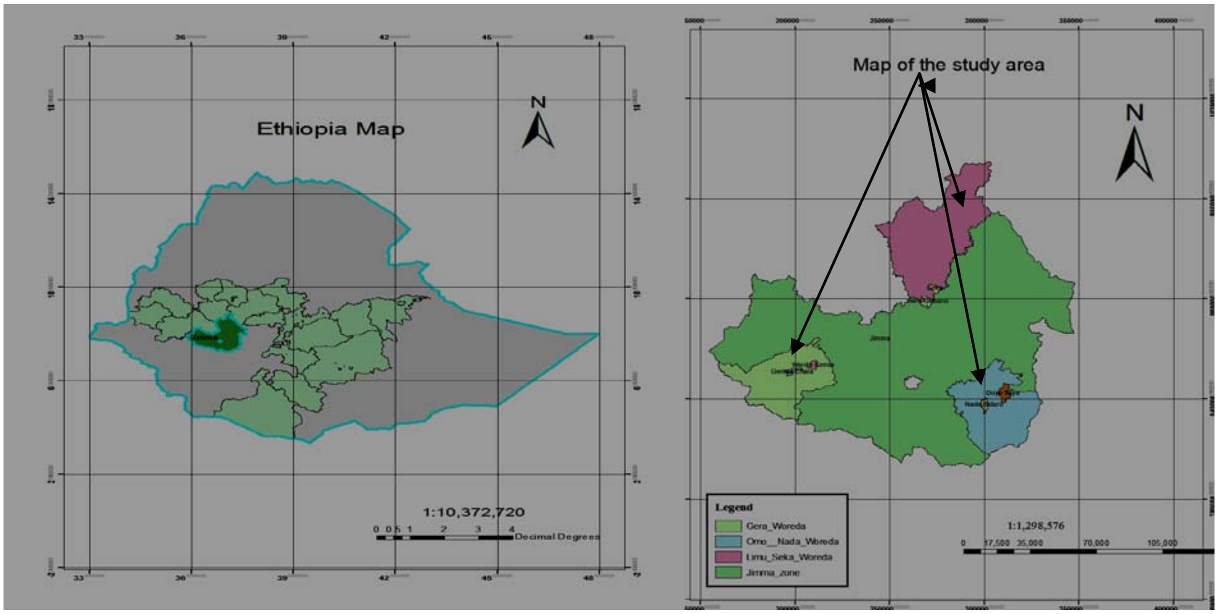

Figure 1.Location Map of the study area

3.2.Agro-ecology and Farming Systems of the Study Area

Most parts of Gera district fall within wet *dega* whereas most parts of Omo Nada and Limu Seka is wet *woyna dega*. The agro-ecology and some basic information of the study area is summarised in the (Table 2). The total area under coffee of the district is 80,830 ha and of this 2014 ha is forest coffee, while 21,733 ha are under other crops. In this district, livestock is a source of income, essential for crop production, and for food consumption (CASCAPE, 2014). Of the total land coverage of Omo Nada district about 48,984 hectares are currently covered by forest and grazing land, while 94,725 hectares are used for crop production. About 19, 375 ha are swampy, degraded or otherwise unusable. The remaining 2518ha is covered by homestead agroforestry, construction and others. Limu Seka's potential for agriculture is estimated to be around 42,704 ha of land. In terms of cereal crops, sorghum covers 21,538 ha and maize covers 1,266 ha. About 10, 241 hectares are currently covered by forest and bush, the rest land are covered by coffee, homestead agroforestry and other land use types.

Table 2. Basic data and basic information of the study area

Back ground information	Gera	Omo Nada	Limu Seka
Agro ecology (%)			
-SM2	50.2	23	13
-H2	46.1	62	55
-SA1	3.7	15	32
Mean annual RF (mm)	1414-2256	1280 - 2584	800 - 1822
Mean annual temperature (C^o)	10.3-27	25-33	11.9-31.9
Altitude (masl)	1500 – 3200	880-3344	1400 – 2200
Population	132,238	248,173	189,463
Major crops grown			
-food crops	Maize, sorghum and *tef*	Maize, *tef*, sorghum, wheat and barley	Maize, sorghum and *tef*
-income generating crops	Coffee and *chat*	Pepper, maize and *chat*	Coffee, maize and sorghum

Source CASCAPE (2014); MOA, (2011) and own computed data, (2015).

Where, SM2 = is tepid to cool sub moist mid highlands, H2 = tepid to cool humid mid highlands and SA1= hot to warm sub moist lowlands.

According to Gera district agricultural development office, the total land coverage of *Ganji Chala* and *Wanja Kersa* is around 992 and 3220.02 hectares, of these cultivated lands covered 992 and 1011 hectares while coffee covered 892 and 892.47 ha, respectively. Maize, *tef*, sorghum and millet are major crops of *Ganji Chala* and *Wanja Kersa*. Next to coffee, honey production and livestock are the most important income generating activities for the majority of the farmers. The total land coverage of *Doyo Yaya* and *Nada Bidaru* is 4593.18 ha and 2214.3 ha, respectively. Out of the total land coverage of *Doyo Yaya* and *Nada Bidaru*, cultivated land accounts for 2537ha and 1223.45ha; forest land accounts for 287 ha and 138.39 ha; grazing land accounts for 1141.4 ha and 550.27 ha, settlement land accounts for 255 ha and 123 ha, respectively. The rest land is covered by home garden agroforestry, construction and others. Maize, *tef*, sorghum and wheat are major crops of *Doyo Yaya* and *Nada Bidaru*. Pepper, *chat* and maize are important income sources in the study *kebeles* of Omo Nada.

The total land coverage of *Dora* and *Seka* are around 3,500 and 2,500 hectares respectively. Out of these cultivated land covers 1200 and 700 hectares while the forest covers 40 and 785 hectares respectively. Maize, sorghum and *tef* are major crops whereas coffee and maize are the dominant income generating agricultural crops of the *kebeles.*

3.3.Source of Data and Data Collection Method

Household survey, focus group discussions (FGD), key informant interviews using checklists, personal observation and semi-structured questionnaire (both open and closed ended) were the tools used to collect primary data (Appendix I-III). Secondary data were collected from *kebeles*, districts agricultural development office and CASCAPE project working papers. The FGD were composed of 10-12 members at each *kebeles* representing wealth, extension status and sex groups. The FGD covers change in crop yield and its causes, perception of soil fertility and soil fertility status, soil fertility management practices and factors influencing the practices.

In order to explore how soil fertility management practices varied across different socioeconomic groups of farmers, a stratified random proportional sampling method was followed. Following this the total farmers of the study area were categorized by sex (male and female), extension status (model and non-model), and wealth group (rich, medium and poor). Participatory wealth ranking using local criteria set by the community (Grandin, 1988 cited in Robin *et al.*, 2001) was followed to group the farmers in wealth group. In order to undertake the stratification effectively the list of all households (land holders) was obtained from each of the *kebele's* administrative office and male and female households were identified. The total households of the study area were 4, 025, of this 3764 (93.52%) of them were male and the rest 261 (6.48%) were females.

The key informants who composed from 8-12 members are selected by the local elders and local leaders based on the assumption that they can categorize the farmers by wealth and extension status. The key informants set criteria of wealth group by using local wealth indicators to differentiate the households into rich, medium and poor wealth groups. Accordingly, in Ganji Chala and Wanja Kersa *kebeles* farmers who have a good house/s from corrugated iron in town and/or in rural, kitchen room, house for animals, greater than or equal to three 3 ha of coffee, greater than or equal to 1ha farm land, five or greater than modern beehives, greater or equal to 200 cultural beehives, two or greater than two oxen, and greater than or equal to 4 cows is said to be rich. Farmers who have house from corrugated iron, kitchen room, 1 ha farm land, 0.5-1 ha coffee, 1- 4 modern beehives, 100-150 cultural beehives, 1-2 oxen, 2-3 cows are said to be medium wealth group. Farmers who have house from corrugated iron or grass roofed, 0-0.25 ha coffee, 0.125-0.5 ha farm land, 0-50 cultural beehives, 0-1 ox, 0-3 small ruminants and 0-5 poultry were poor wealth group.

In Doyo Yaya and Nada Bidaru rich farmers owned good house from corrugated iron, house for kitchen and animals, farm land greater than or equal to 4 ha, greater than 3 oxen, greater than 3 cows, greater than or equal to 1 horse and greater than or equals to 20 quintal cereals. Medium farmers owned medium house from corrugated iron roof, house for kitchen and/or animals, 1-2 ha of farm land, greater than or equal to 1 oxen, greater than or equals to 3 cows, 0-0.25 ha of chat, and 10-15 quintals of cereals. Poor farmers owned house from corrugated iron or grass roof, less than 1ha of farm land, 0-2 oxen, 0-1 cow, and 0-2 small ruminants.

In Limu Seka, farmers who have good house from corrugated iron, kitchen room and/or house for animals, farm land greater than or equal to two ha, greater than or equal to two ha coffee, greater than or equal to 20 quintals of cereals, greater or equals three oxen, greater or equals to four cows are said to be rich farmers. Medium farmers have medium house from corrugated iron, kitchen room, 1-2 ha of farm land, 0.5-1 ha of coffee, 1-2 oxen, greater or equal to 3 cattle, 10-20 cereals in quintals. Poor farmers have house from corrugated iron or grass roof, less than 1ha farm land, 1 or no oxen, less than 2 cattle, 0-2 small ruminants, and 0-5 quintals of cereals.

The questionnaire was focused mainly on the socio-economic aspects, physical and agronomic practices of soil fertility management practices employed by the sample households. The socio-economic aspect includes household wealth status, extension status, ownership of livestock, number of economically active family members, and area of cultivated land per household which are crucial on farmers' soil fertility management decisions. The physical and agronomic aspects essentially were focused on the current soil fertility management practices employed by the farmers of different social groups. These include the use of mineral fertilizers, farmyard manure, compost, crop residue management, crop rotation, fallowing, physical and biological soil and water conservation measures and soil amendments. Preliminary test of the questionnaire was undertaken to check its validity and necessary corrections were taken place.

Table 3.Stratification of sex, wealth category and extension status of the total households

District	*Kebele*	Number of households in the all strata									
		Sex			Wealth status				Extension status		
		M	F	Tot	R	Med	P	Tot	Mod	NM	Tot
Gera	GCh	399	25	424	102	169	153	424	153	271	424
	WK	623	37	660	69	295	296	660	156	504	660
Omo Nada	NB	580	27	607	87	243	277	607	121	486	607
	DY	988	59	1047	105	645	297	1047	227	820	1047
Limu Seka	Seka	518	36	554	104	277	173	554	156	398	554
	Dora	656	77	733	209	297	227	733	244	489	733
Total		3764	261	4025	676	1926	1423	4025	1057	2968	4025

Source: Own survey data, 2015

Where GCh = Ganji Chala, WK = Wanja Kersa, DY= Doyo Yaya, NB = Nada Bidaru, M = male, F = female, R = rich, Med = medium, P = poor, Mod = model, NM = non-model and Tot = total.

The key informants who claim to know each and every household in every neighbourhood were grouped according to their wealth category following the above criteria. In response to this 676 (16.80%) of them were rich, 1926 (47.85%) and 1423 (35.35%) of them were medium and poor, respectively (Table 3). Based on adoption of agricultural technologies, the extension status of the farmers was already categorized by the *kebeles* office of agriculture. According to this 1057 (26.26%) of them were models and the rest 2968 (73.74%) were non-models.

3.4.Sample Size

The sample size was determined by applying probability proportional formula (Cochran, 1977).

Sample size, $n_\circ = Z^2pq/e^2 = \; n = \frac{n_\circ}{1+\frac{n_\circ - 1}{N}}$

$= (1.96)^2(0.2)\,(0.8)/\,(0.05)^2 = 246 \longrightarrow \frac{246}{1+\frac{246-1}{4025}} = \underline{232}$

Where;

n^o = desired sample size Cochran's (1977) when population greater than 10,000

n = finite population correction factors Cochran's (1977) formula less than 10,000

Z = standard normal deviation (1.96 for 95% confidence level)

P = 0.2 (proportion of population to be included in sample *i.e.*, 20%)

q = is 1-P *i.e.*, (0.8)

N = is total number of population

e = is degree of accuracy desired (0.05)

Based on Cochran (1977) population correction factors, 232 households were drawn from the stratum. The proportionate formula was used to draw sample sizes from the *kebeles* and from the stratum by applying (A/B) ×C and (A'/B') ×C' formula respectively (Hunt *et al*., 2001).

Where,

A = Total households in a given *kebele*

B = Total households of the study area (*i.e.*, 4025)

C = Total determined sample households (232) at *kebele* level

and

A' = Determined sample size in a given *kebele*

B' = Total households in that *kebele*

C' = Total number of households in that strata

Accordingly, 63 of them were drawn from Gera (Ganja Chala = 25and Wanja Kersa= 38), 95 from Omo Nada (Nada Bidaru = 35 and Doyo Yaya = 60) and 74 from Limu Seka (Seka = 32 and Dora = 42).

3.5.Socioeconomic Profile and Strata of the Respondents

Out of the total respondents, 218 (93.97%) of them were male headed households and the remaining 14 (6.03%) were female headed households. Among the respondents, 111 (47.85%) of them were medium, and the rest 82 (35.35%) and 39 (16.81%) of them were poor and rich respectively. Concerning the extension status of the farmers 171 (73.71%) and 61 (26.29%) of them were non-model and model households respectively. Sample size drawn from the *kebeles* and the strata are illustrated in (Table 4).

Table 4. Summary strata of the sampled households

District	*Kebele*	Number of sampled households in the all strata									
		Sex			Wealth status				Extension status		
		M	F	Tot	R	Med	P	Tot	Mod	NM	Tot
Gere	GCh	24	1	25	6	10	9	25	9	16	25
	WK	36	2	38	4	17	17	38	9	29	38
Omo	NB	33	2	35	5	14	16	35	7	28	35
Nada	DY	57	3	60	6	37	17	60	13	47	60
Limu	Seka	30	2	32	6	16	10	32	9	23	32
Seka	Dora	38	4	42	12	17	13	42	14	28	42
Total		218	14	232	39	111	82	232	61	171	232

Source: Own survey data, 2015

Where GCh = Ganji Chala, WK = Wanja Kersa, NB = Nada Bidaru, DY = Doyo Yaya, M = male, F = female, R = rich, Med = medium, P = poor, Mod = model and NM = non-model and Tot = total.

