# SOCIO-ECONOMIC DETERMINANTS OF SUSTAINABLE LAND MANAGEMENT PRACTICES AMONG SMALLHOLDER FARMERS IN SABATIA SUB-COUNTY, KENYA

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## DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with our approval as University supervisors.

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# DEDICATION

This thesis is dedicated to my father the late JoramAmbuziAndahi.

## ABSTRACT

This study investigated the socio-economic factors that determine farmers' decision to use sustainable land management practices (SLMP) – agroforestry, terracing, and manure use - aimed at achieving long-term agricultural productivity in Sabatia Sub-County, Kenya. Four specific objectives were addressed, namely: (a) to identify the SLMP in the study area; (b) to assess the effects of farmers' social characteristics on their use of SLMP; (c) to examine the effects of farmers' economic characteristics on their use of SLMP; and to establish the impact of use of SLMP on agricultural productivity in the study area.

The study was guided by two hypotheses that is (i) there is no significant relationship between farmer's social characteristics and use of SLMP. (ii) there is no significant association between farmer's economic characteristics and adoption of SLMP. A multi-stage random sampling technique was applied in selecting farmers to be used in the study. A sample size of 125 farmers cultivating undulating farms which were deemed most vulnerable to land degradation was tested in the clusters that were selected. Primary data for the study was collected through household questionnaire surveys, key informants interviews, and personal observations while secondary data was obtained from relevant published and unpublished reports and records. Data was analyzed by the use of mean, frequency count, percentage, simple regression, chi-square ($\chi^2$) test and stepwise multiple regression analysis.

The study established that smallholders'; membership to farmers' group(s) gender and farming experience (r = 0.420) had an influenced on their use of manure while; farm size, annual income, and level of education did not affect the use of manure among small-scale farmers in Sabatia. Farmers’ decision to use terraces and agroforestry was determined by; farm size (r = 0.218), annual income (r = 0.364), gender, level of education (r = 0.258) and membership to farmers’ group(s). The farming experience of the peasants, however, did not have an impact on terraces and agroforestry in the study area. Use of sustainable land management practices (SLMP) positively impacted on agricultural productivity in the study area

The study recommends the need for the government through agricultural extension officers to mobilize smallholders to embrace the use of SLMP so as to boost their agricultural productivity. The study further suggests the need to involve both female and male household heads in the uptake of agroforestry and terracing. It also recommends the need to boost access to formal education so as to improve farmers' awareness and use of SLMP. The study also found out that smallholders should engage more in income generating activities which are likely to translate into improved use of SLMP. Smallholders are encouraged to join farmers' groups to improve their awareness and adoption of SLMP. Initiatives that are aimed at popularizing the use of alternative sources of wood fuel should be encouraged to reduce deforestation by the smallholders.

## ACKNOWLEDGEMENT

First, I would like to thank the Almighty God for good health during my entire study period.

I also wish to thank my employer, the Teachers' Service Commission for granting me study leave to pursue this course. Without being exempted from my day to day duties, it would have been difficult to realize this dream.

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My acknowledgment and appreciation cannot be complete without paying tribute to my entire family especially my wife, Emily, and children; Maureen, Faith and Bruce whose patience, encouragement, moral support and prayers I depended on.

All said and done; I am solely responsible for any error, omission and mistakes in this thesis.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **CAN** | Calcium Ammonium Nitrate |
| **CBO** | Community Based Organization |
| **CBS** | Central Bureau of Statistics |
| **DAP** | Diammonium Phosphate |
| **df** | degrees of freedom |
| **FAO** | Food and Agricultural Organization |
| **GOK** | Government of Kenya |
| **KNBS** | Kenya National Bureau of Statistics |
| **MDG** | Millennium Development Goals |
| **MOA** | Ministry of Agriculture |
| SDG | Sustainable Development Goals |
| **SLMP** | Sustainable Land Management Practices |
| **SPSS** | Statistical Package for Social Sciences |
| **SWC** | Soil and Water Conservation |
| **UNCCD** | United Nations Convention to Combat Desertification |
| **WCED** | World Commission on Environment and Development |
| **WOCAT** | World Overview of Conservation Approaches and Technologies |
| $\chi^2$ | Chi square |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the Study

Agriculture is an important pillar of Kenya's economy. It contributes approximately 24 percent of the Gross Domestic Product (GDP), about 75 percent of the industrial raw material and 60 percent of export earnings (GoK, 2013). The sector accounts for 18 % and 60 % of formal and total employment respectively (ibid). Land degradation, however, continues to undermine agricultural productivity and threatens food security in the country. Heyi and Mberegwa (2012) define land degradation as the temporary or permanent lowering of the soils productive capacity. The major types of land degradation which occur include water and wind erosion, chemical degradation processes (*including depletion of organic matter and loss of nutrients, salinization, acidification and soil pollution*) and physical degradation processes (*including compaction, crusting and waterlogging;*Syers*et al.*, 1997). As a result of degradation cropland in Kenya has decreased from 0.43 ha to 0.26 ha per capita in the period from the 1960s to the 1990s (Gabathuler*et al.,*2009). If this trend is not adequately addressed the country will be faced with acute food shortage in future. Land degradation occurs mainly due to; mismanagement, overgrazing and deforestation (Syers*et al.,*1997).

Recently, Sustainable Agriculture (SA) has emerged as an alternative agricultural system that addresses adequate food production and the same time ensures environmental conservation. Sustainable agriculture emphasizes food systems that are profitable, environmentally sound, energy efficient and improves the standard of life for both producers and the consumers. Sustainable agriculture is attainable through the adoption of sustainable land management practices (SLMP). These include activities such as; manure use, terracing, and agroforestry.

Concerns have been raised as to whether sustainable agriculture can be productive enough to ensure food security. It has however been established that sustainable agriculture practices have increased agricultural productivity with minimum damage to the environment compared to conventional farming. A review of 286 sustainable agriculture projects carried out by Kassie and Zikhali (2009) between 1999 and 2000 in 57 developing countries in Asia, Africa, and Latin America revealed that farmers increased their yield by an average of 79 percent by adopting sustainable agricultural practices.

Efforts have been made by both colonial and post-colonial governments to halt and reverse the ugly trend of land degradation in the country. In the 1930s the Colonial Government in Kenya recognized and attempted to address the problem of land degradation (Thomas, 1997) through the construction of terraces to reduce soil erosion. This initiative which was implemented using forced labour was short-lived as it was abandoned in 1963. Alarmed by the adverse effects of continued soil erosion, Kenya's Independence Government established a program to deal with the problem in 1974 (Nyangena and Köhlin, 2008). Between 1974 and 1993, about 1.4 million farms were conserved, and roughly 800,000 farmers, 50,000 youth, 43,000 community leaders, 23,000

Government officers and 14,000 school teachers were trained on sustainable land management practices (Thomas, 1997).

The current trends of soil degradation suggest that the present levels of sustainable land management practices adoption are inadequate. As recent as 2003 the degraded land in Kenya was 104 994 $km^2$ representing 18.02 percent of the total surface area (Bai *et al*., 2008). Although farm productivity capacity can be enhanced by application of chemical fertilizer, Kassie, and Zikhali (2009) observe that inorganic fertilizer loses effectiveness when the organic matter in the soil is low.

There is a need for sustained investment in optimizing and adapting land management technologies to their specific environments so as to improve agricultural productivity. In dry areas, investing in water harvesting and improved water use efficiency, combined with improved soil fertility management, should be emphasized to increase production, reduce the risk of crop failure and lower the demand for irrigation water. In humid areas like the study area, long-term investments are required to maintain soil fertility and minimize on-site and off-site damage caused by soil erosion (WOCAT, 2007).

**1.2 Statement of the Problem**

This is a geographical study that seeks to establish the socio-economic determinants of sustainable land management practices (SLMP) among smallholder farmers in Sabatia Sub-County. Contrary to the Kenya Government aspiration to grow the agricultural sector so as to reduce food insecurity by 30 percent by the year 2020, agricultural productivity in Sabatia is low and declining. Low maize yield that averages four (4) bags per acre per season as compared to its potential of fifteen (15) bags attest to this (GoK, 2013).

Land degradation is one of the primary reason behind poor agricultural performance in the study area.Kuile (2004) and GoK (2013) blame land degradation in Sabatia on; low adoption of SLMP, poor land management practices such as over-cultivation, inadequate and unaffordable credit, expensive farm inputs and reduced access to agricultural and extension services by smallholder farmers. Although the decrease in agricultural yields, to some extent, can be reversed by an increase in fertilizer inputs, many farmers are too poor to afford. Also, fertilizers, if not properly used, may aggravate negative environmental externalities, such as pollution of surface and ground water.

Empirical studies (Nyangena and Köhlin, 2013 and Musikoyo, 2012), have shown that adoption of SLMP can turn around low farm productivity. However, according to Babalola and Olayemi (2013), the rate at which farmers are adopting soil and water conservation technologies in developing countries including Kenya is worrying. This study was designed to determine smallholders' attributes that influence their decision to use or not to use SLMP. The findings of this study are important to planners and other stakeholders in the agricultural sector in addressing the challenge of land degradation.

Several studies (Simon, et al., 2013; Babalola and Olayemi, 2013; Fakoya, et al., 2007; Heyi and Mberegwa, 2012)have been done in several countries on land degradation and determinants of land management practices. In Kenya, two studies (Nyangena and Köhlin, 2013 and Musikoyo, 2012) investigated land degradation and the impact of adopting SLMP on agricultural productivity and food security. WOCAT (2007) pinpoints; manure use, terracing, and agroforestry as the most important land management practices on undulating farms within the tropics at an altitude between 1000 metres and 2000 metres above sea level. These regions experience relatively high precipitation (about 2000 millimeters per annum) which renders them susceptible to soil degradation.

None of the reviewed empirical studies has analyzed the composite application of the three SLMPs within the ecological set up of the study area and the factors that influence their adoption. Further, previous studies on determinants of SLMP might not have given the actual picture on the ground as they analyzed variables at nominal level. The current study analyzed the variables at ordinal level and above.

## 1.3 Study Objectives

### 1.3.1 General Objective

The general aim of the study was to establish the socio-economic determinants of Sustainable Land Management Practices (SLMP) among smallholders in the study area.

### 1.3.2 Specific Objectives

The study addressed the following specific objectives;

1. To identify the SLMP practices in the study area.
2. To assess the effects of farmers' social characteristics on the use of SLMP

3. To examine the effects of farmers' economic characteristics on the use of SLMP
4. To establish the impact of SLMP use on agricultural productivity in the study area.

## 1.4 Research Questions

This study sought to answer the following questions;

1. To what extent are sustainable land management practices (SLMP) used by smallholder farmers in Sabatia?
2. How do small-scale farmers' social characteristics determine their choice of SLMP in the study area?
3. How do smallholders' economic attributes determine their choice of SLMP in the study area?
4. To what extent do use of SLMP impact on agricultural productivity in the study area?

## 1.5 Research Hypothesis

1. $H_o$: There is no significant relationship between farmer's social attributes and use of SLMP.