Out of 63 respondents from Gera district 60 (95.24%) of them were male and the remaining 3 (4.76%) of them were female. In terms of their wealth group, about 10 (15.87%) of them were rich, 27 (42.86%) and 26 (41.27%) of them were medium and poor, respectively. Among the respondents of this district 18 (28.57%) of them were model and 45 (71.43%) of them were non-model farmers. Of the 95 respondents of Omo Nada district 90 (94.44 %) of them were male and 5 (5.56 %) of them were female headed households. Of the total respondents of this district 11 (11.58 %) of them were rich, 51(53.68 %) of them were medium and 33 (34.74 %) of them were poor. In terms of their extension status, 20 (21.05 %) of them were model and 75 (78.95 %) of them were non-model farmers. Out of the 74 respondents from Limu Seka District 68 (91.89 %) of them were male and 6 (8.11) of them were female headed households. With regard to the wealth group, 18 (24.32 %) of them were rich, 33 (44.59 %) and 23 (31.08 %) of them were medium and poor, respectively. Among the respondents of this district 23 (31.08 %) of them were models and the rest 51(69.92 %) were non-model farmers.

3.6. Statistical Analysis

The data were subjected to SPSS version 20 and STATA version 13. Descriptive statistics such as, mean, frequency, and graphs were used to present the out puts of the analysis. The overall rank of the causes of crop yield decline, declining of soil fertility and other ranking was determined by calculating the total points *i.e*., multiplying the rank frequencies by the relative weight of each rank (1st rank= 4 points, 2nd rank= 3 points, 3rd rank= 2 points, and 4th rank = 1 points) and the total points for each cause are summed up to get total points. Chi square test was used to determine the significance differences among wealth group and among extension status of the soil fertility management practices. Binary logistic regression model was used to determine factors affected soil fertility management practice.

3.7. Multicollinearity Diagnosis

Prior to running the logistic regression model, variables were checked for the existence of multi-collinearity problem. The problem arises when at least one of the independent variables is a linear combination of the others. The existence of multi-collinearity might cause the estimated regression coefficients to have the wrong signs and smaller t-ratios that might lead to wrong conclusions (Gujarati, 2003). The technique of variance inflation factor (VIF) was employed to detect the problem of multi-collinearity among the variables. As a rule of thumb, if the VIF of a variable exceeds 10, there is a multi-collinearity problem. Based on the VIF results, the data were found to have no serious problem of multi-collinearity since the value of VIF were much less than 10 (Appendices Table 1 and 2).

3.8. Definition of variables and specifications of working hypotheses

3.8.1. Independent variables

Sex- this is a dummy variable that assumes a value of "1" if the head of the household is male and "0" otherwise. It was hypothesized as male households can perform soil fertility management practices more than female households especially for physical soil and water conservation practices.

Age - it is a continuous variable and defined as the age of household at the time of interview and measured in years. Due to the inabilities of older farmers to practice physical soil and water conservation, it was hypothesized that younger farmers may have more chance to apply physical soil and water conservation and other soil fertility management practices. So, that age of the farmers can affect negatively the physical soil and water conservation practices.

Wealth status of the farmers - it is a categorical variable that is categorized as rich (economically best), medium (economically better) and poor (economically low) based on the local criteria set by the key informants of the study area. Being better in wealth status could positively associate with soil fertility management practices.

Extension status of the farmers - it is a dummy variable that assumes "0" for non-model farmers and "1" for model farmers, and the being a model could influence positively soil fertility management practices.

Economically active family members - refers to the total number of family members of the household who have the potential to work. The larger the number of family labor, the more the labor force available for some soil fertility management practices. So, that labor availability in the house hold may influence positively some soil fertility management practices.

Educational status - refers to the educational status of the household head taking a value of 1 for illiterate households, 2 for read and write, 3 for grade 1-8 and 4 for high school and above. This is a proxy for the capacity of the head of a household to access and understand technical aspects related to soil erosion and soil conservation. Educated farmers can understand, analyze, and interpret the advantages of new technologies easily than uneducated farmers. Paulos (2002) and Yitayal (2004) found a positive relationship between education and the decision to use conservation measures. Therefore, farmers who are better in educational status are expected to have more likely hood to practice soil fertility management.

Land size - land is one of the most important factors that determine the level of agriculture. It is a continuous variable that measures the specific land size of the individual farmers. The hypothesis is that the larger the land sizes the better the soil fertility management practices.

3.8.2.Dependent variables

The dependent variables for the logit analysis are of dichotomous nature representing small holder farmer's practices of soil fertility management measures. This is to distinguish or discriminate between those farmers who are employing soil fertility management measures and not employing.

Intercropping- it is dummy variable that assumes "1" if the farmers employed cereal/legume inter cropping and "0" if not. According to Tamiru (2014) cereal/legume intercropping systems reduces the depletion of nutrients from the soil as compared to sole crops and increases N and C content of soils. So, that it is hypothesized as farmers who employ it are keeping their field fertility than others.

Contour ploughing - is a practice of tilling the land along the contours of the slope in order to reduce the runoff on a steep sloping land and it is dummy variable that assumes "1" if the farmers employed it and "0" if not. It is used separately or in combination with other conservation structures such as plantation trees and cut-off drains (Mushir and Kedru, 2012). It is a dummy variable which received "0" for not practiced and "1" for farmers who were practiced it.

Physical soil and water conservation measures- it is dummy variable that assumes "1" if the farmers employed it and "0" if not. Physical soil and water conservation measures are structures built for soil and water conservation by considering some principles that aimed to decrease run off and protect the soil from erosion (Tidemann, 1996). So, that those farmers who exercised physical soil and water conservation measures are keeping their soil fertility better than farmers who do not. This practice can be influenced by sex, age, wealth and extension status of the farmers.

Crop residue management - Crop residues are materials left in an agricultural field or orchard after the crop has been harvested. According to Unger *et al.* (1991) crop residues contains large quantities of plant nutrients that could serve as an effective means of maintaining the organic matter and nutrient levels in soil. Since most of the respondents either partially or totally remove residues, the variable is considered as dummy that assumes "0" if the farmers totally remove it and "1" if partially. Level of education, wealth status and extension status of the farmers can influence the cop residues management practices.

Planting row of vetiver/any other grasses - it is dummy variable that assumes "1" if the farmers employed it and "0" if not. Vetiver system is a very simple, practical, inexpensive, low maintenance and very effective means of SWC, sediment control, land stabilization and rehabilitation. It is also environmentally friendly and when planted in single rows it will form a hedge which is very effective in slowing and spreading runoff water, thereby reducing soil erosion, conserving soil moisture and trapping sediment and farm chemicals on site (Takelegn, 2011). It is hypothesized education level, sex, wealth status, and extension status of the farmers could influence soil fertility management practices by planting vetiver or row of any other grasses.

Therefore, the cumulative logistic probability model is econometrically specified as follows:

$$P_i = F(Z_i) = F\left(\alpha + \sum \beta_i X_i\right) = \frac{1}{1 + e^{-Z_i}} \quad \text{...} (1)$$

Where,

P_i is the probability that an individual will use soil fertility management practices or does not use given X_i;

e denotes the base of natural logarithms, which is approximately equal to 2.718;

X_i represents the i^{th} explanatory variables; and

α and β_i are parameters to be estimated

Hosmer and Lemeshew (1989) pointed out that the logit model could be written in terms of the odds and log of odds, which enables one to understand the interpretation of the coefficients. The odds ratio implies the ratio of the probability (P_i) that an individual would choose an alternative to the probability ($1-P_i$) that he/she would not choose it.

Therefore,

$$(1-P_i)= \frac{1}{1+e^{Z_i}} \quad \ldots\ldots (2)$$

$$\left(\frac{P_i}{1-P_i}\right)=\left(\frac{1+e^{Z_i}}{1+e^{-Z_i}}\right)=e^{Z_i} \quad \ldots\ldots (3)$$

Or,

Taking natural logarithm of equation (4)

$$Z_i = Ln\left(\frac{P_i}{1-P_i}\right)=\alpha+\beta_1 X_1+\beta_2 X_2+ \ \ldots \ + \beta_m X_m \quad \ldots\ldots (5)$$

If the disturbance term (u_i) is taken in to account, the logit model becomes,

$$Z_i = \alpha + \sum_{i=1}^{m}\beta_i X_i + u_i \quad \ldots\ldots (6)$$

This study was intended to analyze which and how much the hypothesized regressors were related to the small holder farmers' practicing soil fertility management practices. As already noted, the dependent variable is a dummy, which takes a value of zero or one depending on whether farmers are exercising some soil fertility management practices. However, the independent variables were both continuous and discrete. There are several methods to analyze the data involving binary outcomes. However, for this particular study, logit model was selected over discriminant and linear probability models. If the independent variables are normally distributed the discriminant-analysis estimator which follows ordinary least square procedures (OLS) is the true maximum likelihood estimator (MLE) and therefore asymptotically more efficient than the logit model which requires maximum-likelihood method. However, if the independent variables are not normal, the discriminant-analysis estimator is not consistent, whereas the logit MLE is consistent and therefore more robust (Maddala, 1983; Amemiya, 1981).

The linear probability model (LPM) which is expressed as a linear function of the explanatory variables is computationally simple. However, despite its computational simplicity, as indorsed by Pindyck and Rubinfeld (1981), Amemiya (1981), and Gujarati (1988), it has a serious defect in that the estimated probability values can lie outside the normal 0-1 range. Hence logit model is advantageous over LPM in that the probabilities are bound between 0 and 1. Moreover, logit best fits the non-linear relationship between the probabilities and the explanatory variables.

The justification for using logit is its simplicity of calculation and that its probability lies between 0 and 1. Moreover, its probability approaches zero at a slower rate as the value of explanatory variable gets smaller and smaller, and the probability approaches 1 at a slower and slower rate as the value of the explanatory variable gets larger and larger (Gujarati, 1995). Hosmer and Lemeshew (1989) pointed out that the logistic distribution (logit) has got advantage over the others in the analysis of dichotomous outcome variable in that it is extremely flexible and easily used model from mathematical point of view and results in a meaningful interpretation. Hence, the logistic model is selected for this study.

4.RESULTS AND DISCUSSIONS

4.1.Socio-economic Characteristics of the Households

4.1.1. Demographic characteristics

The mean age of the respondents of Gera was 48.3, whereas that of Omo Nada and Limu Seka was 46.5 and 45.5 years respectively. Comparatively Gera district respondents' average age was the greatest whereas that of Limu Seka was the least. The average age of Gera's rich, medium and poor respondents was 43.4, 48.6, and 46.9 years, respectively whereas that of Omo Nada respondents was 41.2, 48.4 and 47.2 years, respectively. The mean age of rich, medium and poor respondents was 42.2, 49.6 and 47.1 years respectively.

Table 5. Demographic characteristics of households by wealth group and district

District	Wealth status	Age of HH head	Family Size	
			Total	Adults
Gera	Rich (N = 10)	43.4	7.3	3.2
	Medium (N = 27)	48.6	6.8	2.0
	Poor (N = 26)	46.9	5.6	1.5
	Mean	48.3	6.4	2.0
	SD	10.5	1.4	0.8
Omo Nada	Rich (N = 11)	41.2	7.7	3.0
	Medium (N = 51)	48.4	6.9	1.9
	Poor (N = 33)	47.2	5.8	1.4
	Mean	46.5	6.6	1.8
	SD	9.1	1.7	1.0
Limu Seka	Rich (N = 18)	42.2	7.4	2.9
	Medium (N = 33)	49.6	6.0	1.5
	Poor (N = 23)	47.1	6.5	1.6
	Mean	45.5	6.2	1.9
	SD	11.2	1.2	1.0

Source: Own survey data, 2015
Where N= number of respondents, SE = standard error of mean

The mean family size of Gera, Omo Nada and Limu Seka district was 6.4, 6.6 and 6.2 respectively. As shown in (Table 5), except in Limu Seka's medium and poor wealth group, the total average family members and adult family members increased as wealth status of the respondents increased. This could be due to the fact that in the study area better wealth group had large family size and in most cases, rich wealth group has more than one wife.

4.1.1.Educational level

On average about 52.4% respondents of Gera, 67.4% Omo Nada and 36.5% of Limu Seka were illiterate. More than half of the respondents of Gera and Omo Nada were fallen under illiterate educational level whereas, that of Limu Seka was fallen under grade 1-8 educational level. About 23.8% of Gera, 8.4% of Omo Nada and 13.5% of Limu Seka fallen under those who can read and write.

Table 6. Educational status of the households by wealth group

District	Wealth status	Educational level (%)			
		1	2	3	4
Gera	Rich (N = 10)	-	20.0	60.0	20.0
	Medium (N = 27)	59.3	18.5	14.8	7.4
	Poor (N = 26)	65.4	30.8	3.8	-
	Mean	52.4	23.8	17.5	6.3
Omo Nada	Rich (N = 11)	-	18.2	72.7	9.1
	Medium (N = 51)	64.7	7.8	21.6	5.9
	Poor (N = 33)	93.9	6.1	-	-
	Mean	67.4	8.4	20.0	4.2
Limu Seka	Rich (N = 18)	5.6	5.6	72.2	16.7
	Medium (N = 33)	36.4	6.1	48.5	9.1
	Poor (N = 23)	60.9	30.4	8.7	-
	Mean	36.5	13.5	42.0	8.1

Where N = number of respondents, 1= illiterate, 2 = can read and write, 3 = grade 1 – 8, and 4 = secondary and above

Whereas 17.5% of Gera, 20% of Omo Nada and 42 % of Limu Seka respondents were educated from grade 1–8. Only few respondents joined high school and above educational level i.e. about 6.3% of Gera, 4.2% and 8.1% of Omo Nada and Limu Seka respectively. In all of the districts, most of the rich respondents' educational status is fallen under grade 1-8 whereas, most of the medium and poor respondents are fallen in illiterate and can read and write groups (Table 6).

4.1.2. Land holding and livestock ownership

In all of the study districts farm land and total livestock units (TLU) are increased as the wealth group rise up from poor to rich, since they are indicators of wealth status of the respondents (Table 7). The mean farm land of Gera, Omo Nada and Limu Seka districts respondents was 0.935 ha, 1 ha and 0.835 ha with standard error of 0.130 ha, 0.120 ha and 0.073 ha, respectively.