$H_1$: Alternative

2. $H_o$: There is no significant relationship between farmer's economic characteristics and use of SLMP.

$H_1$: Alternative

## 1.6 Justification and Significance of the Study

Sustainable land management practices (SLMP) promise to improve agricultural productivity (Thomas, 1997) and hence address the challenge of food security in the study area. However, adoption of SLMP by smallholder farmers is low and calls for attention. This study is significant as it seeks to establish why some farmers fail to embrace SLMP while others do.

The identification of active socio-economic determinants of SLMP will inform decision makers and instruct policy on satisfactory SLMP intervention programme in the study area hence improve agricultural productivity.

## 1.7 Scope and Limitations of the Study

This study was conducted in Sabatia Sub-County of Vihiga County, Kenya. This study area was chosen because it is characterized by low agricultural productivity resulting from land degradation among other factors. Beside, Sabatia is highly populated as suggested by the areas' high population density of 1,203 persons per $Km^2$(GoK, 2010). A lot of food is needed to feed this population which is projected to grow even higher.

Several SLMP can be used to address the challenge of land degradation. However, the use of; manure, terraces, and agroforestry were deemed most appropriate in the study area (WOCAT 2007) hence studied.

Many factors influence the use of SLMP including but not limited to; agro-ecological, biophysical and even socio-economic factors. This study, however, was restricted to the impact of socio-economic determinants of SLMP use.

Inadequate time, as well as limited finances, was the primary limiting factor to the success of the study. Multi-stage sampling which is less costly than Simple random sampling and Systematic random sampling was used to help cut on time and cost. Four clusters (Kigama, Bukulunya, Kisatiru and Kedoli sub-locations) were selected and households obtained by simple random sampling technique.

## 1.8 Operational Definition of Terms and Concepts

**Agroforestry:** this is land use system in which woody perennials are grown in association with crops or pastures and or livestock in one management unit. (Gitonga, 2012).

**Composting:** this isthe natural process of turning organic materials, such as crop residues and farmyard manure, into valuable plant food or humus (Mati 2005).

**Farmers group**: this is an association of farmers who have come together to pursue a mutual interest especially related to agricultural or environmental issues. They are a basis for community participation development activities, extension services and lead to community empowerment. They are a form of social capital among farmers that enable mutual support, shared learning and pooling of resources together. They generate peer pressure and collective wisdom that nudges and guides farmers towards good practices (Gitonga, 2012).

**Household:** refers to individuals who live together in the same dwelling unit or homestead and eat from the same pot (GoK 1990).

**Land degradation:** refers to the temporary or permanent lowering of the soils productive capacity (Heyi and Mberegwa 2012).

**Manure:** this refers to organic materials, such as crop residues and farmyard manure that is used to fertilize the land.

**Socio-economic factors:** Socio-economic rather than economic or social factors is a term adapted to explicitly emphasize the interconnection between social and economic factors as seen from an agricultural standpoint (Wambua 2008). Socio-economic is applied in this study to refer to human social characteristics (age, educational level, membership to farmers' association and gender) as well as economic attributes (farm size, household income).

**Sustainable Agriculture:** refer to site-specific ranching and farming practices that are designed to address the present and future demands for food, fiber, energy, and ecosystem services (Menallede*et al.* 2008)

**Sustainable Land Management Practices (SLMP):** alsotermed as Soil and Water Conservation (SWC)Technologies SLMP refer to agronomic, vegetative, structural and management measures that prevent and control land degradation and enhance productivity in the field (WOCAT, 2007).

**Smallholder farmers:** these are farmers who cultivate farms sized under two hectares (5 acres) (Hilmi, 2012). About 80 per cent of farmers in Kenya are smallholders (Acland 1971). Smallholder farmers and small scale farmers will be used interchangeably in this study.

**Terraces:** unit consisting of a relatively steeply faced structure across the slope, that supports above it a relatively flat lawn bed (Gebregergis, 2016).

# CHAPTER TWO

# LITERATURE REVIEW, THEORETICAL AND CONCEPTUAL FRAMEWORK

## 2.1 Introduction

This section focused on the literature related to the current study. Theoretical and empirical aspects of sustainable land management practices among the smallholder farmers were reviewed with regard to global continental and national perspective which are also related to the local area of study. Consideration of these empirical studies acted as a guide to the identification of gaps from previous researches carried out in the same area. The literature review also enabled the identification of appropriate theoretical model to guide the investigation. Both literature review and theoretical model formed the basis for study hypothesis formulation.

## 2.2 Literature Review

### 2.2.1 The Concept of Sustainable Agriculture

Latest estimates indicate that nearly 2 billion hectares of land worldwide are already seriously degraded, some irreversibly (FAO, 2010). About 16%, representing over 494.2 million hectares of land is degraded in Africa (Babalola and Olayemi, 2013). By 2003 the degraded land in Kenya was 104 994 km2 representing 18.02 percent of the total surface area (Bai et at.2008). This poses a threat to agriculture as in the near future it may not meet its obligation of feeding the ever-increasing world population. In the recent times, sustainable agriculture has emerged as an alternative agricultural system that addresses adequate food production and the same time prevents or reverses land degradation.

Sustainable agriculture also termed as regenerative farming aim to produce food and fibre on a sustainable basis and repair the environmental damage caused by farm practices (SARE 2003).

Sustainable Land Management Practices (SLMP) is perhaps the vehicle to achieving sustainable agriculture. Table 3.1 summarizes the most widely used SLMP.

***Table 2.1: Sustainable Land Management Practices***

| No. | Category | Example of SLMP |
|---|---|---|
| 1 | Soil and Water Management | (i) Terraces<br>(ii) Contour ploughing<br>(iii)Hedgerows and living barriers<br>(iv)Conservation tillage<br>(v) Mulches, cover crops<br>(vi)Water harvesting |
| 2 | Soil fertility management | (i) Agro-forestry<br>(ii) Manure and compost<br>(iii)Biomass transfers and green manure |
| 3 | Crop establishment | (i) Intercropping<br>(ii) Alley cropping |
| 4 | Controlling Pests and Diseases | (i) Intercropping<br>(ii) Crop rotation |

Source: Adapted from Kassie and Zikhali, (2009)

Different SLMP technologies are adapted to the prevailing environmental conditions. Manure use, agroforestry, and terraces are the most important SLMP for inter-tropical areas that are characterized by hilly terrain and high precipitation above 1000 mm per annum (WOCAT, 2007). These areas are susceptible to land degradation such as soil erosion, leaching, compaction and acidification (ibid). Given the undulating nature of its topography and the amount of annual rainfall (1900mm) experience, Sabatia is such an area.

In the present study, the socio-economic factors (gender, membership to farmers' groups, education status, farming experience, income and farm size) that determine the use of SLMP (manure, terraces, and agroforestry) among smallholders in Sabatia Sub-County are investigated. It is hypothesized that the use of SLMP is determined by farmers' socio-economic characteristics among other factors. The following empirical studies attempt to demonstrate and support the hypothesis.

### 2.2.2 Sustainable Land Management in Sub-Saharan Africa

According to Babalola and Olayemi (2013), adoption of sustainable land management practices (SLMP) among farmers can be more effective if their access to education is enhanced and also if they participate more in Community Based Organization (CBO). These two factors were found to have a significant positive influence on the adoption of; agroforestry, terracing, multiple cropping, mulching, crop rotation, minimum tillage and zero tillage in Ogun state, Nigeria. This study was rather too broad as it examined many SLMPs concerning only two crops – maize and cassava. The present study reviewed the adoption of fewer SLMPs – terracing, manure use, and agroforestry as applied in the production of a variety crops in the study area, not just maize and cassava. Further in Babalola and Olayemi (2013) study variables were analyzed at nominal scale. The current study will examine variables at interval scale.

Based on their findings, Simon, et al., (2013) recommended that arable crop farmers in the Taraba State of Nigeria should be exposed to agricultural education, as this variable has the likelihood of increasing the use of SLMP.

This study though similar to the current study did not analyze the influence of household's income and gender on the adoption of SLMP, which the present study addressed among other determinants.

Heyi and Mberegwa (2012) found out that educational status of farmers and their access to extension services had significant positive impact on farmers' use of both terracing and manure. Besides, the age of farmers and number of livestock had significant positive influence on manure application, but not on terracing. Heyi and Mberegwa (2012) also observed that access to credit had a significant adverse impact on the use of terraces. Other factors such as farmers' perception on land degradation on their farmland, farm size and the number of economically active household members were found not to have a significant influence on both terracing and manure application. Unlike Heyi and Mberegwa’s study which focused on only two SLMPs - terracing and fertilizer use- this study also included agroforestry which is hypothesized to be prominent in the study area.

According to Raufu and Adetunji (2012), male education at secondary and tertiary level had significant positive impact on land management practices use contrary to female education among crop farmers in South-Western Nigeria. Males with Secondary and Tertiary Level of education had a higher likelihood of practicing crop rotation and encouraging fallowing. Education at the tertiary level in men is a signal of higher opportunity cost of labor in more educated households, directly encouraging fallowing of agricultural land. But female education at all levels had no significant impact on land management practices.

They also found no significant relationship between access to credit and land management practices.

Fakoya, et al. (2007) established that women attitude towards adoption of sustainable land management practices was low to neutral in South-Western Nigeria. They attributed this to ignorance on the part of the farmers as the majority of them are not aware of the benefits or damaging effects of certain land management practices. Based on their findings they recommended an increase in environmental education campaign, particularly on land management. Unlike this study which dwelt on women farmers' attitude towards sustainable land management practices the current research focused on both genders, among other variables.

Kassie et al. (2009) observed that reduced tillage rather than chemical fertilizers enhance crop productivity in the low-rainfall region of Ethiopia. In the humid area, however, chemical fertilizer is overwhelmingly superior, and reduced tillage potentially results in productivity losses. Their results underscored the need to understand the role of agroecology in determining the profitability (regarding productivity gains) of farm technologies. Unlike this study that focused only on one sustainable land management practice in two different agro-ecological zones, the current study analyzed key SLMP in one ecological zone.

### 2.2.3 Sustainable Land Management in Kenya

In Kibos near Kisumu in Kenya, Onim et al. (1990) established that small-scale farmers who were using goat manure had superior farm yields than their counterparts who were relying on DAP fertilizer.

Nyangena and Köhlin, (2008) investigated the impact of soil and water conservation (SWC) investment on farm productivity in three regions in Kenya. They established that SWC increased the returns from degraded plots. Returns to soil and water conservation were the main interest to Nyangena and Köhlin (2008) study. The current study, besides paying attention to the impact of SLMP, also analyzed the socio-economic determinants of farm technology adoption among farmers.

In Ndabibi Location of Nakuru County in Kenya, farmer's socio-economic characteristics namely; educational level, membership to farmers' association, accessibility to extension services, the level of income, and land tenure system had a significant positive influence on the adoption of agroforestry. Dependence on forest products and services was however inversely related to adoption of agroforestry that is farmers who are more dependent on forest exhibit low adoption of agroforestry compared to those who least depend on it (Gitonga 2012).

According to Musikoyo (2012), adoption of sustainable agricultural land management practices had positive influence on food security in Bungoma County. Before adoption of SLMP, 31.3 percent of the sampled farmers were food-secure for at least seven months in a year. However, four years after the adoption of sustainable agricultural land management practices all the sampled households were food secure for at least seven months.

**2.3 Summary of Literature and Research Gaps.**

From the review of the empirical studies done in the area of sustainable land management practices (SLMP), the main socio-economic which have been hypothesized to influence adoption of SLMP are; educational status of farmers, access to extension services, Age of farmers, farm size, gender and membership of Community Based Organization.

Manure application, agroforestry, terracing, multiple cropping, mulching, crop rotation minimum tillage and zero tillage are the most prominent SLMP assessed in the previous empirical studies reviewed. Some studies have examined determinants of a single land management practice while others have investigated the determinants of SLMP adoption regarding particular crops. Other studies have focused on the impact of adopting SLMP. Some research gaps were identified which this study attempted to fill. These included;

1. Most similar studies examined variables at nominal scale (dummies) that is they considered only whether or not a farmer has adopted SLM practice. They may not have portrayed the actual picture on the ground. This study thus analyzed the variables at interval scale that is the number of trees per acre; the amount of manure applied and the number of terraces established per acre.
2. No research on socio-economic factors that influence the use of Sustainable Land Management Practices has been done in the study

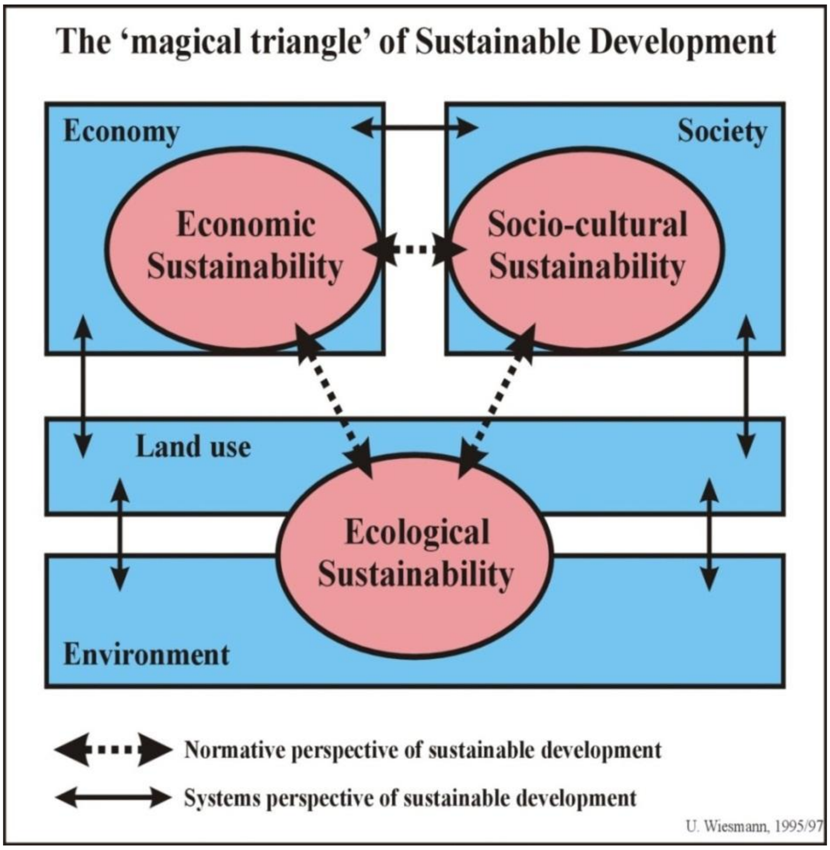
area. It would be wrong to assume that findings of similar studies elsewhere also apply to Sabatia.

## 2.4 Theoretical and Conceptual Framework

### 2.4.1 Theoretical Framework

This study was based on two theoretical models; the environmental possibilism and the sustainable development models. The theory of environmental possibilism opine that nature does not wholly determine the activities of human beings but rather it creates the possibilities from which man can make choices (Singh & Dhillon 1984). Fekadu (2014) observes that man is never entirely free from the influence of environment, but there is room for the effort of man, such as technology, attitude, habits, and values of human, which enable him to influence the physical environment.Environmental Possibilism Model inspires attainment of food security. This is in the sense that man can manipulate the otherwise unfavorable farming environment to increase food production. The use of SLMP in the study area is seen as man's intervention to stop and/or reverse the adverse impact of land degradation.

Sustainable development coined and propagated by the World Commission on Environment and Development (WCED) in 1987; refer to development which meets the needs of the present without compromising the ability of future generations to meet their needs (Harris 2000). This concept stresses three elements of sustainability namely; economic, environmental and social aspects (Figure 2.1).




Source: Wiesmann 1995/97

***Figure 2.1: Interconnectivity between the Economic, Social and Ecological Aspects of Sustainable Agriculture***

Sustainable agriculture and by extension use of SLMP is geared towards making agriculture and environmentally, socially, and economically viable activity for both present and future generations (Harris, 2000).

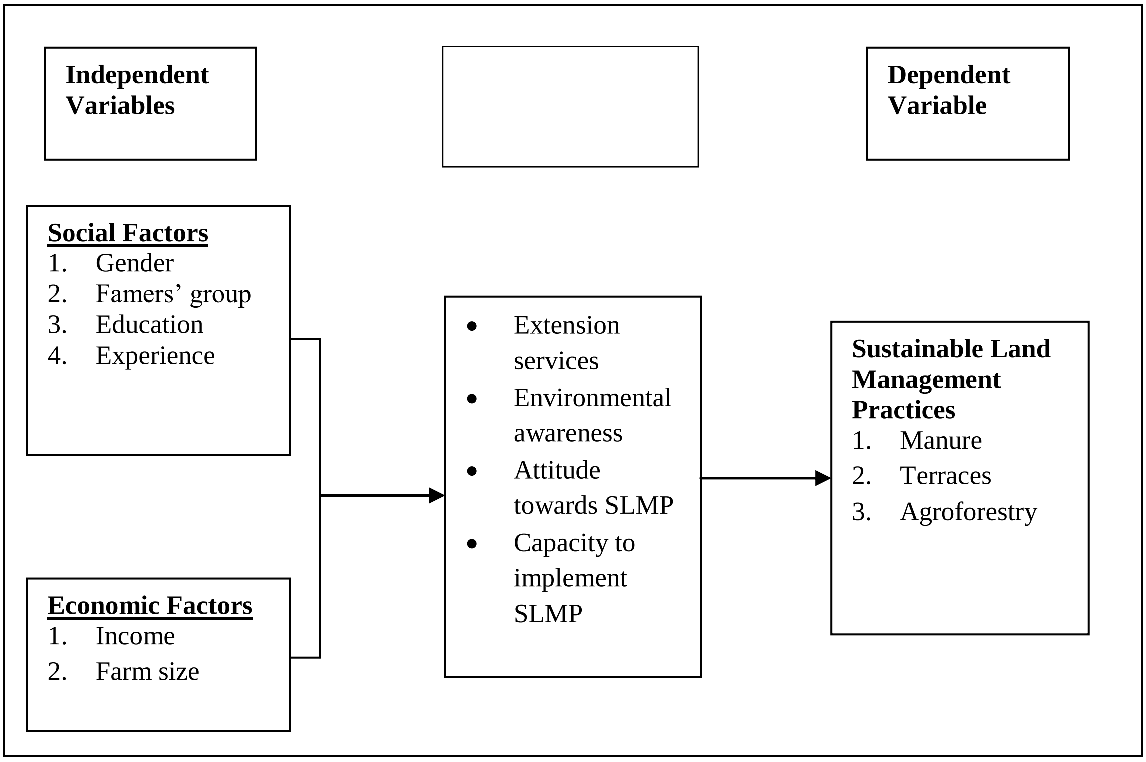
Agriculture is truly sustainable if farming is economically profitable. Sustainable agriculture can boost the economic viability of the farm in many ways. Improving soil health by addition of organic content can increase yields. Reducing the use of farm machinery, chemical fertilizers and pesticide as is the case under sustainable agriculture enhances the economic viability of the sector (Kassie and Zikhali, 2009).

Ecological sustainability in the agricultural sector is achieved through the use of ecologically sound practices – SLMP – that have a minimum adverse effect on natural ecosystems or even enhance the environmental quality upon which agriculture depends on. Under sustainable agriculture, a synthetic fertilizer that can supplement natural inputs is applied on needs basis. Agrochemicals that are known to harm soil organisms, soil structure, and biodiversity, are avoided or reduced to minimum use (ibid).

Social sustainability is achieved if the quality of life of those who live and work on the farm as well as` the surrounding communities is seen to improve. Agrochemicals that are likely to injure them should be minimized or eradicated. Further, they should access yields at affordable prices (ibid)

### 2.4.2 Conceptual Framework

The conceptual framework of this study (Figure 3.2) shows the interrelationship between the independent variables (Social and Economic factors) intervening variables and dependent variable (use of SLMP).




Source: Researcher (2015)

***Figure 2.2 Conceptual Framework***

It is hypothesized that Farmer's socio-economic characteristics (Age, Gender, Level of education, membership to farmers' group(s), annual income and farm size) influence smallholder's; attitude towards use of the SLMP, capacity to implement SLMP and environmental awareness. These, in turn, determine whether or not a farmer will employ SLMP – terracing, manure application, and agroforestry – on their farm. Positive influence results in the use while negative control results in none or less use of SLMP. Adoption may translate to improved agricultural productivity hence food provision for present and future generations.

# CHAPTER THREE

# HUMAN AND PHYSICAL CHARACTERISTICS OF THE STUDY AREA

## 3.1 Introduction

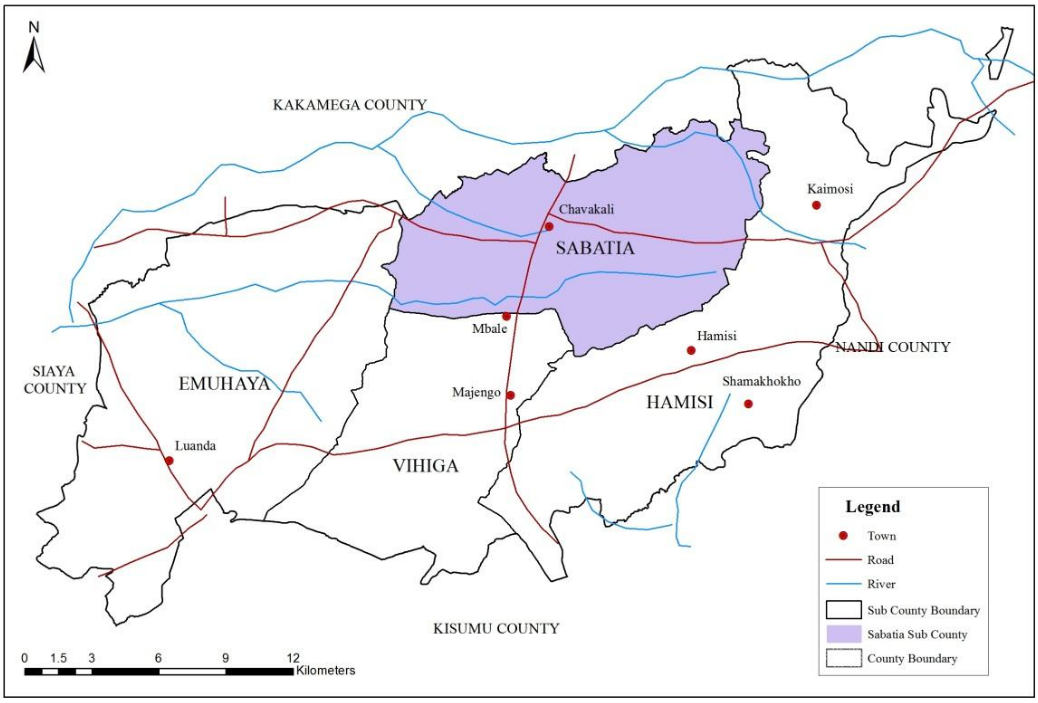
This section gives the background information on the socio-economic and physical factors that have a bearing on land degradation in Sabatia sub-county. The issues described here are; location and size of the study area, physiographic and natural conditions, soils and land degradation, demographic features, ecological conditions and climatic conditions. Also, it provides information on crop and livestock production and financial institutions.