Table 7.Farm land, livestock ownership – disaggregated by districts and wealth groups

Districts	Wealth status	Farm land size (ha)	TLU	Cattle (#)	Oxen (#)	Equine (#)	Small ruminants (#)
Gera	Rich (N = 10)	2.367	6.8	6.8	2.3	0.5	1.4
	Medium (N = 27)	0.760	5.0	4.6	1.6	0.1	1.5
	Poor (N = 26)	0.570	1.5	1.0	0.0	0	0.5
	Mean	0.935	3.8	3.4	1.4	0.1	1.1
	SD	1.034	0.50	3.4	0.9	0.4	0.8
Omo Nada	Rich (N = 11)	3.031	10.0	7.2	3.3	1.6	3.2
	Medium (N = 51)	0.840	4.7	2.9	1.7	0.5	1.8
	Poor (N = 33)	0.513	2.1	1.0	0.8	0	1.3
	Mean	1.00	4.4	2.7	1.6	0.5	1.8
	SD	0.155	2.8	2.5	1.3	0.7	0.2
Limu Seka	Rich (N = 18)	1.626	5.5	4.2	2.1	1.1	1.1
	Medium (N = 33)	0.721	4.0	3.0	1.4	0.5	1.2
	Poor (N = 23)	0.379	2.0	1.0	0.7	0	1.1
	Mean	0.835	3.7	2.5	1.2	0.5	1.1
	SD	0.630	2.0	1.8	0.7	0.09	0.7

Source: Own survey data, 2015

Tropical Livestock Unit (TLU) has been calculated as follows: 1 adult cattle or equine = 0.7 TLU; 1 goat or sheep = 0.1TLU; 1 calf = 0.4 TLU (Jahnke, 1982 cited in Eyasu (2002)). Where N = number of respondents, SE = standard error of mean, no = number

There are little differences in the mean farm land among the districts but, great differences among wealth group of the districts and among rich respondents of the districts. On average TLU of the respondents of Gera, Omo Nada and Limu Seka districts was 3.8, 4.4 and 3.7 with standard error of 0.50, 0.39 and 0.22 respectively. Averagely the respondents of Gera, Omo Nada and Limu Seka owned 3.4, 2.7 and 2.5 cattle excluding oxen with standard error of 0.42, 0.26 and 0.21, respectively. The mean oxen for plough of the respondents of Gera, Omo Nada and Limu Seka districts were 1.4, 1.6 and 1.2, respectively with standard error of 0.11, 0.14 and 0.08, respectively.

4.2. Farmers Perception of Soil Fertility Decline

Low crop yield, stunted growth and color changes of crops, changes in soil color and soil thickness, shift in weed biomass and weed species were the most important indicators of soil fertility status in the study area. According to focal group discussions, farmers of the study area were perceived fertile soil as good crop yielding, *sondi* (black colored), *furda* (good thickness) and good for working. If grasses such as *chookorsa (Cynodon dactylon), mujjaa (Snowdina polysatarch), asangra (Datura stramonium)* are grown up on the land the soil is fertile. Yellowed and stunted growth of crops, red soil color, reduced soil thickness, growing of plants such as *Hiddi adii (Solanum sp) and Qorxobbii (Plantago lanceolata. L,)* on the land are indicators of infertile soil. The present study is in agreement with Eyasu (2002); Yifru (2010) and Abush (2011).

4.3. Change in Crop Yield as Indicator of Soil Fertility Decline

One of the indicators of declining of soil fertility is, comparing the present and past time crop yield. As indicated in (Table 8) about 60% of rich, 77.8% of medium and 92.3% of poor respondents of Gera district reported that crop yield is declining. Similarly, about 66.7% of the model and 86.7% of non-model respondents of the district reported the declining of crop yield. Whereas about 30% of rich, 14.8% of the medium and 7.7% of the poor respondents of the district reported that crop yield is increasing. About 22.2% of the model and 11.1% of the non-model farmers responded increasing of crop yield.

About 81.8 % of the rich respondents, 86.3% of the medium and 87.9% of the poor respondents of Omo Nada district reported that crop yield is decreasing. Whereas about 18.2% of the rich, 13.7% of the medium and 9.1% of the poor respondents of Omo Nada respondents reported that crop yield is increasing. Regarding the extension status, about 80% and 88% of the model and non-model respondents of the district reported that crop yield is decreasing respectively. Whereas about 20% of the model and 10.7% non-model responded that crop yield is increasing.

Of the total respondents of Limu Seka, about 72.2% of the rich, 78.8% of the medium and 95.7% of the poor reported that crop yield is decreasing; whereas about 27.8% of the rich, 21.2% of the medium and 4.3% of the poor responded that crop yield is increasing. About 69.6% of the model and 88.2% of the non-model respondents of the district reported that crop yield is decreasing whereas, about 30.4% and 1.8% of the model and non-model farmers reported the opposite respectively.

As indicated in Table 8, most of the respondents of all wealth group and of all the districts reported that crop yield is decreasing. However, the percentage of respondents who reported declining of crop yield is increased as wealth status decreased from rich to poor. Whereas the percentage of respondents who reported increasing of crop yield increased as wealth status increased from poor to rich. Similarly, the same is true among the extension status of the respondents. This might be due the difference in soil fertility management practices among wealth group and extension status of the respondents. This study is in agreement with Bahilu *et al.* (2016) who reported that rich farmers had a capacity to apply more manure and mineral fertilizer to maintain soil fertility and productivity.

In general, without considering wealth group and extension status, most of the respondents of the districts (about 83.6%) perceived that crop yield is decreasing when compared to the past time. About 14.7% and 1.3% reported that crop yield is increasing and started to increase from the past 2-5 years respectively. Even though soil fertility is not the only factors that limit crop yield, the result implies that soil fertility is declining since crop yield is declined. The survey result of Amanuel (2014) which was carried out in Omo Nada also reported declining of the current crop productivity as compared to levels of some years ago, as a result of soil fertility declining, unaffordable price of fertilizers and others factors.

Table 8. Percentage of responses to change in crop yield by wealth group and extension status

District	WS/ES	Yes, declining		Yes, increasing		Started to increase from the past 2 - 5 years		Remained the same	
		N	%	N	%	N	%	N	%
Gera	Rich	6	60	3	30	-	-	1	10
	Medium	21	77.8	4	14.8	2	7.4	-	-
	Poor	24	92.3	2	7.7	-	-	-	-
	Model	12	66.7	4	22.2	1	5.6	1	5.6
	Non-model	39	86.7	5	11.1	1	2.2	-	-
Omo	Rich	9	81.8	2	18.2	-	-	-	-
Nada	Medium	44	86.3	7	13.7	-	-	-	-
	Poor	29	87.9	3	9.1	-	-	-	-
	Model	16	80	4	20	-	-	-	-
	Non-model	66	88	8	10.7	1	1.3		
Limu	Rich	13	72.2	5	27.8	-	-	-	-
Seka	Medium	26	78.8	7	21.2	-	-	-	-
	Poor	22	95.7	1	4.3	-	-	-	-
	Model	16	69.6	7	30.4	-	-	-	-
	Non-model	45	88.2	6	11.8	-	-	-	-

Where WS = wealth Status, ES = extension status, N = number of respondents

4.4. Soil Fertility as One of the Major Causes for Declining in Crop Yield

In general, the respondents of the study area recognized soil fertility as the major causes of declining of crop yield. Gera district rich respondents reported that weed infestation, pest and disease (WPD) are the first ranked problem whereas, the medium and poor respondents ranked declining of soil fertility as their number one ranked problem. Rich respondents of the district ranked DSF and unseasonal and erratic rainfall (URF) as the 2^{nd} and the 3^{rd} causes of crop yield declining. Both medium and poor respondents of the district reported WPD and URF as the 2^{nd} and 3^{rd} ranked causes of crop yield declining.

As indicated in the Table 9, Omo Nada's rich, medium and poor respondents reported DSF, WPD and URF as 1^{st}, 2^{nd}, and 3^{rd} ranked causes for crop yield declining respectively. According to Limu Seka's rich wealth group URF, DSF and WPD as the 1^{st}, 2^{nd}, and 3^{rd} ranked causes of declining of crop yield, respectively. Whereas the medium reported DSF, WPD and URF were ranked in the order of their importance for the declining of crop yield. The poor respondents reported that DSF, URF and WPD are ranked in the order of their importance to determine crop yield.

In the case of the extension status of the respondents, the model respondents of Gera ranked WPD, URF and DSF in the order of their importance, respectively. Whereas the non-model reported that DSF, URF and WPD were ranked in the order of their importance to determine crop yield respectively. Without considering wealth status and extension status of the respondents in all the three districts declining of soil fertility is top ranked problem to cause declining of crop yield. The present study agreed with the findings of some researchers who identified soil fertility problem as number one causes for crop yield declining in south western parts of the Ethiopia as well as other parts of the country (Taye and Yifru, 2010; Bahilu *et al*., 2014).

Table 9. Causes of crop yield declining in the study districts

WS/ ES	Cause of DCY	Gera (N= 63)						Omo Nada (N= 95)						Limu Seka (N= 74)					
		Rank frequency				TP	R	Rank frequency				TP	R	Rank frequency				TP	R
Rich		1	2	3	4			1	2	3	4			1	2	3	4		
	DSF	2	1	3	-	17	2	9	-	-	-	36	1	-	11	2	-	37	2
	URF	1	3	1	-	15	3	-	2	6		18	3	1	11	1	-	38	1
	WPD	3	2	1	-	20	1	1	7	1	-	27	2	-	1	12	-	27	3
	Others	-	-	-	-		4	-	-	-	-	-	4	-	-	-	-	-	4
Med	DSF	13	4	4	-	72	1	45	2	-	-	186	1	24	1	2		79	1
	URF	4	7	10	1	58	3	1	22	24	-	118	3	1	8	16	-	60	3
	WPD	5	10	7	-	64	2	1	24	23	-	122	2	3	15	9		75	2
	Others	-	1	1	1	6	4				1	1	4	-	1	-	-	3	4
Poor	DSF	18	6	1	-	92	1	29	1	-	-	90	1	20	1	-	-	83	1
	URF	2	16	17	-	90	2	-	11	19	-	71	3	-	15	6	-	57	2
	WPD	5	3	16	-	61	3	-	19	11	-	79	2	1	5	15	-	49	3
	Others	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	4
Mod	DSF	2	5	3	1	30	3	18	2	-	-	60	1	14	1	2	-	49	2
	URF	4	2	5	-	32	2	-	7	9	-	39	3	1	11	5	-	57	1
	WPD	5	4	2	-	36	1	-	11	7	-	47	2	2	3	12	-	41	3
	Others	-	-	-	1	1	4	-	-	-	-	-	4	-	-	-	-	-	-
NM	DSF	30	8	3	1	151	1	65	3	-	-	269	1	41	3	-	-	173	1
	URF	6	25	17	1	131	2	1	28	-	-	88	3	1	23	18	-	73	3
	WPD	8	11	22	-	109	3	2	39	28	-	181	2	2	18	24	-	110	2
	Others	-	1	1	-	5	4	-	-	-	-	-	4	-	-	-	-	-	4

Source: Own survey data, 2015

Where WS = wealth status, ES= extension status, CYD = declining of crop yield, DSF = declining of soil fertility, URF = unseasonal rain fall, WPD = weed, pest and disease, Med = medium, Mod = model, NM = none-model

4.5. Causes of Soil Fertility Decline

Continuous cropping (CC) is the 1st ranked problem to cause declining of soil fertility in the entire districts of all wealth groups. Low fertilizer application (LFA) and soil erosion (SE) were ranked as the 2nd and 3rd rank to cause declining of soil fertility in Gera. Whereas soil erosion and low fertilizer application were the 2nd and 3rd causes of crop yield both in Omo Nada and Limu Seka. Similarly, the models and non-models identified continuous cropping as the 1st ranked problem to cause declining of soil fertility in Gera and Limu Seka whereas, soil erosion was the 1st ranked problem in Omo Nada. LFA and SE were the 2nd and 3rd important causes in Gera, but, CC and LFA were the 2nd and 3rd ranked causes of soil fertility decline in Omo Nada. SE and LFA were the second and third causes of declining of crop yield in Limu Seka. The non-model respondents of Gera and Limu Seka reported the same rank with that of model whereas, that of Omo Nada ranked CC, SE and LFA in the order of their importance to influence crop yield.

Continuous cropping with either cereal mono-cropping or cereal followed by cereal rotation that did not include leguminous crops was perceived as one of the most causes for nutrient depletion which caused declining soil fertility which in turn caused crop yield declining in the study area. According to the respondents, continued cultivation on the same piece of land without fallowing over the years had led to declining of soil fertility for the farm plots. Even though farmers are aware of the soil fertility problems, they continue to cultivate and overexploit the available soil nutrients due to land shortage pressurised by increased human population. This result is in line with Belay (2015) and Lechisa *et al*. (2015) who reported the aggravation effect of continuous cropping for soil fertility declining.

Low fertilizers input that do not match with the amount of nutrients taken-up by the crops was another challenges of soil fertility of the area. Since there is no addition of enough external input to replenish nutrients that was removed through harvesting crops and other factors, the crops continued to grow as the expense of soil nutrient reserve that led the soil to unproductive stage. Currently, most of the respondents of Omo Nada, reported that crops do not properly emerge without fertilizers (meaning they are yellowed, stunted and died after some weeks of emergency). This indicates that already the soil has lost its fertility and cannot be productive like the past years in which plants were grown for many years with little or no external input.

Table 10.Causes of soil fertility decline in the study districts

WS/ ES	Causes of SFD	Gera (N= 63)						Omo Nada (N= 95)						Limu Seka (N= 74)					
		Rank frequency				TP	R	Rank frequency				TP	R	Rank frequency				TP	R
Rich		1	2	3	4			1	2	3	4			1	2	3	4		
	CC	-	7	2	-	25	1	9	1	-	-	39	1	15	1	-	-	63	1
	SE	-	2	5	-	16	3	2	6			26	2	1	15	-	-	49	2
	LFA	-	6	2	-	22	2		2	4		14	3	-	-	15	-	30	3
	Others	-	-	2	1	5	4	-	2	-	3	9	4	-	-	-	1	1	4
Med	CC	21	3	2	-	97	1	38	7	3	-	179	1	27	2	-	-	116	1
	SE	3	9	8	-	55	3	9	24	14		127	2	2	20	7	-	82	2
	LFA	2	10	9	-	56	2	2	17	27	1	114	3		8	19		62	3
	Others	-	-	2	2	6	4	-	-	2	1	5	4	-	-	-	-	-	4
Poor	CC	20	5	1	-	87	1	26	5	2	-	123	1	20	3	-	-	89	1
	SE	2	7	14	-	57	3	4	21	8	-	91	2	2	14	7	-	64	2
	LFA	3	16	7	-	74	2	3	12	8	-	64	3	1	7	15	-	55	3
	Others		1	-	1	4	4	-	1	4	1	14	4	-	-	2	-	4	4
Mod	CC	16	1	-	-	67	1	14	2	2	-	52	2	19	1	-	-	79	1
	SE	1	3	8	-	29	3	5	9	4	-	55	1	1	17	2	-	63	2
	LFA	-	10	3	-	36	2	1	6	8	-	35	3	-	2	16	-	40	3
	Others		-	-	3	3	4		-	-	3	3	-	-	-	-	-	-	4
NM	CC	34	7	3	-	163	1	58	10	4	-	270	1	43	5	-	-	187	1
	SE	6	15	9		87	3	10	42	18	-	202	2	4	32	12	-	136	2
	LFA	5	22	15		116	2	4	25	41	1	173	3	1	13	33	-	109	3
	Others	-	1	2	1	8	4	-	2	-	-	6	4	-	-	-	3	3	4

Source: Own survey data, 2015

Where WS = wealth status, ES = extension status, N = number of respondents, DSF = declining of soil fertility, CC = continuous cropping, SE = soil erosion, LFA = low fertilizer application, TP = total points, R = rank, Med = medium, Mod = model, NM = none- model

The farmers of the study area are not applying recommended rate of fertilizers for all crops due to high cost of fertilizers. Although they are experienced with the advantages of fertilizers, the cost of fertilizers which is beyond the purchasing capacity of the farmers limited them to apply. This result is in agreement with that of Belay (2003); Abebayehu *et al*. (2011) and ATA (2013) who reported low fertilizer application which is unbalanced with nutrient removed by the crops. Even most of the respondents were not applying fertilizers to many crops such as sorghum and millet. Most of their crop rotation was either maize followed by *tef* and sorghum or maize followed by sorghum and *tef*, in this sequences they did not apply fertilizers to sorghum. They perceived as there is a recovery of fertilizers that was left in the soil from the past season application so that the sorghum can exploit it from the soil.