## 3.2 Location and Size

Sabatia Sub-County is located within Vihiga County, on the western part Kenya (Figures 3.1). It lies between longitudes $34^{o}30'$ - $35^{o}0'$ east of the Greenwich Meridian and latitudes $0^{o}$ - $0.15^{o}$North of the equator. The total surface area of the study area is 110.9 $km^2$. Sabatia borders Emuhaya Sub-County to the west, Vihiga Sub-County to the south, Hamisi Sub-County to the east and Kakamega-south Sub-County to the north (Figure 3.2).


Source: Survey of Kenya (2011)

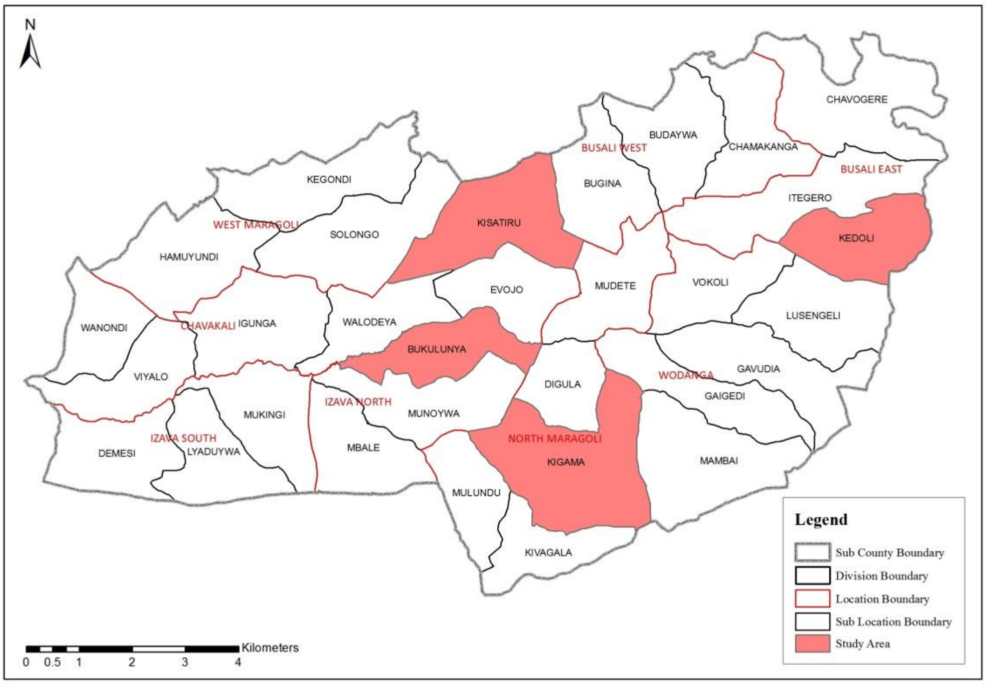
***Figure 3.1: Location of Vihiga County in Kenya***




Source: Survey of Kenya (2011)

***Figure 3.2: Location of Sabatia Sub-County in Vihiga County***

It is subdivided into two divisions; Sabatia and Chavakali Divisions which are further sub-divided into eight locations (Chavakali, Izava North, Izava South, West Maragoli, Busali East, Busali West, North Maragoli and Wodanga locations) and thirty-one sub locations for the administrative purpose (Figure 3.3).

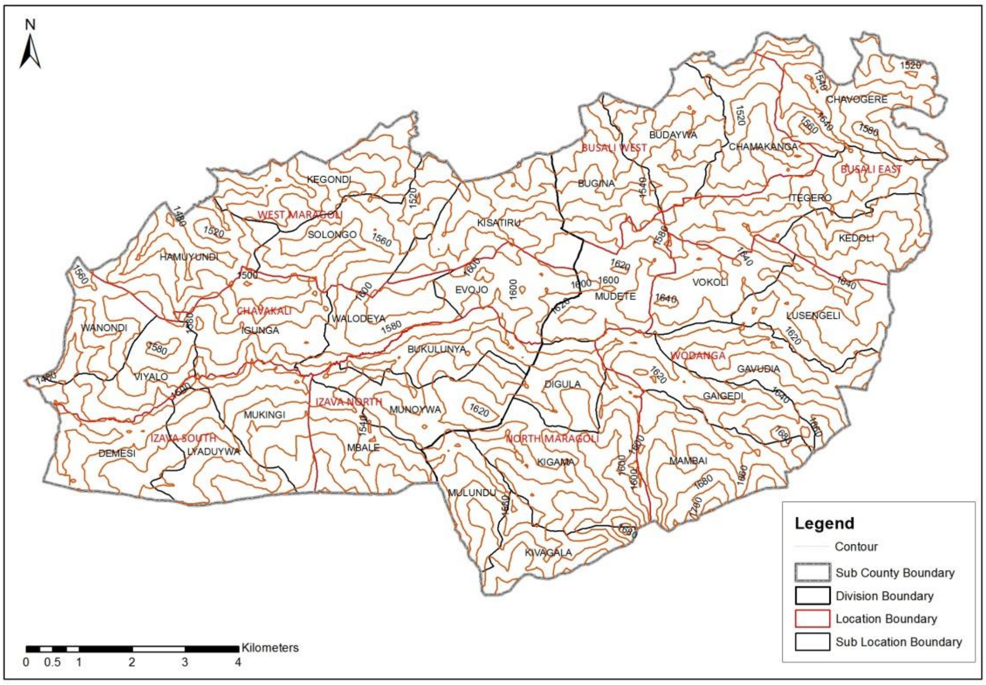



Source: Survey of Kenya (2011)

***Figure 3.3: Survey Areas in Sabatia Sub-County***

### 3.3 Physiographic and Natural Conditions

The altitude of Sabatia sub-county ranges between 1300 meters and 1800meters above sea level and slopes from west to east as shown in Figure 3.4. The sub-county has undulating hills and valleys with streams flowing from Northeast to Southwest and draining into Lake Victoria. The nature of the study areas' topography is conducive to soil erosion, especially during the rainy season. Improvement of farmers' socio-economic conditions in Sabatia may result in more adoption of structural measures such as the construction of terraces as well as vegetative such as agroforestry and grass strips to curb soil erosion.




Source: Survey of Kenya (2011)

***Figure 3.4: Topography of Sabatia Sub-County***

## 3.4 Soils and Land Degradation

Most areas in Sabatia have fertile well drained red soils derived from volcanic rocks (Mukhovi 2009). There are also a few perches of loamy sands from sediments and basement rocks. Three main types of rocks are dominant namely; humicacrisols, dysticnitosols and orthicferasols (ibid).

Soil fertility has deteriorated due to high rainfall that causes soil erosion and leaching, high land use intensity, low adoption of farming technologies and the fact that use of use of nutrient replenishing inputs such as fertilizer and organic manure is low (GoK, 2013). The soils is especially deficient in two crucial nutrients namely nitrogen and phosphorous (Mukhovi 2009).

### 3.5 Climatic Conditions

Sabatia sub-county has a high equatorial climate with fairly well-distributed rainfall throughout the year. The rainfall ranges from 1800mm to 2000mm with an average amount of 1900mm per annum. Temperature ranges between $14^o$ centigrade to $32^o$ centigrade with a mean of $23^o$ centigrade. Long rains are experienced in the months of March, April and May which are deemed to be the wettest while short rains are experienced in the months of September, October, and November. The driest and hottest months are December, January, and February with an average humidity of 41.75 percent (GoK, 2013). The high rainfall experienced increases the vulnerability of soil erosion and leaching culminating in Sabatia's low agricultural productivity. However with the improvement of smallholders socio-economic characteristics, land degradation can be contained hence improved farm yields.

### 3.6 Demographic Features

Kenya National Bureau of Statistics (GoK, 2010) basing on the 2009 national census results estimate the current population of Sabatia sub-county at 133,448 persons with female accounting for 70,728 while male the remaining 62,720 of the total population. The sub-county currently has an estimated population density of 1,203 persons per $Km^2$ (GoK, 2010). The high population density exerts pressure on land leading to its uneconomical sub-division hence negatively influencing agriculture. The average farm size in Sabatia is 0.4 hectares for small scale and 3 hectares for large scale farming (GoK 2013).

## 3.7 Crop and Livestock Production

A majority of smallholder farmers in Sabatia sub-county practice mixed farming. Maize and beans are the main crops produced while cattle, poultry, sheep and goats are the key livestock reared. Maize and beans are cultivated to serve mainly as food crops but most of what is produced end up in the market. Other crops being planted are sorghum, cassava, sweet potatoes and bananas.

# CHAPTER FOUR

# RESEARCH METHODOLOGY

## 4.1 Introduction

This chapter focused on the methodological aspects of the study. These included; study design, study population, sample size, sources of data, methods of data collection, as well as methods of data analysis and presentation

## 4.2 Study Design, Study Population, Sample Size and Sampling Procedure

### 4.2.1 Study Design

Descriptive research design was used for this study. Descriptive research (Walliman, 2005) examine situations to establish what is the norm; that is what can be predicted to happen under similar circumstances. The design was appropriate because it was anticipated that adoption or failure to adopt SLMP by small-scale farmers depended on their social and economic attributes.

### 4.2.2 Study Population

According to the 2009 Kenya population and housing census results, Sabatia Sub-County as a whole comprised of 27,742 households spread across 31 administrative sub-locations (GoK 2010). On average each sub-location had 895 households. Using multi-stage random sampling technique 4 clusters – sub-locations – were selected.

Since some of the SLMP - notably the use of terraces - earmarked for analysis applied to households cultivating undulating land, farmers on flat or near flat land were not incorporated in the sample frame. A sample frame of 1600 farmers who cultivated undulating farmlands in Kisatiru, Kedoli, Bukulunya and

Kigama sub-locations was constructed to enable an appropriate sample size to be obtained.

### 4.2.3 Sample Size

The principal objective of a sampling procedure is to secure a sample size which subject to the limitation of size will reproduce the characteristics of the population especially those of immediate interest to the researcher. While recommending as big sample as possible, Mugenda and Mugenda (2003) caution that time and resources at the disposal of the researcher should be considered. The following formula was used to determine the sample size for this research after construction of the sample frame;

$$n = [NCv^2] \div [Cv^2 + (N-1)\ e^2]$$

where:

n = the desired sample size

N= the Target Population (1600)

Cv = Coefficient of variation (take 0.5)

e = tolerance at desired level of confidence (0.05 at 95% confidence level) Nassiuma,(2000).

$$n = [1600 \times 0.5^2] \div [0.5^2 + (1600 - 1) \times 0.05^2]$$

$$n = 400 \div 4.248$$

$$n = 94$$

The sample size was purposively expanded from 94 to125 households to take care of the questionnaires that may not have been filled adequately during data collection. Incidentally, all the questionnaires were duly filled and hence analyzed.

### 4.2.3 Sampling Procedure

Due to high population density in the study area coupled with inadequate finances and time, multi-stage sampling was used to derive an appropriate sample of households which were surveyed. Multi-stage sampling was used because of the following reasons (Mugenda and Mugenda, 2003);

a) It is less costly than simple or stratified random sampling regarding obtaining a frame that lists all population elements in the study area.

b) The technique is best applicable in a population that does not have a defined sampling frame. Sabatia sub-county does not have a list of smallholder farmers who cultivate undulating land in place.

The multi-stage sampling procedure was applied as follows: The first stage involved selection of two locations from each of the two divisions (Chavakali and Sabatia) that make up Sabatia Sub-County to form primary sampling units for study. Both divisions comprised of four (4) locations each. Using simple random sampling method, North Maragoli, and Busali East locations were selected in Sabatia Division. In Chavakali Division West Maragoli and Chavakali locations were selected.

The second stage involved selection of one sub-location from each of the four locations, as the secondary sampling unit. This was also done using simple random sampling method. Table 4.1 shows the sub-location sampled in the selected locations.

***Table 4.1: Multi-Stage sampling in the study area***

| **Division** | **Sabatia** | | **Chavakali** | |
|---|---|---|---|---|
| **Location** | North Maragoli | Busali East | Izava North | West Maragoli |
| **Sub-Location** | Kigama | Kedoli | Bukulunya | Kisatiru |
| **Target Population** | 365 | 430 | 425 | 380 |
| **Sample Size** | 28 | 34 | 33 | 30 |

Source: Researcher (2015)

The third stage involved sampling of individual households in the selected sub locations after the construction of sampling frame of farmers with sloping land in the selected Sub-Locations. The process of selecting the households was done using a simple random sampling technique. Simple random sampling technique was preferred because it allowed each sampling unit in the population an equal chance of being included in the sample (Kothari, 2004).

The sample size was distributed proportionately among the four (4) sub locations (Table 4.1).

## 4.3 Data Collection Methods

### 4.3.1 Secondary Data

Content analysis was used to obtain secondary data from a variety of published and unpublished sources. District agricultural offices, Central Bureau of Statistics (CBS) and Ministry of Agriculture (MoA) provided vital information on land degradation and extent of adoption of sustainable land management technologies among others.

Maps and diagrams were also be used to generate secondary data on climatic condition, soil, and infrastructural facilities in the study area. These statistics were useful in understanding the study area.

### 4.3.2 Primary Data

Primary data were obtained from the sampled households. The head of the family who makes day to day decision of farm management was the key respondent during the administration of the questionnaire. The household head was; husband, the wife or the elder son/daughter. Primary data concerning land degradation and agricultural productivity in the sub-county was obtained from Sabatia Sub-County agricultural officer. The following methods were used to obtain raw data:

#### 4.3.2.1 Questionnaire

A structured questionnaire, with both open and closed-ended questions, was used to obtain; demographic information as well as socio-economic attributes of the respondents, the nature of land degradation, land management practices employed by farmers and other related issues. The questionnaires were piloted in un-sampled sub-location to check its validity and necessary adjustments were made. Since farmers in the study area speak *Lulogooli*, the questionnaire that was initially prepared in English was translated into the local dialect for easier communication. The questionnaire was administered by two research assistants as well as the researcher to the household head.

#### 4.3.2.2 Observation

The observation was used to obtain information concerning; farm size, land degradation, and sustainable land management practices especially agroforestry and terracing among others. It was also be used to corroborate data obtained via the questionnaire.

#### 4.3.2.3 Interview

Key informants such as the Sub-County agricultural officer were interviewed to obtain information which was beyond ordinary smallholder farmers.

### 4.4 Study Variables

***Table 4.2 Operational definition of study variables***

| VARIABLE | PARAMETER | SCALE |
|---|---|---|
| **Dependent Variable**<br>Adoption of Sustainable Land Management Practices (SLMP) | Was determined by whether or not the sampled farmer was using either of the following SLMP; manure application, terracing/grass strips and agroforestry. | |
| a) Manure use | a) Amount (number of wheelbarrows) applied per acre per season was investigated. | a) Interval |
| b) Terracing/ Grass Strips | b) Number of terraces or grass strips established was analyzed | b) Interval |
| **c)** Agroforestry | **c)** The number of trees on cropland | c) Interval |
| **Independent Variables**<br>**<u>Social Factors</u>** | | |
| a) Farming experience | a) Number of farming years. | a) Interval |
| b) Gender | b) Being male or female | b) Nominal |
| c) Educational level | c) level attained in school that is "Primary", "Secondary" or "Tertiary." | c) Ordinal |
| d) Membership to a farmers' group (CBO) | d) Registered member of an active farmers' group – "Yes" or "No." | d) Nominal |
| **<u>Economic Factors</u>** | | |
| a) Household income | a) The amount in Kenya shillings from both On-farm and off-farm activities. | a) Interval |
| **b)** Farm size | **b)** Number of acres. | b) Interval |

| | | |
|---|---|---|
| | | |

Source: Researcher, 2015

### 4.5 Statistical Analysis of Data

Raw data collected using the questionnaires were edited to check errors and omissions. The necessary corrections were done. The data were then arranged and grouped according to specific objectives. After editing, they were coded and keyed into the computer where Statistical Package for social sciences (SPSS) version 20 was used to classify responses into meaningful categories for analysis, interpretation, and presentation.

Land degradation forms in the study area were identified. After that SLMP adopted to address the problem of degradation were determined. Farmers' social and economic attributes were then related to the rate of SLMP adoption. Finally, the impact of SLMP adoption on agricultural productivity was assessed. The analytical tools used are explained below.

#### 4.5.1 Descriptive Statistics

Descriptive statistics was used to summarize, simplify and organize data for statistical representation and easy understanding. The descriptive statistics involved; bar graphs, pie charts, frequency distribution tables, percentage distributions, measures of central tendency and dispersion. This basic level analysis was important in describing smallholders demographic and socio-economic attributes, as well as SLMP, adopted before proceeding to inferential statistical techniques (simple regression analysis and chi-square analysis).

### 4.5.3 Simple Regression Analysis

For both objective one and two of the study stated earlier in chapter one, simple regression analysis was used to show the correlation between smallholders' social and economic characteristics (level of education, farming experience, farm size and level of income) and use of SLMP (manure application, terracing, and agroforestry).

The following simple regression formula was used;

**y = a + bx.**

Where: **y –** the dependent variable (manure, terraces, and agroforestry)

**x –** the independent variable (age, level of education, household income and farm size)

**a -** represent the **y**-intercept when **x = 0** (a constant) – a= y-bx

**b -** represents the gradient (slope)

The simple correlation coefficient represented by **r** also known as Pearson Correlation Coefficient show strength of the relationship between the independent (x) and dependent (y) variable.

According to Puri (1996) Pearson Correlation Coefficient denoted by **r** ranges as follows;

(i) **r** =1: perfect positive correlation

(ii) 0 < **r** < 1: positive though not perfect correlation

(iii) **r** = 0: no correlation

(iv)-1 < **r** < 0: negative though not perfect correlation

(v) **r** = -1: perfect negative correlation

In line with objective three, simple regression analysis was also used to determine the relationship between use of SLMP and agricultural productivity in the study area.

### 4.5.4 Stepwise Multiple Regression Analysis

Stepwise multiple regression analysis was used to test the two null hypotheses $H_0 – 1$ and $H_0 – 2$ stated in chapter one.

Multiple regression analysis is widely used in geographical research because of the following reasons;

1. It has the power to analyze complex interacting variables (Kothari, 2004)
2. It has a means of controlling other factors to evaluate the contribution of a specific independent or a set of variables influencing the use of SLMP (Wambua, 2008).
3. It also enables us to tell the most significant factors from a set of variables entered into the program.

Obara (1983) and Wambua (2008) used this technique in the field of Agricultural Geography. The multiple regression equations used was as follows;

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 \ldots\ldots\ldots\ldots + b_kX_k + e$$

Where: $X_1X_2X_3 \ldots\ldots X_k$ - are the independent variables (gender, farming experience, membership to farmers groups, education level, farm size and income)

$Y$ - *is* the dependent variable (Use of SLMP – manure or terraces or agroforestry)

a – the intercept value (the average value of *Y* when each independent variable *(X)* equals zero (0)

$b_1 b_2 b_3 b_k$ – the gradient/slope of the regression line

*e* –error (Kothari 2004)

F – statistic test was used to identify the independent variable that had the greatest influence on the dependent variable. The null hypotheses were tested at 0.05, significance level. Where F-calculated was greater than F-critical, the null hypothesis was rejected and the alternative hypothesis adopted.

### 4.5.3 Chi-Square Analysis

Chi-square ($\chi^2$) was used to test the relationship between smallholders' social attributes (gender and membership to farmers' groups) and the adoption of SLMP (manure application, terracing, and agroforestry) in the study area. The Chi-square ($\chi^2$) was computed using the formula:

$$\chi^2 = \Sigma\ (O-E)^2/E$$

Where: O – Observed frequency

E – Expected frequency

$\Sigma\ (O-E)^2$ – Sum of the squares of the differences between Observed and Expected Frequencies.

The $\chi^2$calculated was compared with $\chi^2$critical at a significance level of 0.05 and degrees of freedom which was determined as follows:

Degrees of freedom (df) = (r – 1)(c – 1)

Where r: number of rows

c: number of columns

Null hypothesis ($H_0$) was rejected where $\chi^2$calculated was greater than $\chi^2$critical and the alternative hypothesis ($H_1$) adopted.

**4.6 Study Limitations**

This study encountered the following challenges;

(i) It was challenging to administer a questionnaire prepared in English to the respondents. This limitation was overcome by translating the questionnaire to the local *Lulogooli*language by the enumerator.

(ii) Inadequate farm records: Some respondents did not keep records on; farm operations, farm inputs and yields. The researcher relied on their estimation.