4.6. Soil Fertility Management Practices

Soil fertility is the most important asset worldwide and especially in developing countries like Ethiopia where most of the nation economy is dependent on agriculture. Maintenance of soil fertility is an important aspect of agriculture. The soil fertility problem has been studied in many countries and scientists have brought to light several facts concerning soil fertility and its management. The farmers of the study area have been maintaining fertility of their soils by applying organic manures, mineral fertilizers and other agronomic practices but none of the respondents applied lime for soil amendments.

Many farm crops and their residues are removed from the land and the supply of essential elements becomes depleted. Under continuous cultivation soils are losing organic matter and mineral nutrients faster than they can be replaced. Regular loss of nutrients from the soil results in the loss of soil fertility. So, for the maintenance of soil fertility, replacement of the organic matter and mineral nutrients removed from the soils is necessary. Application of *kosii*, farm yard manure and inorganic fertilizers are the major practices of soil fertility management in the study area.

Kosii- is a practice of spreading households' wastes to the field located around home to maintain soil fertility. '*Kosii"*, which literally means waste, consists all kinds of human and livestock residues/leftovers in and around the residence and applied (thrown) over the land almost on daily basis (Tekilu and Gezehagn, 2003).

Farm yard manure (FYM) - application of manure is another important means of soil fertility management. Some of the farmers constructed house for their animals and the animals stay in the house during night time. The manure of the cattle cleaned from the house and spread over the land. While others construct fence near their home for keeping their cattle during night and morning time, so that manures accumulated will be spread over the land to maintain fertility of the soil. Unlike other areas, kraaling (keeping cattle at night in the barn and rotating the position of the barn regularly in order to uniformly distribute manure to crop fields) is not a common practice in the study area except in Wanja Kersa *kebele* in which some respondents practiced it.

Inorganic fertilizers - due to its immediate effects on crop production, inorganic fertilizers are a good option for improving soil fertility. Most of the respondents of the study area commonly applied DAP and Urea. NPS is the recently introduced one and few of them started to use it.

"Kosii" is the common practice and almost all of the respondents of the study area applied to their farm land. As shown in (Table 11) most of the respondents in the entire districts, wealth group and extension status applied *kosii*, farm yard manure (FYM) and mineral fertilizers (MF). Almost all of the rich respondents, about 24 (88.9%) of the medium and 19 (73.1%) of poor respondents of Gera applied *kosii*, FYM and MF and the Pearson chi-square test revealed that there was no statically significance difference among wealth group and extension status. Similarly, about 10 (90.9%) of the rich, 50 (98%) of the medium and 30 (90.9%) of the poor respondents of Omo Nada applied *kosii*, FYM and MF and statically there was significant difference among wealth group of the district ($\chi^2 = 20.429$, df = 4, P = 0.001).

In Limu Seka district almost all of the rich respondents, about 32 (97%) of medium and 22 (95.7%) of the poor respondents applied *kosii*, FYM and MF and statically there was significant difference among wealth group ($\chi^2 = 17.238$, df = 4, P < 0.001). None of the rich respondents of the study area and a single medium respondent of Gera and Omo Nada applied only *kosii* and FYM. Whereas about 6 (23.1%) of poor wealth group of Gera, 3 (9.1%) of Omo Nada and a single respondent of Limu Seka applied only *kosii* and FYM. Compost (C) application is not common practice in the study area.

In Gera district about 2 (7.4%) of medium and 1 (3.8%) of the poor wealth group applied *kosii*, FYM, MF and Compost (C). In the case of their extension status, most of the model respondents of the study area applied *kosii*, FYM and MF. More specifically about 16 (88.9%) model respondents of Gera, all model respondents of Omo Nada and Limu Seka applied *kosii*, FYM and MF.

Table 11. Soil fertility management practices employed by the respondents

District	WS/ES	Apply *Kosii* and FYM		Apply *Kosii*, FYM and MF		Apply *Kosii*, FYM, MF and C			
		N	%	N	%	N	%	χ^2 value	P-value
Gera	Rich	-	-	10	100%	-	-		
	Medium	1	3.7	24	88.9	2	7.4		
	Poor	6	23.1	19	73.1	1	3.8	7.122^{ns}	0.121
	Model	-	-	16	88.9	2	11.1		
	NM	7	15.6	37	82.2	1	2.2	4.279^{ns}	0.117
Omo Nada	Rich	-	-	10	90.9	1	9.1		
	Medium	1	2.0	50	98.0	-	-		
	Poor	3	9.1	30	90.9	-	-	20.429***	0.001
	Model	-	-	20	100	-	-		
	NM	4	5.3	70	93.3	1	1.3	2.980^{ns}	0.366
Limu Seka	Rich	-	-	18	100	-	-		
	Medium	-	-	32	97	1	3		
	Poor	1	4.3	22	95.7	-	-	17.238***	0.000
	Model	-	-	23	100	-	-		
	NM	1	2	49	96.1	1	2	4.645*	0.064

Source: Own survey data, 2015
Where WS = wealth status, ES = extension status, N = number of respondents, FYM = farm yard manure, MF = mineral fertilizer, C = compost, ns = non-significance *** and * represent level of significant at 1% and 10%.

Likewise, most of the non-model respondents of the districts applied *kosii*, FYM and MF. About 7 (15.6%) of non-model respondents of Gera, 4 (5.3%) of Omo Nada and 1 (2%) of Limu Seka applied only *kosii* and FYM. Statistically there was a significant difference among model and non-model respondents only in Limu Seka ($\chi^2 = 4.645$, df = 2, P = 0.064).

Compost- compost preparation was not common practice in the study districts and majority of the respondents do not prepared it. Only about 2 (7.4%) of medium and 1 (3.8%) of poor respondents of Gera, 1 (9.1%) of rich respondent of Omo Nada, 1(3%) of Limu Seka's medium respondents were prepared compost (Table 12). There were no significant differences among wealth group and extension status in all the study districts in Pearson chi-square test. According to the respondents, most of the farmers were not preparing compost since 2011 when the mass training was given by the government. Due to this, statistically there were no significant differences among wealth group and extension status of the respondents across all the studied districts.

Table 12. Frequency, percept and chi-square test of compost application

WS/ES	Gera (N = 63)				Omo Nada (N = 95)				Limu Seka (N = 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	-	-	10	100	1	9.1	10	90.9	-	-	18	100
Medium	2	7.4	25	92.6	-	-	51	100	1	3	32	97
Poor	1	3.8	25	92.6	-	-	33	100	-	-	23	100
χ^2 value	0.965				7.718				1.259			
P-value	0.823				0.116				1.000			
Model	2	11.1	16	88.9	-	-	20	100	1	4.3	22	95.7
Non-model	1	2.2	44	97.2	1	1.3	74	98.7	-	-	51	100
χ^2 value	2.240^{ns}				0.270^{ns}				2.248^{ns}			
P-value	0.194				0.789				0.311			

Source: Own survey data, 2015
Where WhG = wealth status, ES = extension status, N = number of respondents

4.6.1.Application of FYM

Most of the respondents applied FYM to their farm land but the application is limited mainly to home-garden and parcel of land around their home used either for vegetables or for local maize variety. Averagely the respondents of Gera, Omo Nada and Limu Seka applied 690.1, 798.8, and 670.2 *gundo (sefed)*/ha of fresh FYM respectively. One *gundo/sefed* is estimated to be 4 kg.

Table 13.Amount of FYM applied across the study districts

District	WS/ES	Do you apply FYM				Rate of application (*Gundo*/ha)
		Yes		No		
		N	%	N	%	
Gera	Rich (N=10)	10	100	-	-	1275.6
	Medium (N=27)	27	100	-	-	908.2
	Poor (N=26)	26	100	-	-	260.8
	Model (N=18)	18	100	-	-	1315.5
	Non-model (N=45)	45	100	-		713.3
	Mean	63	100	-	-	690.1
	SD	-	-	-	-	332.4
Omo Nada	Rich (N=11)	11	100	-	-	1825
	Medium (N=51)	51	100	-	-	857.8
	Poor (N=33)	32	97.0	1	3.0	360.7
	Model (N=20)	20	100	-	-	1894.3
	Non-model (N=75)	75	100	-	-	885.5
	Mean	94	98.9	1	1.1	798.8
	SD	-	-	-	-	498.3
Limu Seka	Rich (N=18)	18	100	-	-	821.4
	Medium (N=33)	33	100	-	-	730
	Poor (N=23)	23	100	-	-	368
	Model (N=23)	23	100	-	-	904.8
	Non-model (N=51)	51	100	-	-	702.3
	Mean	74	100	-	-	670.2
	SD	-	-	-	-	404.8

Source: Own survey data

Where WS = wealth status, ES = extension status, N = number of respondents, SD = standard deviation

On average Gera's rich, medium and poor respondents apply 1275.6, 908.2, and 260.8 *gundo*/ha of fresh FYM respectively. In average model respondents of the district applied 1315.5 *gundo*/ha whereas the non-model applied 713.25 *gundo*/ha. Omo Nada's rich, medium and poor respondents applied 1825, 857.8, 360.7 *gundo*/ha of fresh FYM respectively. Model respondents of Gera district applied 1894.3 *gundo*/ha while non-model of the district applied 885.5 *gundo*/ha. Limu Seka's rich, medium and poor respondents applied 821.4, 730, and 368 *gundo*/ha of fresh FYM respectively. Model and non-model of this district applied 904.8 and 702.3 *gundo*/ha.

As indicated in the table (13) the amount of FYM applied per hectare is increased as the wealth status of the respondents gets better in the entire district. Similarly, model farmers are applied more than non-model respondents. This is due to the fact that number of livestock was one of the criteria to indicate wealth status of the farmers that can determine the amount of manure that can be obtained from the animals. There were greater differences in the amount of FYM applied among wealth groups of the districts but, the greatest standard deviation is observed in Omo Nada.

4.6.2. Application of mineral fertilizers

Most of the farmers applied mineral fertilizers only to maize improved variety and *tef* but, the farmers also cultivate maize local variety. If the amount of total applied fertilizes is divided by total cultivated land the average amount of applied fertilizers/ha would be very small. Even though some of the farmers started to use NPS fertilizer, DAP and Urea were the common fertilizers used for production. The farmers applied band application form to maize and broadcast application form to *tef*.

On average rich respondents of Gera applied 105.3 kg/ha of DAP and105.3 kg/ha of urea to maize whereas, 88.3 kg/ha of DAP and 25 kg/ha of urea to *tef*. The medium respondents of this district applied 100.7 kg/ha of DAP and 97.3 kg/ha of urea to maize, and 86 kg/ha of DAP and 26.2 kg/ha urea *to tef* (Table 14). The poor wealth group applied 72.1 kg/ha of DAP and 64.4 kg/ha of urea to maize and, 52.1 kg/ha of DAP and 5.2 kg/ha of urea to *tef*. In the case of their extension status the model respondents of the district applied 110.3 kg/ha of DAP plus 110.3 kg/ha of urea to maize, and 100 kg/ha of DAP plus 25 kg/ha of urea to *tef*. Whereas the non-model applied 79.3 kg/ha of DAP plus 77 kg/ha of urea to maize, and 65 kg/ha of DAP plus 14.4 kg/ha urea to *tef*. The mean fertilizer application of the district's respondents to maize was 88.2 kg/ha of DAP and 86.5 kg/ha of urea with standard deviation of 45.5 and 40.5 kg/ha for DAP and urea respectively. Whereas the mean to *tef* was 72.4 kg/ha of DAP and 17.4 kg/ha of urea with the standard deviation of 39.8 and 32 kg/ha of DAP and urea respectively. There were variations in the amount of fertilizers applied to the major crops among the respondents.

Table 14. Application of mineral fertilizers by wealth group and extension status

District	Wealth/Extension status	Do you apply mineral fertilizer				Rate of application (kg/ha)			
		Yes		No		Maize		*Tef*	
		N	%	N	%	DAP	Urea	DAP	Urea
Gera	Rich (N=10)	10	100	-	-	105.3	105.3	88.3	25.0
	Medium (N=27)	26	96.3	1	3.7	100.7	97.3	86.0	26.2
	Poor (N=26)	20	76.9	6	23.1	72.1	64.4	52.1	5.2
	Model (N=18)	18	100	-	-	110.3	110.3	100	25.0
	Non-model (N=45)	38	84.4	7	15.6	79.3	77.0	65.0	14.4
	Mean	56	88.9	7	11.1	88.2	86.5	72.4	17.4
	SD	-	-	-	-	45.5	40.5	39.8	32.0
Omo Nada	Rich (N=11)	11	100	-	-	111.5	102.4	89.4	27.3
	Medium (N=51)	50	98	1	2	93.4	92.2	72.2	16.5
	Poor (N=33)	30	90.9	3	9.1	85.6	79.5	61.7	3.0
	Model (N=20)	20	100	-	-	113.8	113.8	85.4	25.0
	Non-model (N=75)	71	94.7	4	5.3	85.7	84.5	66.5	10.0
	Mean	91	95.8	4	4.2	91.1	90.7	70.5	13.0
	SD	-	-	-	-	35.0	35.6	35.4	29.5
Limu Seka	Rich (N=18)	18	100	-	-	127.3	127.3	91.1	19.4
	Medium (N=33)	33	100	-	-	109.3	104.3	79.4	15.6
	Poor (N=23)	22	95.7	1	4.3	90.8	89.7	60.0	5.5
	Model (N=23)	23	100	-	-	126.6	125.0	87.6	17.4
	Non-model (N=51)	50	98	1	2	100.0	96.5	69.2	11.5
	Mean	73	98.6	1	1.4	108.0	105.4	75.0	13.4
	SD	-	-	-	-	26.6	29.1	30.7	30.4

Source: Own survey data, 2015, N = number of respondents, SD = standard deviation

The rich respondents of Omo Nada applied 111.5 kg/ha of DAP and 102.4 kg/ha of urea to maize crop. The amount of fertilizers applied to *tef* by this wealth group was 89.4 kg/ha of DAP and 27.3 kg/ha of urea. Whereas the medium respondents of this district applied 93.4 kg/ha of DAP and 92.2 kg/ha of urea to maize, and 72.2 kg/ha of DAP and 16.5 kg/ha of urea to *tef*. Poor respondents of the district applied 85.6 kg/ha of DAP and 79.5 kg/ha of urea to maize, and 61.7 and 3 kg/ha of DAP and urea respectively. Model respondents of Omo Nada applied 113.8 kg/ha of DAP plus 113.8 kg/ha urea maize, and 85.4 kg/ha DAP plus 25 kg/ha urea to *tef*.