(iii) Unwillingness to disclose information: For unclear reasons, some respondents were not comfortable to divulge information about their annual income. The researcher assured them of confidentiality of their response.

# CHAPTER FIVE

# RESULTS AND DISCUSSIONS

## 5.1 Introduction

Results of the study are presented in this section as per the specific research objectives. The first section presents the sustainable land management practices adopted towards control of land degradation in the study area. The second and third sections present the influence of small-scale farmers' social and economic attributes on their adoption of SLMP. Finally, the last section presents the impact of SLMP use on agricultural production in the study area. Descriptive statistics, Simple regression analysis, Stepwise multiple regression, and chi-square tests are used to analyze data and test hypotheses.

Out of the 125 sampled households, majority 70 (56%) were managed by women while the remaining 55 (44%) were under male supervision. Concerning the age of the respondent, approximately 19 (15%) were above 60 years old, 93 (75%) between the ages of 30 and 60 years, while only 13 (10%) were below 30 years old.

## 5.2 Sustainable Land Management Practices (SLMP) in Sabatia

In line with objective one, the study focused mainly on smallholder farmers who cultivate undulating land in the study area. This was cognisant of the fact that terraces among others, which was subject to the investigation were not applicable to farmers tilling flat or near flat parcels.

Majority 106 (85%) and 99 (79%) of the respondents believe their farms experience soil erosion and loss of soil fertility respectively. Sheet and rill erosion are the dominant forms of soil erosion though small gullies occur in some areas (Plate 5.1).

Source: Researcher (2015)
***Plate 5.1: Soil Erosion in Sabatia***

Soil erosion and loss of soil fertility in the study area can be attributed to; over cultivation which destroys soil structure, the high mean annual rainfall - 1900mm p.a. - experienced and the undulating terrain in the area (GoK 2013).

Several land management practice have been adopted by smallholder farmers in Sabatia to tame land degradation. All smallholders 125 (100%) use farmyard and compost manure, but the amount applied per acre varies. Approximately 96 (77%) of the farmers use terraces while 78 (62%) use agroforestry in the study area. Application of chemical fertilizer and use of grass strip is also done.

### 5.2.1 Manure Application

According to Smaling et al. (1993) approximately 112kg of nitrogen, 2.5kg of phosphorous and 70 kg of and potassium are lost from agricultural soil per hectare per year in Kenya. In many small-scale farms in the study area, crop residues are harvested and fed to livestock, and very little is returned to the soil to replenish lost nutrients. The depletion of organic matter thus compromises agricultural productivity. The main reason behind manure application is to replenish soil fertility so as to improve agricultural productivity.

Farmyard manure and compost manure (Plate 5.2) are the most populartype of fertilizer applied by smallholders in Sabatia Sub-County.

Source: Researcher (2015)
***Plate 5.2: Compost Manure***

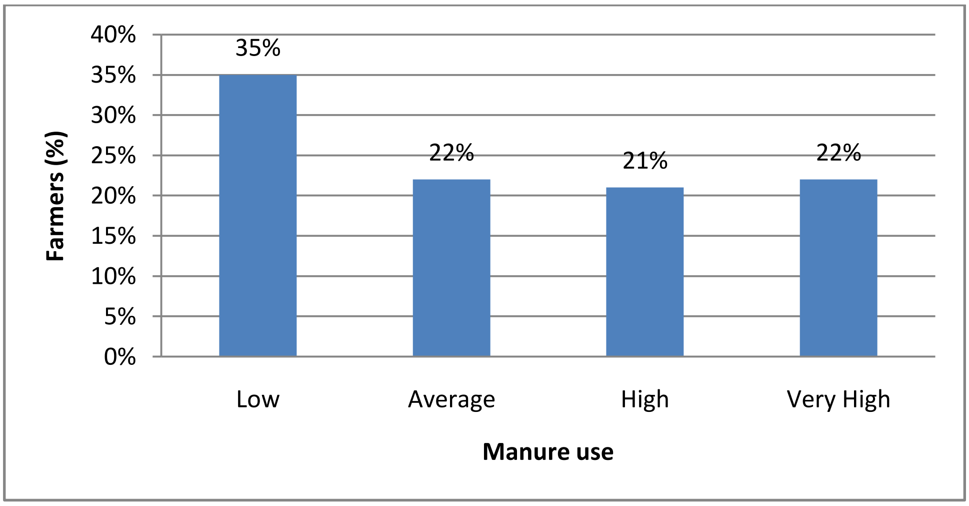
The rate at which small-scale farmers use manure in the study area was determined by the number of wheelbarrows of manure applied per acre. Farmers' use of fertilizer was categorized into four classes that is; Low, Average, High and Very High (Table 5.1).

*Table 5.1: Categories of Manure Application*

| Rate of Manure Use | No. of Wheelbarrows per acre |
|---|---|
| **Low** | ≤ 20 |
| **Average** | 21 – 30 |
| **High** | 31 – 40 |
| **Very High** | 41 + |

Source: Researcher (2015)

Manure use in the study area is fair given that all smallholders applied one form of manure or the other. However, the amount applied varied across the farmers. The least amount of manure applied per acre was estimated at three wheelbarrows while the highest amount used was 54 wheelbarrows. During the year 2014, majority 81(65%) of farmers applied over 20 wheelbarrows of manure per acre (average to very high), while 44(35%) applied 20 wheelbarrows and below (low) per acre (Figure 5.1).




Source: Researcher (2015)

*Figure 5.1: Manure Application per acre in Sabatia in 2014*

Bivariate correlation of manure use and farm productivity showed that farmers who applied more manure per acre registered higher yields than their counterparts who applied less. This is further illustrated in section 5.5 of this thesis.

### 5.2.2 Terraces

Terraces are primarily adopted to reduce soil erosion. On sloping lands, terracing is also necessary for reduction of overland flow thereby contributing to water and nutrient conservation (Nyangena and Kohlin 2008).

In the study area, "fanyajuu" terraces (Figure 5.2) are the most common. However, in some parcels where the gradient of the land is less steep grass strip (Napier grass) has been planted along contours where it serves the purpose of terraces.

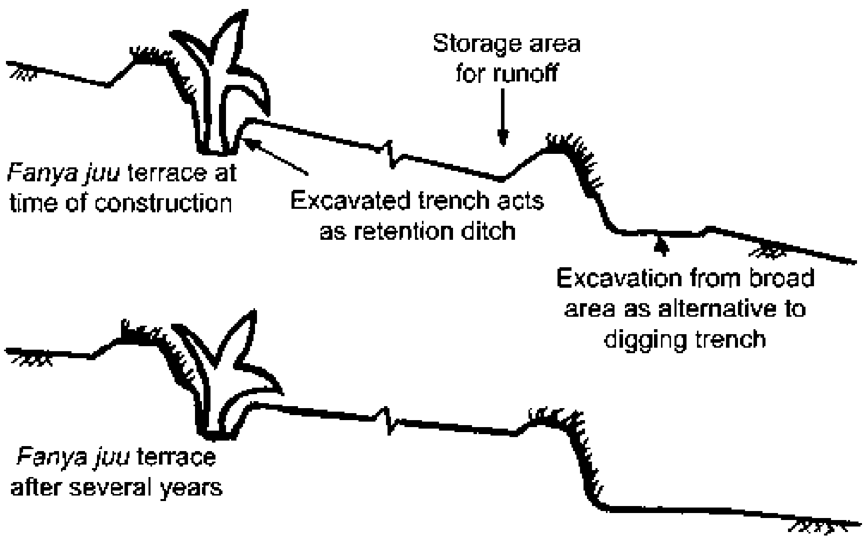


***Figure 5.2: FanyaJuu Terraces***

The use of terraces in Sabatia was determined by the number of terraces established per acre of land. This was categorized as shown in Table 5.2.

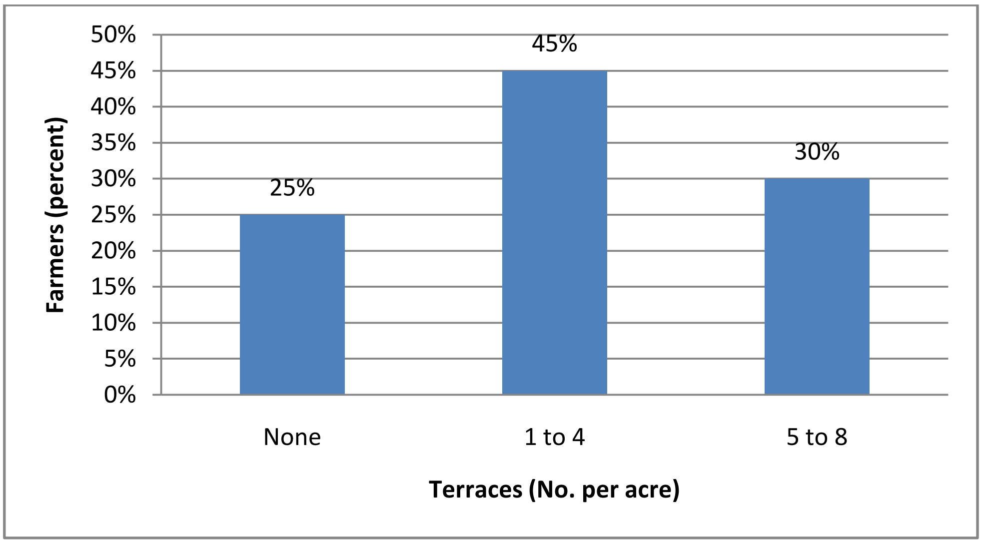
***Table 5.2: Categories of Terraces Use***

| **Rate of Terraces Use** | **No. of Terraces per acre** |
|---|---|
| **None** | 0 |
| **Low** | 1 – 4 |
| **Average** | 5 – 8 |

Source: Researcher (2015)

According to Mati (2005), the space between two successive terraces should be determined by a vertical interval not exceeding 1.8 meters. This guideline has not been implemented by most smallholders farming undulating land as the spacing between terraces is rather large.

Field survey statistics indicate that the rate of terraces use in the study area is rather low. About 31 (25%) of smallholders did not have terraces on their plots despite the sloping nature of their land. Majority 56 (45%) had four terraces per acre or less while about 38 (30%) had established 5 to 8 terraces per acre (Figure 5.3).




Source: Researcher (2015)

***Figure 5.3: Rate of Terraces Use among Smallholders in Sabatia Sub-County***

Smallholders who have established more terraces have better yields per acre as illustrated in section 5.5 of this thesis.

### 5.2.3 Agroforestry

The benefits of agroforestry to the farmer are numerous. Mati (2005) observes that trees provide nutrient inputs to crops by capturing nutrients from atmospheric deposition, biological nitrogen fixation, tapping nutrients from deep in the subsoil and storing them in the biomass. Trees also enhance nutrient cycling through conversion of soil organic matter into available nutrients. Agroforestry also benefits farmers directly through the provision of poles for building, fruits for sale and consumption, fuel wood and fodder for livestock. The trees also prevent soil erosion, conserve soil water and improve soil fertility and the micro climate. Mati (2005) notes further that the environmental benefits from trees through; soil conservation, biodiversity conservation and the conservation of terrestrial carbon.

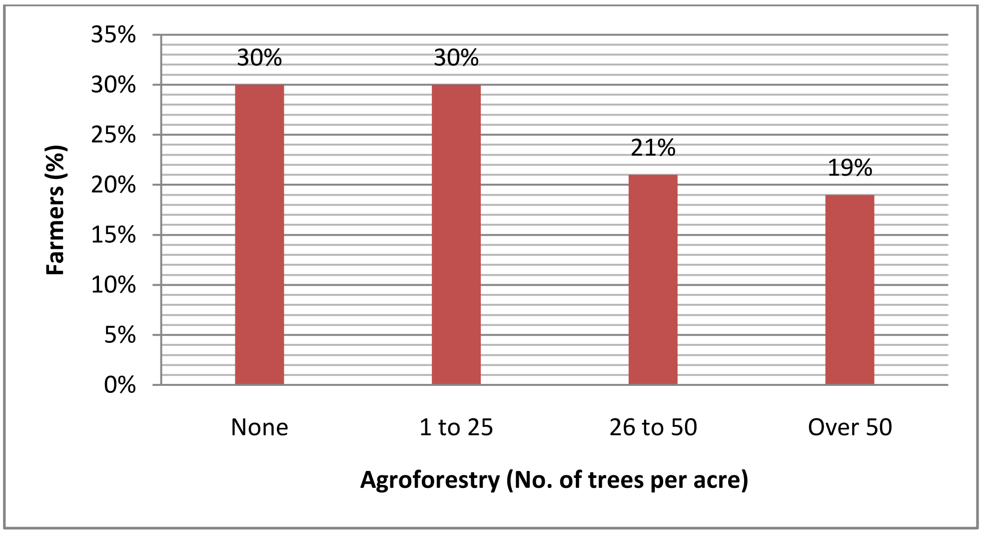
The rate of agroforestry use in the study area was measured based on the number of trees planted on the respondents' farm per acre. For analysis sake, agroforestry use was categorized as shown in Table 5.3.

***Table 5.3 Categories of Agroforestry Use***

| **Rate of Agroforestry** | **No. of Trees per acre** |
|---|---|
| **None** | 0 |
| **Low** | 1-25 |
| **Average** | 26-50 |
| **High** | 51+ |

Source: Researcher (2015)

The rate of agroforestry use in Sabatia Sub-County is rather low. Of the smallholders 38 (30%) did not have a single tree on their cropland. Another 37 (30%) had just a handful of trees on their plots estimated at 25 or less on their cropland. While 26 (21%) of smallholders had between 26 and 50 trees on their farms, only 24 (19%) had at least 51trees per acre (Figure 5.4).




Source: Researcher (2015)

***Figure 5.4: Agroforestry use in Sabatia Sub-County***

The major types of trees cultivated alongside crops in the study are included; Silky oak *(Grevillea robusta)* (Plate 5.3)*, 'Lusiola*' (*Markhamialutea)*, Mango *(Mangiferaindica)*, and Guava *(Psidiumguajava)*.

Source: Researcher (2015)
***Plate 5.3: Agroforestry Terraces and Grass strip in Sabatia Sub-County***

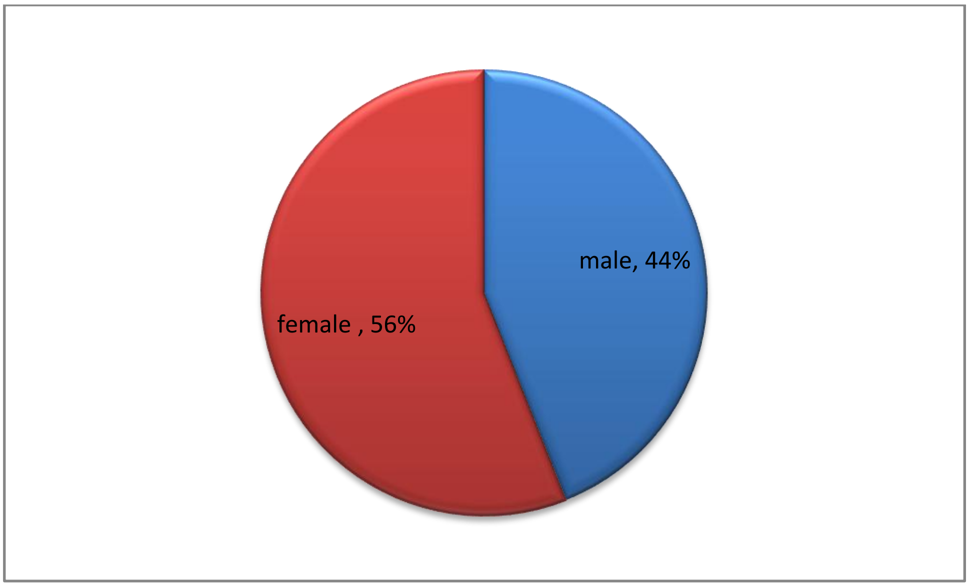
As illustrated later in this thesis (section 5.5) small-scale farmers who had more agroforestry trees per acre harvested more than those without or fewer trees on their cropland.

### 5.3 Smallholders' Social Attributes and Use of SLMP in Sabatia

Under objective two of this study, smallholders' social attributes that are hypothesized to influence the use of SLMP are discussed here according to field survey results. They include household headships'; gender, membership to farmers' group, education status, and farming experience. The household head was targeted as the respondent because they were thought to be the key decision makers concerning major operations on the farm.

### 5.3.1 Gender and Use of SLMP

Respondents were categorized as being either male or female. Households managed by males were 55 while those controlled by females were 70 female constituting 44 and 56 percent respectively (Figure 5.5). This compares favourably with the Kenya 2009 national census and housing results which put the population composition of Sabatia Sub-County at 48 and 52 per cent for male and female respectively (The Republic of Kenya, 2010).




Source: Researcher (2015)

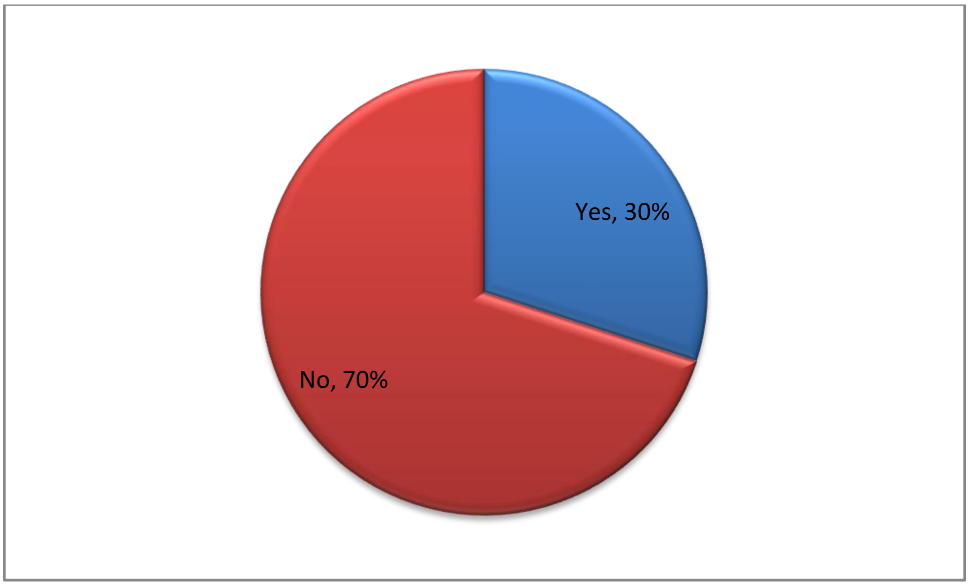
***Figure 5.5: Gender of Smallholders in Sabatia Sub-County***

Lack of gender parity among the respondents could be attributed to the fact that a good number of males dwell in urban areas and engage themselves mainly in off-farm economic activities. The burden of farming thus is left to women.

Heyi and Mberegwa (2012) observe that women are not effective implementers of SLMP. They are sometimes inhibited from making decisions about land management practices while their husbands are away. Also, women are commonly busy in household activities, and their prime responsibility is usually child care.

**5.3.2 Membership to Farmers' Group(s) and Use of SLMP**

Approximately 37 (30%) of smallholder farmers in Sabatia Sub-County were members of at least one farmers' group. These included; One Acre Fund, Kedoli Farmers Group, Havukwi Women Group, Kiritu Neighborhood Group, Rock Group and Kihinda Women Group. Majority of the farmers, 88 (70%) did not belong to any of the farmers' groups (Figure 5.6).




Source: Researcher (2015)

***Figure 5.6: Membership to Farmers' Group(s) in Sabatia***

Ordinarily farmers' associations provide a forum through which they learn from one another good farm practices including but not limited to SLMP (Gitonga, 2012). Through such groupings, agricultural extension officers can gain access to smallholders and share with them new research findings in the field of SLMP.

### 5.3.3 Level of Education and use of SLMP

Small-scale farmers' level of education was measured based on the number of years the respondents had spent in school. Educational attainment was then categorized as illustrated in Table 5.4.

***Table 5.4: Categorization of Education Level***

| Education Level | No. of Years Spent in School | No. of Farmers |
|---|---|---|
| **None** | 0 | 5 |
| **Primary** | 1 – 8 | 71 |
| **Secondary** | 9 – 12 | 39 |
| **Tertiary** | 13 + | 10 |

Source: Researcher (2015)

Majority 71 (57%) of smallholder farmers in Sabatia Sub-County have attained primary school level of education. About 39 (31%) and 10 (8%) have reached secondary and tertiary education respectively. Few of the smallholders 5 (4%) have not attained formal education (Table 5.4).

Education is expected to have significant positive influence on adoption of sustainable land management practices due to its impact in raising the level of farmers' awareness and improving their planning horizon.

### 5.3.4 Farming Experience and Use of SLMP

The agricultural experience was assessed in terms of the number of years the small-scale farmers have been cultivating. This was grouped into three classes; Low, Average, and High (Table 5.5).