The non-model respondents applied 85.7 kg/ha DAP plus 84.5 kg/ha urea to maize, and 66.5 kg/ha DAP and 10 kg/ha urea to *tef*. The mean fertilizer application of the district's respondents to maize was 91.1 kg/ha of DAP and 90.7 kg/ha of urea with standard deviation of 35 and 35.6 kg/ha for DAP and urea respectively. Whereas the mean to *tef* was 70.5 kg/ha of DAP and 13 kg/ha of urea with the standard deviation of 35.4 kg/ha and 29.5 kg/ha of DAP and urea respectively (Table 14). As the SD indicates there is a great variation in the amount of fertilizers used among the respondents.

The mean fertilizers application of Limu Seka's rich respondents was 127.3 kg/ha of DAP and 127.3 kg/ha of urea to maize, and 91.1 kg/ha of DAP and 19.4 kg/ha of urea to *tef*. Whereas the medium respondents of this district applied 109.3 kg/ha of DAP and 104.3 kg/ha of urea to maize while 79.4 kg/ha of DAP and 15.6 kg/ha of urea to *tef* respectively. The poor wealth group of the district applied 90.8 kg/ha of DAP and 89.7 kg/ha of urea to maize crop, and 60 kg/ha of DAP and 5.5 kg/ha of urea to *tef* respectively. Model respondents of this district applied 126.6 kg/ha DAP plus 125 kg/ha urea to maize, and 87.6 kg/ha DAP plus 17.4 kg/ha urea to *tef.* Non-model respondents of Limu Seka applied 100 kg/ha of DAP plus 96.5 kg/ha urea to maize, and 69.2 kg/ha DAP and 11.5 kg/ha urea to *tef.*

The mean fertilizer application of the respondents of this district to maize was 108 kg/ha of DAP and 105.4 kg/ha of urea with standard deviation of 26.6 and 29.1 kg/ha for DAP and urea respectively. Whereas the mean fertilizer applied to *tef* was 75 kg/ha of DAP and 13.4 kg/ha of urea with the standard deviation of 30.7 kg/ha and 30.4 kg/ha of DAP and urea respectively.

The amount of DAP and urea fertilizers applied to maize by rich respondents of Omo Nada is greater than the blanket recommendation by 5.3%. Similarity the amount of DAP and urea applied to maize by the medium respondents is better than the blanket recommendation by 0.7 and 2.75 respectively. The application rate was also better for model respondents by 10.3%. Whereas the amount of fertilizers applied to maize by poor and non-model respondents was negative (Table 15). The mean fertilizer applied to maize crop in the district was below the blanket recommendation for both DAP and urea by -11.8% and -14.5% respectively.

The amount of DAP and urea fertilizers applied to maize were also positive for rich respondents of Omo Nada by 11.5% and 2.4% respectively. Similarity, the amount of DAP and urea were positive for the model respondents by 13.8%, whereas, the mean was negative by 8.9% and 9.3% respectively. Similar to Gera district, the application rate of DAP and urea to maize was positive for rich, medium and model respondents by 27.3%, 9.3% and 4.3%, and 26.6% and 25.0%, respectively. The mean rate to the crop was also positive by 8.0% and 5.4% for DAP and urea respectively.

The amounts of both DAP and urea fertilizers applied to *tef* crop was far below the blanket recommendation for all wealth status and extension status. Even though both DAP and urea application rate is far below the blanket recommendation, the application rate of urea to *tef* is too small than DAP. The farmers were not applying sufficient amount of mineral fertilizers to all crops due to high cost of fertilizers and lack of credit without interest. Application of *kosii* and farm yard manure is limited to home-garden and/ or small size farm land near to home due to limited number of livestock. This calls for intervention action that is based on site specific, soil and cultivar testing to identify nutrient efficiency crops and other alternative solutions.

Table 15. Gap analysis of mineral fertilizer application on the basis of blanket recommendation

District	Wealth/Extension status	Gap with respect to blanket recommendation %			
		Maize		*Tef*	
		DAP	Urea	DAP	Urea
Gera	Rich (N=10)	5.3	5.3	-11.7	-75
	Medium (N=27)	0.7	2.7	-14	-75.8
	Poor (N=26)	-27.9	-35.6	-57.9	-94.8
	Model (N=18)	10.3	10.3	-	-75
	Non-model (N=45)	-19.7	77.0	-35	-85.61
	Mean	-11.8	-14.5	-27.6	-82.6
Omo Nada	Rich (N=11)	11.5	2.4	-10.6	-72.7
	Medium (N=51)	-6.6	-7.8	-27.8	-83.5
	Poor (N=33)	-14.4	-20.5	-38.3	-93.0
	Model (N=20)	13.8	13.8	-14.6	-75.0
	Non-model (N=75)	-14.3	-14.5	-33.5	-90.0
	Mean	-9.9	-9.3	-29.5	-87.0
Limu	Rich (N=18)	27.3	27.3	-9.9	-80.6
Seka	Medium (N=33)	9.3	4.3	-19.6	-84.4
	Poor (N=23)	-9.2	-10.3	-40	-94.5
	Model (N=23)	26.6	25.0	-12.4	-82.6
	Non-model (N=51)	-	-3.5	-30.8	-88.5
	Mean	8.0	5.4	-25	-86.6

Where the negative sign (-) before the numbers indicates below the blanket recommendation rate

4.6.3. Crop rotation

Crop rotation entails the growing of different crops in a well-defined sequence on the same piece of land each season. Rotations allow crops with different rooting patterns to use the soil sequentially reduce pests and diseases and sustain the productivity of the cropping system (Kombiok *et al*., 2012). Legume based crop rotation is important way of soil fertility maintenance. In order to investigate rotational practice of the study area, the respondents were interviewed for crops they grew for the last three consecutive years on the same plot of land.

Accordingly, most of the rotational patterns were cereal followed by cereal which was not legume based crop rotation. Even there were some farmers that were interchanging maize varieties of BH-660 followed by BH-140 for consecutive crop calendar. They perceived that BH-140 cannot deplete soil nutrients compared with BH-660. According to their perception rather than cropping BH-660 for two consecutive years, cropping BH-140 in the next year is advantageous. Of the total respondents, only 9 (3.9%) of them practiced legume based crop rotation (maize followed by commom bean).

Generally, without considering wealth group and extension status the most frequently rotated crops in the study areas were:

- Maize followed by *tef*, followed by sorghum by 35 (15.1%) respondents
- Maize followed by *tef*, followed by maize by 24 (10.3%) respondents
- Maize followed by sorghum, followed by *tef* by 16 (6.9%) respondents

This implies that there is a great soil fertility loss due to mono-cropping that exercised either mono-cropping or rotation of cereals that aggravates declining of soil fertility (e.g maize followed by sorghum and *tef*).

In Gera district about 8 (80%) of rich, 20 (74%) of medium and 17 (65%) of the poor respondents practiced crop rotation (Table 16). The remaining 2 (20%), 7 (25.9%) and 9 (34.6%) of the rich, medium and poor respondents do not practiced crop rotation respectively. In this district, about 16 (88.9 %) of the model and 29 (64.4 %) of non-model respondents had practiced crop rotation. About 2 (11.1%) of model and 16 (35.6%) of non-model respondents did not practiced crop rotation. In this district, the chi-square test did not show significant differences among wealth group in practicing intercropping, whereas significant difference was observed among the model and non-model farmers (χ^2 = 3.764, df = 1, P = 0.067).

Almost all of the rich respondents of Omo Nada, about 45 (88.2%) of the medium and 23 (69.7%) of the poor respondents had practiced crop rotation whereas, about 6 (11.8%) of the medium and 10 (10.3 %) of the poor respondents did not. Almost all of the model respondents of the district and about 59 (78.7%) of the non-model respondents had practiced crop rotation whereas, about 16 (21.3%) of the non-model respondents did not practiced. Significant differences in chi-square test were observed between both wealth group and extension status (χ^2 = 7.436, P = 0.025, df = 2 and χ^2 =5.131, P = 0.038, df = 1) respectively.

Table 16.Frequency, percept and chi square test of crop rotation

WS/ES	Gera (N = 63)				Omo Nada (N = 95)				Limu Seka (N = 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	8	80	2	20	11	100	-	-	7	38.9	11	61.1
Medium	20	74.1	7	25.9	45	88.2	6	11.8	13	39.4	20	60.6
Poor	17	65.4	9	34.6	23	69.7	10	30.3	8	34.8	15	65.2
χ^2 value	0.918^{ns}				7.436**				0.074^{ns}			
P-value	0.657				0.025				1.000			
Model	16	88.9	2	11.1	20	100	-	-	10	43.5	13	56.5
Non-model	29	64.4	16	35.6	59	78.7	16	21.3	18	35.3	33	64.7
χ^2 value	3.764*				5.131**				3.091^{ns}			
P-value	0.067				0.038				0.179			

Source: Own survey data, 2015
Where WS = wealth status, ES = extension status, N = number of respondents, ** and * represent level of significant at 1%, 5% and 10% respectively

Of the 18 rich respondents of Limu Seka district, about 7 (38.9%) of them had practiced crop rotation whereas, about 11 (61.1%) did not. About 13 (39.4%) of the medium and 8 (34.8%) of the poor respondents of the district did not practice crop rotation. Similarly, about 20 (60.6%) of the medium and 15 (65.2%) of poor respondents did not practiced crop rotation. In terms of their extension status about 10 (43.5%) of the model and 18 (35.3%) of the non-model farmers had practiced this agronomic practices. There were no significant differences between wealth group and extension status in this district.

4.6.4. Intercropping

Maize and common bean were the main intercropped cereal and legume crops. Those farmers who had practiced intercropping understood well the advantages of intercropping. They used intercropping to respond to land shortage and to improve soil fertility. The farmers are well familiar as the leaves and roots of haricot bean have advantageous to improve soil fertility. All of the rich respondents of Gera district practiced intercropping of legumes with cereals. Most of the medium and poor respondents do not practiced intercropping, only about 8 (29.6%) of the medium and 7 (26.9%) of the poor respondents practiced it (Table 17). In the case of their extension status, about 17 (94.4%) of the model and 8 (17.8%) of the non-model respondents of this district practiced intercropping. Statistically significant difference between wealth group and extension status were observed (χ^2 = 18.108, p = 0.000, df = 2 and χ^2 = 31.573, P = 0.000, df = 1) respectively.

About 9 (90.9%) of rich respondents of Omo Nada, 13 (25.5%) of the medium and 11 (33.3 %) of the poor respondents exercised intercropping of legumes with cereals. Of the 20 model respondents about 14 (70%) of them and 20 (26.7%) of the non-model respondents exercised intercropping. Whereas about 6 (30%) of the model and 55 (73.3%) of the non-model respondents do not practiced intercropping. Statistically significant differences among wealth group and extension status was observed (χ^2 = 16.983, P = 0.000, df = 2 and χ^2 = 12.902, P= 0.000, df = 1) respectively.

Table 17.Frequency, percent and chi-square test of regarding intercropping

WS/ES	Gera (N= 63)				Omo Nada (N= 95)				Limu Seka (N= 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	10	100	-	-	10	90.9	1	9.1	17	94.4	1	5.6
Medium	8	29.6	19	70.4	13	25.5	38	74.5	6	18.2	27	81.8
Poor	7	26.9	19	73.1	11	33.3	22	66.7	3	13	20	87
χ^2 value	18. 108***				16.983***				36.869***			
P-value	0.000				0.000				0.000			
Model	17	94.4	1	5.6	14	70	6	30	17	73.9	6	26.1
Non-model	8	17.8	37	82.2	20	26.7	55	73.3	9	17.6	42	82.4
χ^2 value	31.573***				12.902***				22.091***			
P-value	0.000				0.000				0.000			

Source: Own survey data, 2015

Where WS = wealth status, ES = extension status, N = number of respondents, ***, ** and * represent level of significant at 1%, 5% and 10% respectively

In the case of Limu Seka district about 17 (94.4%) of the rich, 6 (18.2%) of the medium and 3 (13%) of the poor respondents exercised intercropping. In the case of the extension status of the farmers, about 17 (73.9%) of the model respondents and 9 (17.6%) of the non-model respondents exercised intercropping. Similarly, statistically significant differences among wealth group and extension status were observed (χ^2 = 36.869, P = 0.000, df = 2 and χ^2 = 22.091, P = 0.000, df = 1) respectively.

4.6.5. Crop residue management

Almost all of the rich respondents of Gera and Omo Nada, about 17 (94.4%) of Limu Seka retained crop residue partially on the farm land. About 9 (33.3%) of Gera's, 7 (13.7%) of Omo Nada's and 4 (12.1%) of Limu Seka's medium respondents partially removed crop residue. All of the poor respondents of the study area totally removed crop residues. Statistically significant differences between wealth groups were observed in all the districts (χ^2 = 34.514, P = 0.000, df = 2 in Gera, χ^2 = 55.675, P = 0.000, df = 2 in Omo Nada and χ^2 =52.059, P = 0.000, df = 2 in Limu Seka (Table 18).

Regarding the extension status of the farmers, almost all model farmers of Gera district and a single (2.2%) of the non-model respondents reported that they partially remove crop residues. Statistically significant difference among model and non-model respondents were observed ($\chi^{2=}$ 58.358, P = 0.000, df = 1). In Omo Nada, about 15 (75%) of the model and 3 (4%) of the non-model respondents were partially remove crop residues from their farm land. Statically significance difference among model and non-model respondents were observed (χ^2 = 51.828, P = 0.000, df = 1). In Limu Seka district about 18 (78.3%) of the model and 3 (5.9%) of the non-model respondents partially removed crop residues and statistically significant differences among model and non-model respondents were observed (χ^2 = 40.856, P = 0.000, df = 1).

As indicated in the Table 18, out of the total respondents most of them removed crop residues from their land. There was competing uses for *tef* straw for mud house construction and mattress making. Due to this *tef* straw was completely removed from the farm land (Figure 2b). Maize and millet straw were used for animal feeding, whereas sorghum straw was used for fence construction- especially in Omo Nada district and for animal feeding in other districts (Figure 2a and Appendix Figure 2). Using crop straw as household fuel is not common in the study area but, some farmers burn the remaining residues to clean farm land during land preparation for sawing.

In addition to this, grazing of animals on farm land was other means of removing the remaining crop residues. Out of the total respondents of the study area about 217 (93.5%) of the respondents practiced control grazing on grazing land during production season and free grazing both on grazing land and on farm land during off season that could aggravates soil erosion. Of the total respondents, only about 15 (6.5%) of them practiced control grazing on grazing land in all season.

That means there was free grazing on the farm land after the crops were harvested. This result indicates that the crop residues left on the farm land were grazed by the animals and nothing were left on the ground. In addition to this, the animals trampled on the farm land so that, soil erosion could be aggravated.

Table 18. Frequency, percept and chi square test of crop residue management

WS/ES	Gera (N= 63)				Omo Nada (N= 95)				Limu Seka (N= 74)			
	Yes, partially		Yes, totally		Yes, partially		Yes, totally		Yes, partially		Yes, totally	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	10	100	-	-	11	100	-	-	17	94.4	1	1.6
Medium	9	33.3	18	66.7	7	13.7	44	86.3	4	12.1	29	87.9
Poor	-	-	26	100	-	-	33	100	-	-	23	100
χ^2 value	34.514***				55.675***				52.059***			
P-value	0.000				0.000				0.000			
Model	18	100	-	-	15	75	5	25	18	78.3	5	21.7
Non-model	1	2.2	44	97.8	3	4	72	96	3	5.9	48	94.1
χ^2 value	58.358***				51.828***				40.856***			
P-value	0.000				0.000				0.000			

Source: Own survey data, 2015

Where WS = wealth status, ES = extension status N= number of respondents, ***represent level of significant at 1%

Figure 2a.Totally removed maize residues from the field in Gera district

Figure2b. Totally removed *tef* residue from the field in Limu Seka district

Figure 3. Free grazing on farm land during off season in Omo Nada district

4.6.6. Fallowing

In Gera district about 5 (50%) of rich respondents, 11 (40.7%) of medium and 1 (3.8%) of the poor respondents had practiced fallowing, and this was statistically significant among wealth group ($\chi 2$ =18.483, df =4 P < 0.001) (Table 19). Whereas in Omo Nada about 8 (72.7%) of the rich respondents, 12 (23.5%) of the medium and 3 (9.1%) of the poor respondents had practiced fallowing and this was significant among wealth group (χ^2 = 19.154, P< 0.001. About 5 (27.8%), 2 (6.1%) and 1 (4.3%) of rich, medium and poor respondents of Limu Seka had exercised fallowing respectively, and there was statistically significant difference among the wealth group (χ^2 = 7.143, df = 4, P = 0.032).

In the case of their extension status, about 12 (66.7%), 8 (40%) and 5 (21.7%) of model farmers of Gera, Omo Nada and Limu Seka had exercised fallowing, respectively. Likewise, about 5 (11.1%) of Gera, 15 (20%) of Omo Nada and 3 (5.9%) of the non-model respondents of Limu Seka district had exercised this agronomic practice. There were significant differences among model and non-model respondents of Gera (χ^2 =20.226, df= 2, P < 0.001) and Limu Seka (χ^2 = 4.134, df= 2, P = 0.056).

According to the respondents, the main objective of the fallowing was not to restore soil fertility but to reserve a parcel of land used to graze their animals during cropping season. In this way, the soil would maintain its fertility to some extent and the land would return to cultivation after one or two year/s period. It means that the respondents were exercising none improved fallow (grazing during the fallow time). This indicated that the farmers are unable to leave land fallow for longer time due to high pressure on land leading to declining of soil fertility. Larson (1996), Beyene (2011) and Lechisa *et al.* (2015) reported as the population increased shifting cultivation and fallowing which was practiced by the farmers are discontinued to continuously feed the large number of family and predisposed the soil to lose its fertility.

Table 19. Frequency, percent and chi square test for fallowing

WS/ES	Gera (N= 63)				Omo Nada (N=95)				Limu Seka (N=74)			
	Yes		No		Yes		No		Yes		No	
	F	%	F	%	F	%	F	%	F	%	F	%
Rich	5	50	5	50	8	72.7	3	22.3	5	27.8	13	72.2
Medium	11	40.7	16	59.3	12	23.5	39	76.5	2	6.1	31	93.9
Poor	1	3.8	25	96.2	3	9.1	30	90.9	1	4.3	22	95.7
χ^2 value	18.483***				19.154***				7.143**			
P-value	0.000				0.000				0.032			
Model	12	66.7	6	33.3	8	40	12	60	5	21.7	18	78.3
Non- model	5	11.1	40	88.9	15	20	60	80	3	5.9	48	94.1
χ^2 value	20.226***				3.612^{ns}				4.134*			
P-value	0.000				0.164				0.056			

Source: Own survey data, 2015

Where, N = number of respondents, WS = wealth status, ES = extension status, ***, ** and * represent level of significant at 1%, 5% and 10% respectively

4.6.7. Contour cultivation

Contour cultivation was not common practice in the study area whereas '*yafaro*' (inclined to one end and declined to the other end to form slope) was the common one during the first three to four times ploughing which makes easy to plough. Since the soil was already loosen, contour cultivation was only common during the last ploughing time (sowing time). This repeated cultivation and *yafaro* favoured conditions to water erosion. In Gera district about 9 (90%) of rich, 11 (40.7%) of medium, 5 (19.2%) of poor respondents had practiced contour cultivation. The chi square test revealed that statistically there were highly significant differences among wealth group (χ^2 =15.134, P = 0.000, df = 2) (Table 20). About 8 (72.7%), 14 (27.5%) and 4

(12.1%) of rich, medium and poor respondents of Omo Nada had practiced contour cultivation respectively. The chi-square test for this district showed a highly significant difference among wealth group (χ^2 = 15.245, P = 0.000, df = 2). Of the 18 rich respondents of Limu Seka district about 15 (83.3%) of them were practiced contour cultivation. About 6 (18.2%) and 17 (73.9%) of the medium and poor respondents of this district had practiced contour cultivation respectively and this was significantly different among wealth group (χ^2 = 22.891, P = 0.000, df = 2).

Table 20.Frequency, percent and chi-square test for contour cultivation practice among respondents

Wealth/ Extension status	Gera (N = 63)				Omo Nada (N = 95)				Limu Seka (N = 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	9	90	1	10	8	72.7	3	27.3	15	83.3	3	16.7
Medium	11	40.7	16	59.3	14	27.5	37	72.5	6	18.2	27	81.8
Poor	5	19.2	21	80.8	4	12.1	29	87.9	17	73.9	6	26.1
χ^2 value	15.134***				15.245***				22.891***			
P-value	0.000				0.000				0.000			
Model	14	77.8	4	22.2	16	80	4	20	16	69.6	7	30.4
Non-model	11	24.4	34	75.6	10	13.3	65	86.7	11	21.6	40	78.4
χ^2 value	15.279***				35.303***				15.758***			
P-value	0.000				0.000				0.000			

Source: Own survey data, 2015

Where N= number of respondents, ***represent level of significant at 1%

In the case of the extension status of the respondents about 14 (77.8%) of Gera, 16(80%) of Omo Nada, 16 (69.6%) of Limu Seka model respondents had practiced contour cultivation. Similarly, about 11 (24.4%) of non-model respondents of Gera, 10 (13.3%) of Omo Nada and 11 (21.6%) of Limu Seka's non-model respondents had practiced this agronomic measure. The chi-square test revealed a highly significant difference among extension status of the respondents (χ^2 = 15.279, 35.303 and 15.758 for Gera, Omo Nada and Limu Seka respectively at P = 0.000, df = 1).

4.6.8. Fallowing

In Gera district about 5 (50%) of rich respondents, 11 (40.7%) of medium and 1 (3.8%) of the poor respondents had practiced fallowing, and this was statistically significant among wealth group (χ^2 =18.483, df = 4 P = 0.000) (Table 21). Whereas in Omo Nada about 8 (72.7%) of the rich respondents, 12 (23.5%) of the medium and 3 (9.1%) of the poor respondents had practiced fallowing and this was significant among wealth group (χ^2 = 19.154, P= 0.000. About 5 (27.8%), 2 (6.1%) and 1 (4.3%) of rich, medium and poor respondents of Limu Seka had exercised fallowing respectively, and there was statistically significant difference among the wealth group (χ^2 = 7.143, df =4, P = 0.032).

In the case of their extension status, about 12 (66.7%), 8 (40%) and 5 (21.7%) of model farmers of Gera, Omo Nada and Limu Seka had exercised fallowing, respectively. Likewise, about 5 (11.1%) of Gera, 15 (20%) of Omo Nada and 3 (5.9%) of the non-model respondents of Limu Seka district had exercised this agronomic practice. There were significant differences among model and non-model respondents of Gera (χ^2 = 20.226, df = 2, P= 0.000) and Limu Seka (χ^2 = 4.134, df = 2, P = 0.056).

According to the respondents, the main objective of the fallowing was not to restore soil fertility but to reserve a parcel of land used to graze their animals during cropping season. In this way, the soil would maintain its fertility to some extent and the land would return to cultivation after one or two year/s period. It means that the respondents were exercising none improved fallow (grazing during the fallow time). This indicated that the farmers are unable to leave land fallow for longer time due to high pressure on land leading to declining of soil fertility. Larson (1996), Beyene (2011) and Lechisa *et al.* (2015) reported that as the population increased shifting cultivation and fallowing which was practiced by the farmers are discontinued to continuously feed the large number of family and predisposed the soil to lose its fertility.

Table 21. Frequency, percent and chi square test for fallowing

Wealth/Extension status	Gera (N= 63)				Omo Nada (N=95)				Limu Seka (N=74)			
	Yes		No		Yes		No		Yes		No	
	F	%	F	%	F	%	F	%	F	%	F	%
Rich	5	50	5	50	8	72.7	3	22.3	5	27.8	13	72.2
Medium	11	40.7	16	59.3	12	23.5	39	76.5	2	6.1	31	93.9
Poor	1	3.8	25	96.2	3	9.1	30	90.9	1	4.3	22	95.7
χ^2 value	18.483***				19.154***				7.143**			
P-value	0.000				0.000				0.032			
Model	12	66.7	6	33.3	8	40	12	60	5	21.7	18	78.3
Non- model	5	11.1	40	88.9	15	20	60	80	3	5.9	48	94.1
χ^2 value	20.226***				3.612 ^{ns}				4.134*			
P-value	0.000				0.276				0.056			

Source: Own survey data, 2015

Where, N = number of respondents, ***, ** and * represent level of significant at 1%, 5% and 10% respectively

Some of the respondents are practiced other agronomic practices such as alley cropping, contour strip cropping and field strip cropping. Accordingly, without considering the status of the respondents, about 44 (69.8%) of Gera, 53 (55.8%) of Omo Nada and 33 (44.4%) respondents of Limu Seka practiced alley cropping. Only about 6 (9.5%) respondents of Gera, 5 (5.3%) of Omo Nada and 4 (5.4%) of Limu Seka respondents practiced contour strip cropping. About 14 (22.2%) respondents of Gera, 27 (28.4%) of Omo Nada and 11 (15%) of Limu Seka practiced field strip cropping. Mulch tillage and minimum tillage are not exercised by the respondents, in which only minimum tillage is practiced by 4 (5.4%) respondents in Limu Seka.

4.6.9. Soil and water conservation measures

4.6.9.1. Planting of vetiver or row of any other grasses

About 7 (70%) of rich respondents of Gera, 8 (72.7%) of Omo Nada and 14 (77.8%) of Limu Seka respondents planted at least one row of vetiver or row of any other grasses. Out of the medium wealth group about 9 (33.3%) Gera, 18 (35.3%) of Omo Nada and about 12 (36.4%) of the Limu Seka have planted the grasses. Most of the poor respondents of the districts do not practiced this conservation measures. Statistically there were significant differences among wealth groups in all the districts (χ^2 = 20.249, df = 2 $P < 0.001$ in Gera, χ^2 =22.256, df = 2, $P < 0.001$ in Omo Nada and χ^2 = 20.543, df = 2 $P < 0.001$ in Limu Seka) (Table 22). In all the three districts, most of the model respondents exercised this measure than non-model farmers and statistically there were significant differences among wealth groups (χ^2 =29.163, df = 1, $P < 0.001$ in Gera, (χ^2 = 8.797, df = 1, P = 0.005 in Omo Nada, (χ^2 = 18.465, df = 1, P = 0.003 in Limu Seka).

According to Takelegn (2011) vetiver system is a very simple, practical, inexpensive, low maintenance and very effective means of SWC, sediment control, land stabilization and rehabilitation. It is also environmentally friendly and when planted in single rows it will form a hedge which is very effective in slowing and spreading runoff water, thereby reducing soil erosion, conserving soil moisture and trapping sediment and farm chemicals on site (Takelegn, 2011). Similarly, row of any other grasses such as elephant grasses and *cynodon dactylon* have advantage to retard erosion and thereby increase infiltration capacity, in doing so soil erosion would be decreased.

Table 22. Frequency, percent and chi square test for planting vetiver or row of any other grasses

Wealth/Extension status	Gera (N= 63)				Omo Nada (N= 95)				Limu Seka (N= 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	7	70	3	30	8	72.7	3	27.3	14	77.8	4	22.7
Medium	9	33.3	18	66.7	18	35.3	33	64.7	12	36.4	21	63.6
Poor	26	100	-	-	1	3	32	97	2	8.7	21	91.3
χ^2 value	20.249***				22.256***				20.543***			
P-value	0.000				0.000				0.000			
Model	13	72.2	5	27.8	11	55	9	45	17	73.9	6	26.1
Non-model	3	6.7	42	92.3	16	21.3	59	78.7	11	21.6	40	78.4
χ^2 value	29.163***				8.797***				18.465***			
P-value	0.000				0.005				0.003			

Source: Own survey data, 2015
Where N = number of respondents, *** level of significant at 1%

4.6.9.2. Hedge row

Hedgerow is a row of shrubs or trees enclosing or separating fields from another field or from neighbouring fields. Hedge row was the common practice in all the three districts. In Gera district about 9 (90%) of rich, 24 (88.9%) of medium and 24 (92.3%) of the poor respondents used hedge rows. About 10 (90.9%) of rich, 48 (94.1%) of medium and almost all poor of Omo Nada respondents used hedge row. In Limu Seka about 15 (83.3%) of rich, 26 (78.8%) of medium and 21 (91.3%) of poor respondents were planted hedge row around their home or/and around their farm land.

In all the study districts, most of the model respondents had exercised this soil and water conservation measures. About 16 (88.9%) of model respondents of Gera, 19 (95%) of Omo Nada and 19 (82.6%) of Limu Seka had exercised this measure (Table 23). Statistically there were no significant differences among wealth group and extension status in all the study districts. This indicates that practicing hedge row was not determined by wealth status and extension status. This study is in line with Zerihun *et al* (2001) and Zerihun and Kaba (2011) who reported practicing of agroforesty that includes hedgerow by most farmers in Jimma area and south western Ethiopia.

Table 23. Frequency, percent and chi square test of planting of hedge row

Wealth/Extension status	Gera (N= 63)				Omo Nada (N= 95)				Limu Seka (N= 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	9	90	1	10	10	90.9	1	9.1	15	83.3	3	16.7
Medium	24	88.9	3	11.1	48	94.1	3	5.9	26	78.8	7	21.2
Poor	24	92.3	2	7.7	33	100	-	-	21	91.3	2	8.7
χ^2 value	0.183^{ns}				3.329^{ns}				2.369^{ns}			
P-value	1.000				1.000				1.000			
Model	16	88.9	2	11.1	19	95	1	5	19	82.6	4	17.4
Non- model	41	91.8	4	8.9	72	96	3	4	43	84.3	8	15.7
χ^2 value	0.074^{ns}				0.541^{ns}				0.600^{ns}			
P-value	1.000				1.000				0.816			

Source: Own survey data, 2015
Where N = number of respondents

4.6.9.3. Physical soil and water conservation measures

Physical measures are structures built for soil and water conservation by considering some principles that aimed to increase the time of concentration of runoff, thereby allowing more of it to infiltrate into the soil; divide a long slope into several short ones and thereby reducing amount and velocity of surface runoff; reduce the velocity of the surface runoff and protect against damage caused due to excessive runoff (Tidemann, 1996).

In Gera district, almost all of the rich respondents, about 9 (33.3%) of medium and 3 (11.5%) of poor respondents had exercised soil bund on their farm land and statistically there was significant differences among wealth group (χ^2 = 24.921, df = 2, P < 0.001) (Table 24). Similarly, all rich respondents of Omo Nada, about 13 (25.3%) of the medium and none of the poor respondents had exercised this measure and statistically there was significant difference among the wealth group in applying physical soil and water conservation measures (soil bund) (χ^2 = 43.698, df = 2, P < 0.001). About 17 (94.4%) of the rich, 5 (15.2%) of the medium and 2 (8.7%) of the poor respondents of Limu Seka had practiced soil bund and statistically there was significance different among the wealth group in applying physical soil and water conservation measures (χ^2 = 41.998, df = 2, P < 0.001).

In the case of the extension status of the farmers most of the model farmers constructed bunds. Almost all model respondents of Gera, about 75% of Omo Nada and 78.3% of Limu Seka constructed bunds. About 8.9% of non-model respondents of Gera, 12% of Omo Nada and 11.8 % of Limu Seka had exercised bunds. Statistically there were significant differences among model and non-model respondents in all the study districts (χ^2 = 46.964, df = 1, P < 0.001 in Gera, χ^2 = 33.191, df = 1, P < 0.001 in Omo Nada and χ^2 = 31.985, df = 1, P < 0.001 in Limu Seka). The common physical SWC measures in the study area were soil bund, and both stone and soil bund were practiced only by very few (about 0.9% respondents).

Most of the farmers of the study area had developed several indigenous technologies since antiquity to overcome the problem of soil erosion by water. These are cut-off-drains locally called *"Boraatii lolaa"*, drainage furrows called *"Bo'oo"* and ridges are other important structures used for soil and water conservation measures. *"Boraatii"* and *"Bo'oo"* are constructed mainly by oxen drawn plough in which *“Boraatii”* are deeper, wider and reinforced by hoeing and other materials than *“Bo’oo”* depending on the amount of slope length and gradient, amount of runoff produced from the field.

“Boraatii” is constructed at the upper end of the field and is used to divert runoff before entering to the crop field. *“Bo’oo”* (semi-parallel drainage furrows) is common in the field of small seeded crops like *tef* and wheat and constructed at relatively closer interval depending on the slope. Ridges are constructed across the slope from the accumulation of weeding over time and makes bund that can serve for soil and water conservation purposes. The practice is similar to the report of Tekilu and Gezahegn (2003) from East Wollega.

Table 24.Frequency, percent and chi square test for PSWC (soil bund) practices

Wealth /Extension status	Gera (N = 63)				Omo Nada (N = 95)				Limu Seka (N = 74)			
	Yes		No		Yes		No		Yes		No	
	N	%	N	%	N	%	N	%	N	%	N	%
Rich	10	100	-	-	11	100	-	-	17	94.4	1	5.6
Medium	9	33.3	18	66.7	13	25.3	38	74.5	5	15.2	28	84.8
Poor	3	11.5	23	8.5	-	-	33	100	2	8.7	21	91.3
χ^2value	24.921***				43.698***				41.998***			
P-value	0.000				0.000				0.000			
Model	18	100	-	-	15	75	5	25	18	78.3	5	21.7
Non-model	4	8.9	41	91.1	9	12	66	88	6	11.8	45	88.2
χ^2value	46.964***				33.191***				31.985***			
P-value	0.000				0.000				0.000			

Source: Own survey data, 2015

Where, PSWC = physical soil and water conservation *** represent level of significant at 1%

4.7. Factors Influencing Farmers Soil Fertility Management Practices

4.7.1. Physical soil and water conservation measures (PSWC)

All of the seven variables hypothesized to explain factors affecting physical soil and water conservation practices were found to influence the practice, except the factors under wealth category (poor category) and educational status (read and write category) (Table 25). Sex was found to be an important variable to influence negatively physical soil and water conservation practices and statistically significant (P = 0.016). Thus, female-headed households are less likely to apply physical soil and water conservation practices as compared to male-headed households by a factor of 0.026. This could be due to the fact that bund construction needs labor and female headed households have less capacity and power to perform the task. Additionally, female headed households are responsible for both farm work and housekeeping which makes them busy and exhausted. This study is inconsistent with previous study conducted by Benin (2006), Desta (2012) and Endrias *et al.* (2013) who reported significant negative relationship between female headed households and terracing.

Binary logistic regression model showed a highly significant negative relationship between age and bund construction. As the age increased the odd of employing physical soil and water conservation decreased by a factor of 0.88. This might be due to the fact that bund construction needs more labor and power, for this reason aged farmers cannot perform the practices. Thus, older household headed have less energy, younger headed households can perform better than aged households. This result agreed with the findings of Million and Kassa (2004) and Derejew *et al.* (2013) who showed non-significant negative relation.

In reference to the rich wealth group, the model output indicated that the application of physical soil and water conservation measure of medium farmers was decreased by a factor of 0.0058 and statistically significant at less than 10% probability level. This result implies the expectation of rich farmers could apply physical soil and water conservation measures than medium and poor farmers. Since wealth status has its own implication on PSWC practices, rich farmers have more probability to invest on their farm land than medium and poor farmers. Mulugeta (1999) and Million and Kassa (2004) reported the influence of wealth status on the application of soil and water conservation practices. Even though there were negative relationship between the third wealth category and the application of the conservation measures statistically it was not significant.

Table 25. Binary logistic regression for physical SWC measures

Variables influenced PSWC	Coef.	Std.error	Odd ratio	P>|z|
Sex of the household	-3.657686 *	1.520612	0.0257921	0.016
Age of the household	-.1261129***	0.0435069	0.8815153	0.004
Wealth status				
Medium	-5.155337*	2.743786	0.0057685	0.060
Poor	-3.559233 ns	2.651131	0.0284606	0.179
Model vs non-model	-3.710465***	1.358085	0.0244661	0.006
Economically active FM	1.886683***	0.4880668	6.597447	0.000
Level of education				
Read and write	-0.2015709 ns	1.048277	0.8174456	0.848
Grade 1-8	2.226044**	.9835492	9.263146	0.024
Secondary and above	3.713931**	1.769875	41.01473	0.036
Farmland size	0.8813332**	0.4179753	2.414116	0.035
Cons	13.75571**	6.007199	-	0.022

Source: Computed from survey data, 2015
Log likelihood = -27.973119, LR chi2 (10) = 228.17, Prob > chi2 = 0.0000, Pseudo R2 = 0.8031
***, ** and * represent level of significant at 1%, 5% and 10% respectively

Extension status of the farmers and number of economically active family members were also important variables that have shown significant relationships. The extension status influenced negatively and significantly. The model result predicted that non-model farmers less likely to apply PSWC practices by a factor of 0.024 as compared to model farmers. This could be due to the fact that model farmers had more chances to be visited by agricultural extension agents than non-model farmers which resulted in the application of PSWC practices. Thus, the present study is in line with Asfaw *et al*. (1997), Baidu-forson, (1999) and Derejew (2013) who reported positive correlation between conservation decision and extension contact.

Whereas, economically active family members influenced PSWC practices positively and statistically highly significant at less than 1% probability level. Respondents who had more economically active family member practices PSWC measures by a factor of 6.60 than farmers with less economically active family members. This means is that the larger economically active family members are the more the likely wood of exercising of PSWC practices which is power intensive. This finding is in line with Million and Kassa (2004) who reported positive and significant results on the influences of economically active family members on terracing activities.

The other categorical variable that influenced positively and significant at 5% probability level was level of education. In references of illiterate households those farmers who attended from grade 1 to 8 had a probability of applying PSWC measures by a factor of 9.26 and statistically significant at 5% probability level. Likewise, those who joined high school and above had a probability of applying the practices by a factor of 41.02, and statistically significant at less than 5% probability level. The first two order of educational level (i.e. illiterate and only read and write) had less likely to apply PSWC practices. This implies that as level of education increases the adoption and application of PSWC practices would increase. This finding was in line with that of Desta (2014) who reported the positive and highly significant influence of education on terracing.

The last continuous variable was farm land size of the farmers which influenced positively and significant at less than 5% probability level. The odd is increased the probability of applying PSWC practices by a factor of 2.41 for farmers with larger farm land size. The possible implication is that those farmers with larger size of land had more likely to participate on the application of PSWC practices than farmers with less farm land size. Greater farms are associated with greater wealth and increased availability of capital, which increase the probability of investment in soil conservation measure (Million and Kassa, 2004).

4.7.2.Intercropping

Among the six variables hypothesized to influence intercropping of legume plants with cereal, five of them had a significant influence (Table 26). Age, wealth, and extension status had influenced negatively and significantly at less than 1% probability level. Thus, older farmers are less likely to practice intercropping of legumes with cereals by a factor of 0.94 than younger farmers. In reference to rich farmers, medium farmers had less probability of applying the practices by a factor of 0.081. Non- model farmers had less likelihood of planting legumes in intercropping with cereals by a factor of 0.148 than model farmers.

Table 26. Binary logistic regression for intercropping of cereals with legumes

Variables influenced intercropping	Coef.	Std. error	Odd ratio	P>|z|
Sex of the household	-0.9408335 ns	0.7501976	0.3903024	0.210
Age of the household	-0.0582056***	0.0202601	0.9434559	0.004
Wealth group				
Medium	-2.513355***	0.961938	0.080996	0.009
Poor	-1.241621 ns	1.058881	0.2889154	0.241
Model vs non-model	-1.908998***	0.5660275	0.1482289	0.001
Education level				
Read and write	0.2014476 ns	0.5286184	1.223172	0.703
Grade 1- 8	0.6017272*	0.5428641	1.825269	0.068
Secondary and above	1.953668**	0.9871391	7.054514	0.048
Farmland size	-0.8616822**	0.3383368	2.367139	0.011
Cons	7.172632***	2.271622		0.002

Source: Computed from survey data, 2015
Log likelihood = -90.45635, Number of obs = 232, LR chi2 (9) =123.94, Prob > chi^2 = 0.0000, Pseudo R2 = 0.4065

Educational status and farm land size were associated positively and statistically significant with intercropping of legumes with cereals. In references of illiterate farmers, those farmers who joined grade 1 to 8 had a probability of applying intercropping of legumes with cereals by a factor of 1.83 and statistically significant at a probability level of less than 10%. Similarly, respondents who joined secondary school and above had a probability of applying intercropping of legumes with cereals by a factor of 7.05 and statistically significant at a probability level of less than 5%. Since education builds the capacity to gather, analyse and interpret information, educated farmers could understand more the importance of intercropping legumes with cereals. Farm land size is also influenced negatively and statistically significant at less than 5% probability level. Farmers with larger farm land size had a less likely wood to practice intercropping of legumes with cereals by a factor of 2.37 than farmers with smaller farm land size. According to the respondents the farmers practiced intercropping in response to land shortage and to keep soil fertility.

4.7.3. Contour plough

Out of the six variables hypothesized to influence contour plough three of them were significantly influenced contour cultivation (Table 27). Sex was associated negatively and statistically significantly at less than 5% probability level. Female headed households are less likely to plough contour by a factor of 0.14 than female headed households. Age of the household also influenced contour plough negatively and significantly.

This implies that older farmers had less likely to practice contour plough than younger farmers by a factor of 0.95. The other variable that influenced negatively and significantly at less than 1% probability level was extension status of the farmers. The non-model farmers had less likely to plough contour than model farmers by a factor of 0.13. The implication is that model farmers have awareness of the advantages of contour plough than non-model, since they had more probability to get training, visiting of development agent and other experts. Whereas the non-model farmers practiced *yafaro* plough which increases the soil erosion.

Table 27. Binary logistic regression for contour plough

Variables influenced contour plow	Coef.	Std.error	Odd ratio	P>|z|
Sex of the household	-1.976739**	0.9387878	0.1385203	0.035
Age of the household	-0.0524798***	0.018713	0.9488735	0.005
Wealth group				
Medium	-1.050956 ^{ns}	0.6811205	0.3496034	0.123
Poor	-1.008027 ^{ns}	0.8075007	0.3649381	0.212
Model vs non-model	-2.025917***	0.491079	0.1318729	0.000
Educational level				
Read and write	0.1069792 ^{ns}	0.5072799	1.112911	0.833
Grade 1- 8	-0.123609 ^{ns}	0.5430402	0.8837253	0.820
Secondary and above	1.420698 ^{ns}	0.8770667	4.140008	0.105
Farm land size	0.158807 ^{ns}	0.2324997	1.172112	0.495
Cons	7.949367***	2.008458		0.000

Source: Computed from own survey data, 2015
Log likelihood = -103.43574, Number of obs = 232, LR chi2 (9) = 89.39, Prob > chi2 = 0.0000, Pseudo R2 = 0.3017

4.7.4. Planting of vetiver or row of any other grasses

Seven variables were hypothesized to influence vetiver and other grass planting that can protect the soil from erosion. Four of them namely, wealth category, extension status, educational level and farm land size had significantly influenced the practices. In reference of rich farmers, wealth category influenced negatively and highly significantly influenced the practice at less than1% probability level. With reference to rich farmers the poor farmers were less likely to plant vetiver/other grasses by a factor of 0.093. It means that rich farmers had a probability of planting the grasses than medium and poor farmers but that of medium farmers was not statistically significant. This implies that rich farmers have more capacity to invest SWC measures on their land. Extension status influenced negatively and statistically significantly at 5% probability level. Non-model farmers had less probability of planting the grass/grasses than model farmers by a factor of 0.37 and statistically significant at 5% probability level. This is in consistency with the prior expectation that model farmers can keep soil fertility than non-model farmers.

Table 28. Binary logistic regression for planting vetiver or row of any other grasses

Variables influenced Vetiver/row of grasses	Coef.	Std.error	Odd ratio	P>|z|
Sex of the household	-1.049022 ns	0.8699085	0.35028	0.228
Age of the household	-0.0078948 ns	0.0196632	0.9921363	0.688
Wealth group				
Medium	-0.7903925 ns	0.6420469	0.4536667	0.218
Poor	-2.378563***	0.8655584	0.0926836	0.006
Model vs non-model	-0.9933839*	0.5071403	0.3703214	0.050
Economically active FM	0.3520934 ns	0.2673724	1.422041	0.188
Educational level				
Read and write	0.7588146 ns	0.5575766	2.135743	0.174
Grade 1- 8	1.704621***	0.4963775	5.499303	0.001
Secondary and above	0.9008768 ns	0.709907	2.461761	0.204
Farm land size	0.5567406**	0.2770638	0.5730739	0.044
Cons	2.514182 ns	2.111486		0.234

Source: Computed from own survey data, 2015
Log likelihood = -96.893364, Number of obs = 232, LR chi2 (10) = 95.18, Pseudo R2 = 0.3294

In reference of illiterate farmers, farmers who joined grade 1 to 8 had a probability of applying the practices by a factor of 5.50 and the difference was statistically significant at less than 1% probability level (Table 28). As it is shown in the table, even though it was not statistically significant educational level was positively correlated to planting of the grasses. Most of the farmers who exercised the practices were found in the educational level of grade 1-8, hence high school and above educational level might use other option of soil and water conservation measures. Farm land size was also associated positively and significantly at less than 5% probability level. Farmers with larger farm size had a probability of planting vetiver/others grasses than farmers with less farm land by a factor of 0.573 and the result was conceded with the hypothesis.

4.7.5. Crop residue management

As indicated in (Table 29), crop residue management was significantly influenced by age, wealth category, educational status and farm land size. Age was negatively associated to crop residue management and significant at less than 10% probability level. Older farmers had less probability of retaining crop residue than younger farmers by a factor of 0.89. There is much competition on crop residue for livestock feed, mad house construction and mattresses. In reference of rich wealth category, the medium farmers had a less likely to retain crop residues on farm land by a factor of 0.00064 than rich farmers which is statistically significant at less than 1% probability level.

This might be due to the farm land size that rich farmers had more lands than medium and poor farmers. The implication is that farmers with larger farm land size could give some of the residues to their livestock and retain partially on the farm land, which is not the case for farmers with smaller farm land size. In reference of rich farmers, the poor category did not show any variation. For this reason, it was not retained in the model.

This implies that the crop residue does not retain on the poor farmers' farm land that might be derived from the small sized farm land. Since poor farmers have less farm land, initially small amount of crop residue was produced on their farm land. This small amount of the residue is grazed by either their animals or others farmer's livestock due to free grazing during off season. In reference of illiterate respondents, respondents who have joined grade 1 to 8 retained crop residues on their farm by a factor of 38.74 which was statistically significant at less than 5% probability level. Those farmers who joined secondary and above had a probability of living residue on their farm lands by a factor of 60.81 than illiterate farmers and this was statistically significant at a probability level of less than 10%.

Table 29. Binary logistic regression for Croprmgt (crop residue management)

Variables influenced Croprmgt	Coef.	Std.error	Odd ratio	P>|z|
Sex of the household	-1.803452 [ns]	2.055955	0.1647292	0.380
Age of the household	-0.1222075*	0.0630384	0.8849647	0.053
Wealth group				
Medium	-7.359271***	2.833749	0.0006367	0.009
Poor				
Model vs non-model	-6.873948***	1.88616	0.0010344	0.000
Educational level				
Read and write	2.679964**	2.838123	14.58457	0.345
Grade 1 – 8	3.656845 [ns]	1.811537	38.73891	0.044
Secondary and above	4.107704*	2.415286	60.80693	0.089
Farm land size	0.9641516 [ns]	1.039048	2.622562	0.353
Cons	20.67797**	8.234545		0.012

Source: Computed from own survey data, 2015

Log likelihood = -13.8411, Number of obs = 150, LR chi2 (8) = 172.49, Prob> chi2 = 0.0000, Pseudo R2 = 0.8617.

5.SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

Agriculture is the pillar of Ethiopian economy and Ethiopians life, which is highly threatened by soil fertility. The study was carried out to reveal how farmers are currently maintaining soil fertility and what are the important socioeconomic factors that influence soil fertility management practices. Decrease in soil fertility, weed, pest and disease and, unseasonal rainfall were the first three ranked causes for crop yield decreasing according to this study. Continuous cropping without crop rotation or cereal followed by cereals, soil erosion, removal of crop residue and low fertilizer applications were the most important factors that causes declining of soil fertility.

The farmers of the study area had been maintaining soil fertility by application of *kosii*, farm yard manures, mineral fertilizers, agronomic and physical soil and water conservation measures. Application of *kosii*, farm yard manure and *boraatii lolaa* (cut off drain) were the important indigenous soil fertility management practices applied by all of the respondents of the study area. However, *kosii* and farm yard manure is limited to home-garden and/ or small size farm land near to home. The farmers were not applying sufficient amount of mineral fertilizers to all crops due to high cost of fertilizers and lack of credit without interest. The farmers applied about 100kg DAP and 100 kg/ha urea with one to one ratio to maize crop whereas to *tef* is far below the blanket recommendation rate. Limited number of cattle and farm land size limited the application of manures and fallowing respectively in the study area. Time and labour consuming and misunderstandings of compost discontinued compost preparation.

Generally, wealth group, extension status, educational level, economically active family members, sex and age of the farmers were important variables that influence soil fertility management practices of the farmers. As a result, those farmers who attended school, who had more economically active family members, male, rich, and model were better in applying soil fertility management practices.

5.2. Recommendations

- The farmers must be involved in the planning process of soil fertility management practices through considering local knowledge and capacity of the farmers.
- Scaling-up of multipurpose trees and improved fodders on marginal and other lands can reduce the competition on crop residues through providing fodders for livestock and at the same time can restore soil fertility.
- Advising and training of the farmers on the expansion of inter cropping (mixed cropping), as much as possible legume based crop rotation that supported with demonstration can change the cropping system of the study area for the improvement of soil fertility.
- Giving training for the farmers on compost preparation aided with demonstration can change the idea of farmers towards compost preparation, so that compost can be an element of soil fertility management in the study area.
- Since high cost of fertilizers and lack of credits are the first two top ranked problems that hindered the farmers to apply sufficient amount of fertilizers regulating cost of fertilizers and facilitating credit with little or no interest can reduce the problem of mineral fertilizes. So, those, smallholder farmers may get access to use mineral fertilizers.
- Initiating the farmers to apply physical soil and water conservation practices on own farm without waiting for turn of mass watershed management and stabilization of the bunds with biological measures is important to maintain soil fertility of the study area.
- Introduction of conservation tillage and training the farmers on contour plough is necessary to reduce the amount of soil lost during repeated cultivation and *yafaro* plough respectively.
- Introducing of lime for acidic soil amendments by soil testing is necessary.
- Planning of strategies that can shift the farmers' economic status can help the farmers to buy mineral fertilizers to improve soil fertility.

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APPENDIX

Appendix I. Interview Questions for Households

1. Identification

Name of the household_____________________________

Zone_______District________*Kebele*_________Zone in the kebele_____*Gare*____________

Enumerator's Name ____________Signature _________Date__________

2. Household characteristics

1.1Household headship 0. Female-headed 1. Male-headed

1.2Age of household head _________________________

1.3Total family size (total number of permanent members of the household) __________

1. Less than 7_____ 2. 7 to 15 ______ 3. Greater than or equal to 15___________

1.4Educational status of household head

1. Illiterate 2. Read and write 3. Grade 1-84. Secondary education and above

3. Household Asset ownership and income

3.1.What is the size of the total area of cultivated land in hectares _______________?

3.2.Total number of animals owned by the household

Type of animal	Number owned	Number held from relative	Total
Oxen and bulls			
Cows and heifers			
Calves			
Donkeys			
Horses			
Mules			
Poultry			
Goat			
Sheep			

3.3.What are the major sources of income for your family?

1.Sell of crop produce 2. Sell of animals 3. Off-farm employment4. Wage labour

5. Other, specify ____

4.Crop husbandry and constraints on crop production

4.1.What are the major crops you grow on your field in order of their importance?

Crop	Rank	Crop	Rank
Maize		Bean	
Tef		Pea	
Sorghum		Others (specify)	
Wheat			
Millet			
Barley			

4.2.Is there change in the yields of the major crops in recent years compared in the past?

1.Yes, declining2. Yes, increasing 3. Decreased and then increased after the past 2-5 years 4. No remained the same

4.3.If crop yields are declining what are the major causes or constraints on production? Rank constraints in the order of importance!

1.Low and erratic rainfall___ 2. Declining soil fertility___ 3. Weeds, pests and disease___ 4. Others, specify ____

4.4.How do you perceive soil fertility? ____

4.5.How do you identify the fertility of your soil? ___________________________________

4.6.If soil fertility is declining, indicate the major causes for it; give in priority ranking?

1.Low fertilizer application____ 2. Soil erosion is severe on my field____

2.Continuous cropping __________4. Other causes, specify _______________

5. Soil fertility management practices employed by the farmer

5.1.How do you maintain fertility of your fields?

1. Applying of *kosii* 2. Applying of mineral fertilizers 3. Applying farm yard manure

4. Compost 5.1, 2 and 3 6. 1, 2, 3 and 4

5.2.If you apply mineral fertilizer, indicate the amount you applied last season by fertilizer type?

Crop	Type and amount of fertilizers applied last season (kg/ha)	
	DAP	Urea

5.3.If you apply fertilizer, what form of application? 1. Broad cast 2. Band

1.Which form of application gives more yields? 1. Broad cast 2. Band 3. No difference

5.4.If you do not apply fertilizer, what are the major reasons for not using fertilizer? Give response in order of importance!

1.High cost of fertilizer________ 2. Lack of credit_____ 3. Risk of crop failure unseasonal rainfall___________4. Fertilizer is not available on time

5.5. Do you apply farm yard manure to crop fields? 0. No 1. Yes

5.6. If you apply farm yard manure to fields, which fields do you apply to?

1.Home gardens 2. Outer fields 3. Both fields

5.7.If you apply farm yard manure indicate the amount you applied last season?

Field type	*Gundo/sefed*/ha

5.8.If you do not apply to outer fields why?

1.Competing for energy source 2. Transportation problem 3. Limited number of livestock 4. My livestock are away from me

5.9. Do you make compost and apply to fields? 0. No 1. Yes

6. Agronomic Practices

6.1. Do you practice crop rotation in your fields? 0. No 1. Yes

6.2. If you rotate crops, indicate rotational pattern in the same plot in the table below

Crop planted before last year in this plot	Crop planted last year in the same plot	Crop to be planted next year in the same plot

6.3. What is the advantage of crop rotation?

1. To improve soil fertility 2. To decrease incidence of pest and diseases 3. Both

6.1. Do you practice intercropping legumes with cereals? 0. No 1. Yes

6.2. If you practice intercropping, indicate which crops are intercropped?

Cereal crop	Legume crop

6.3. What is the purpose of intercropping?

1. To improve soil fertility 2. Respond to land shortage 3. Both 4. Others ________

6.4. Do you practice fallowing? 0. No 1. Yes

1. If yes which type of fallowing? 1. Improved 2. Non-improved

6.5. How long of fallow period? 1. One year 2. 2-5 years 3. 5-10 years

6.6. Are there other agronomical and biological measures that you practice? If you practice indicates which agronomic practice, you employ?

Agronomical and Biological Measures (thick)		
1.Contour plough	Yes	No
2.Strip cropping		
i.Contour strip cropping		
ii. Field strip cropping		
3. Tillage practices		
i. Mulch Tillage		
ii. Minimum tillage		
3.Vetiver grass planting/row of any other grasses		
4. Alley Cropping		

7. Soil and water conservation practices

7.1. Is soil erosion severe on your crop fields? 0. No 1. Yes

7.2. Do you practice soil and water conservation on your fields? 0. No 1. Yes

7.3. If you practice soil conservation, indicate which physical measures you constructed

Soil and water conservation measure	Thick	
Soil bund and trench		
Stone bund		
Terraces (bench or level)		

8. Crop residue management

8.1. Do you remove crop residue from fields? 0. Yes totally 1. Yes, partially

8.2. What do you do with crop residues removed from fields?

1.Burn as household fuel 2. Feed animals 3. Both 1 and 2 4. Other, specify

____

8.3. If you feed crop residue to animals, how do you manage the manure?

1.Burn as household fuel 2. Apply to crop fields – mainly gardens 3. Fence

4. 1, 2 and 3 5. Burn on soil

8.4. How do you manage your farmland with respect to grazing?

1.Free grazing on farm area during offseason and control grazing during production season2. Control grazing on grazing land 1i all season 3. Free grazing on grazing land in all season

9. Do you apply lime for the amendment of acidic soil? 0. No 1. Yes

Appendix II. Interviews for Focal Group Discussion (FDG)

1. Is there change in crop yield compared to the past? If there is change, increased or decreased? Why?
2. How do you understand soil fertility?
3. What is the status of soil fertility on your farmland/ *kebele*?
4. If soil fertility is decreased, what are the major causes?
5. What are your indicators to say this farmland is fertile or not?
6. How you/the farmers manage soil fertility (indigenous and improved)?
7. Do you/other farmers apply sufficient amount fertilizers to all crops? If not, why?
8. Do you/other farmers employ physical soil and water conservation practices? If not, why?
9. What is the problem to apply sufficient number of mineral fertilisers to all crops?
10. What do you do with crop residues?

Appendix III. Interview for Key Informants

1. How you understand wealth status in your area?

2.What are the criteria to categorize farmers as rich, medium and poor? Would you list the criteria's?

Wealth category	Criteria	Remark
Rich		
Medium		
Poor		

3.According to the listed criteria please categorise your *gares and kebeles* farmers?

No	Name of the farmers	Rich (thick)	Medium (thick)	Poor (thick)

Appendix Table 1. Multicollinearity test of predictors of intercropping, contour cultivation and crop residue management

Variables	VIF	1/VIF
HHHSh	1.16	0.861172
AgeHH	1.28	0.778993
WhC		
Medium	3.76	0.266132
Poor	4.86	0.205565
ExtSta	1.89	0.528552
EdStHH		
2	1.16	0.865466
3	1.82	0.549733
4	1.29	0.775343
Farmlandsize	1.66	0.602517
Mean VIF	2.10	

Source: Computed from own survey data, 2015

Where 2 = can read, and write, 3 = grade 1-8, 4= high school and above

Appendix Table 2. Multicollinearity test of predictors of vetiver/any other grasses and physical soil and water conservation measures

Variables	VIF	1/VIF
Variables		
HHHSh	1.16	0.858738
AgeHH	1.33	0.753970
WhC		
Medium	3.82	0.261785
Poor	4.92	0.203217
Noadamhh	2.13	0.469446
ExtSta	2.00	0.499199
EdStHH		
2	1.16	0.858978
3	1.88	0.531722
4	1.30	0.768830
Farm land size	1.71	0.586164
Mean VIF	2.14	

Source: Computed from own survey data, 2015

Where 2 = can read, and write, 3 = grade 1-8, 4= high school and above

Appendix Figure 1. Discussion with FGD, key informants and interviewing

Appendix Figure 2. Crop residues management in Omo Nada