***Table 5.5: Categorization of Farming Experience in Sabatia Sub-County***

| Farming Experience | Number of years | No. of Farmers |
|---|---|---|
| **Low** | Less than 10 | 32 |
| **Average** | 11 – 20 | 27 |
| **High** | Over 21 | 66 |

Source: Researcher (2015)

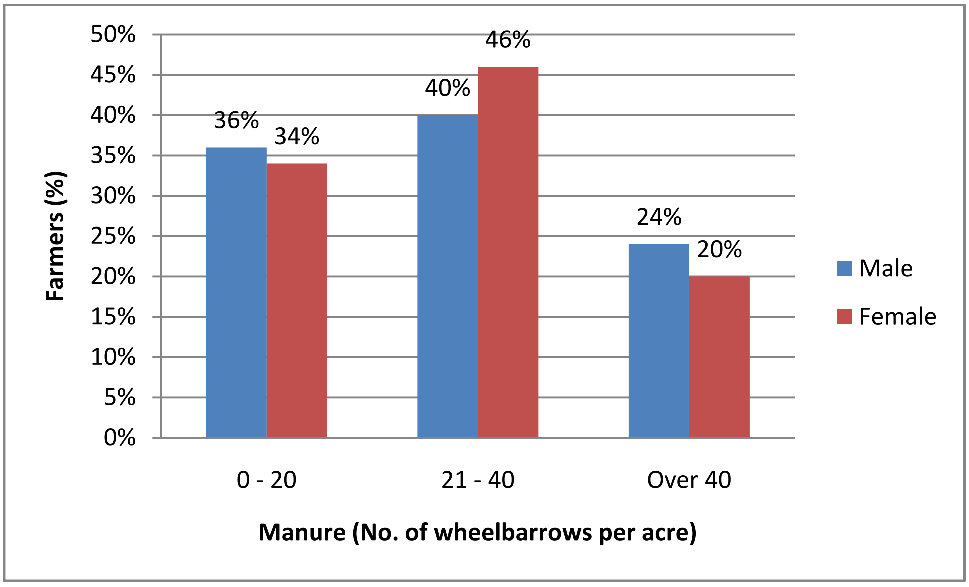
Field study established that smallholders' farming experience ranged between 1 (one) and 48 years. Most of the smallholders 66 (53%) had farmed for over 21 years. About 27 (22%) had farming experience of between 11 and 20 years while approximately 32 (25%) of the smallholders had farmed for ten years or less (Table 5.5).

It is anticipated that farming experience may enhance the use of SLMP as over time farmers' exposure to healthy farming practices is boosted.

### 5.3.5 Farmers' Social Attributes and use of Manure

#### 5.3.5.1 Smallholders' Gender and use of Manure

In the year 2014 more female (80%) than male (76%) managed households applied at most 40 wheelbarrows of manure per acre. On the contrary, more male (24%) than female (20%) led households used more than 40 wheelbarrows of manure per acre (Figure 5.7)




Source: Researcher (2015)

***Figure 5.7: Relationship between Gender and Manure Use in Sabatia***

Chi - square analysis was used to test the hypothesis that “There is no connection between smallholder farmers' gender and adoption of manure application". The observed frequencies were greater than the expected frequencies (Table 5.6)

***Table 5.6: Chi-Square Analysis of the Relationship between Gender and Manure use***

| Manure (No. of wheelbarrows per acre) | Gender | | Total |
|---|---|---|---|
| | Male | Female | |
| ≤ 20 | 18(15.8) | 18(20.2) | 36 |
| 21 - 30 | 11(10.6) | 13(13.4) | 24 |
| 31 - 40 | 16(14.5) | 17(18.5) | 33 |
| > 40 | 10(14.1) | 22(17.9) | 32 |
| **Total** | **55** | **70** | **125** |

Source: Researcher (2015)

Note: Figures in brackets e.g. (15.8) are the expected values (computed)

$\chi^2$computed = 2.939 df = 3 Level of Significance = 0.05

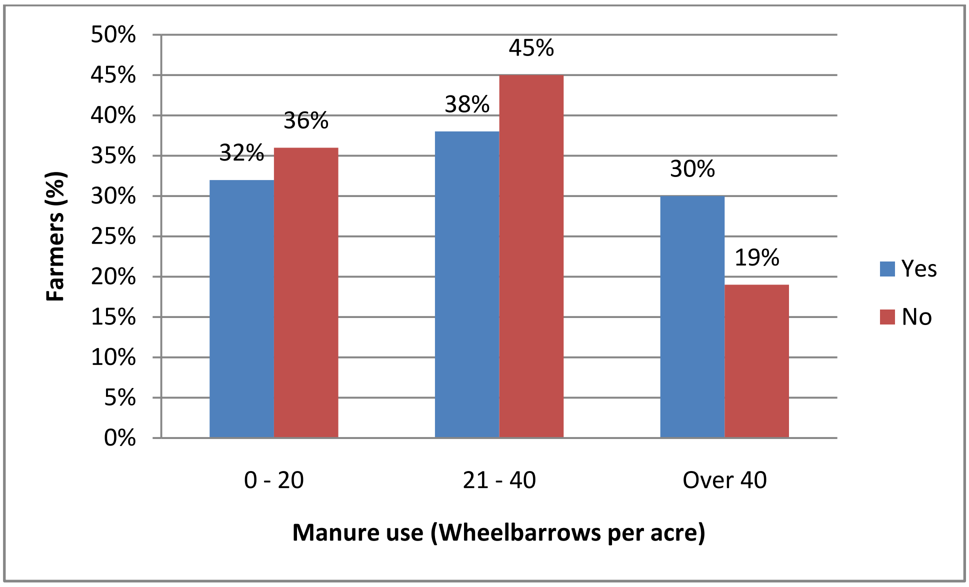
$\chi^2$critical = 0.352

The calculated chi - $\chi^2$statistic (2.939) was greater than the critical chi - $\chi^2$statistic (0.352) at 0.05 confidence level. The null hypothesis was thus rejected and the alternative hypothesis adopted. This finding indicates that there is a significant relationship between farmers' gender and their use of manure.

This contradicts results of previous research. Heyi and Mberegwa (2012) established that there was no significant relationship between sex and application of fertilizer in Tole District, South West Shewa Zone, Oromia National Regional State, Ethiopia.

**5.3.5.2 Membership to Farmers' group and use of Manure**

More farmers' group members (30%) than non-members (19%) applied more than 40 wheelbarrows of manure per acre. On the contrary, more non-members of farmers groups (81%) than members (70%) used 40 wheelbarrows of manure or less per acre (Figure 5.8).




Source: Researcher (2015)

***Figure 5.8: Comparison of Smallholders' Membership to Farmers' Group(s) and Manure Use in Sabatia Sub-County***

Chi - square analysis was used to test the hypothesis that "There is no relationship between membership to farmers' group and use of manure". The observed frequencies were greater than the expected count (Table 5.7).

***Table 5.7: Chi-Square Analysis of the Relationship between Smallholders' membership to farmers' group(s) and application of manure.***

| Manure (No. of wheelbarrows per acre) | Membership to Farmers' Group | | Total |
|---|---|---|---|
| | Yes | No | |
| ≤ 20 | 10(10.7) | 26(25.3) | 36 |
| 21 - 30 | 5(7.1) | 20(16.9) | 24 |
| 31 - 40 | 10(9.8) | 23(23.2) | 33 |
| > 40 | 13(9.5) | 19(22.5) | 32 |
| **Total** | 37 | 88 | 125 |

Source: Researcher (2015)

Note: Figures in brackets e.g. (10.7) are the expected values (computed)

$\chi^2$computed = 3.858 df = 3 Level of Significance = 0.05

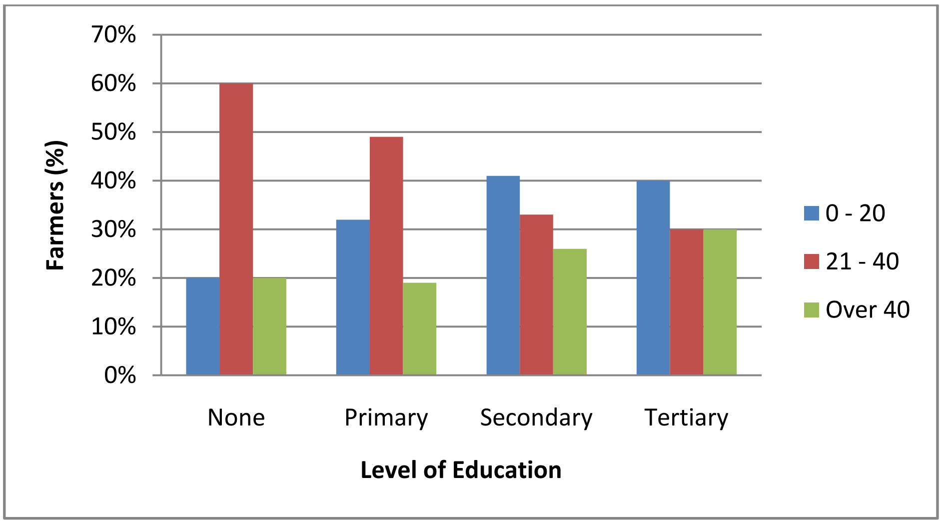
$\chi^2$critical = 0.352

The computed chi - $\chi^2$statistic (3.858) was greater than the critical chi - $\chi^2$statistic (0.352) at 0.05 confidence level. The null hypothesis was therefore rejected, and the alternative adopted.

From the findings, smallholders who belong to farmers group tend to apply manure to their farms more than those who do not belong to any group. Babalola&Olayemi (2013) found out that smallholders' membership to the community-based organization (CBO) significantly determined the use of manure in Ogun state, Nigeria.

### 5.3.5.3 Farmers' Education Level and Use of Manure

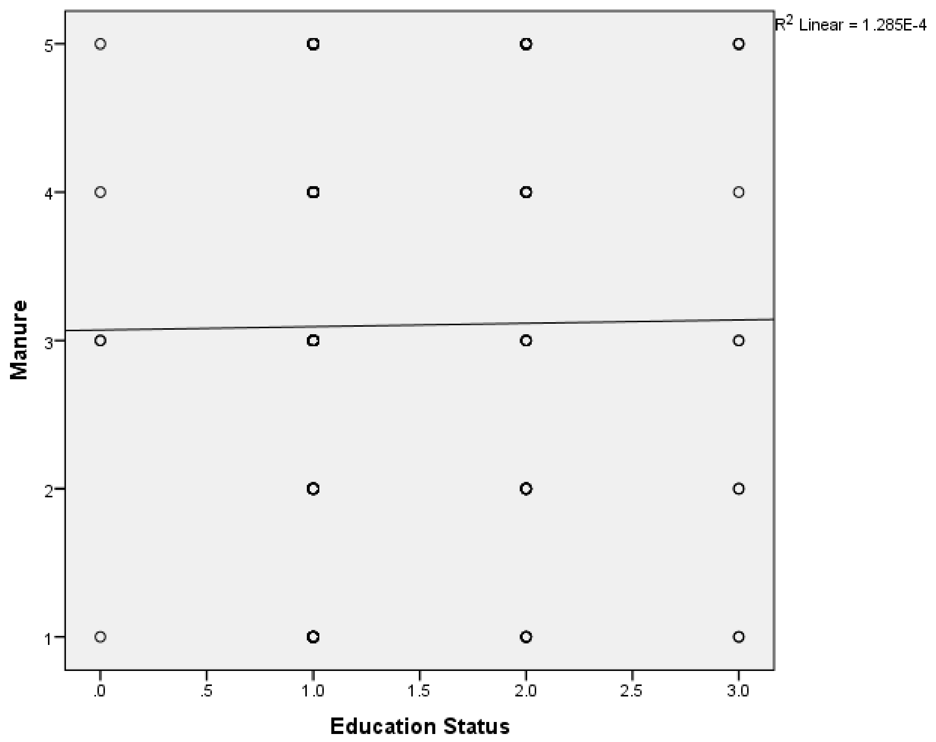
The study found out that the proportion of smallholders applying the least amount of manure (20 wheelbarrows or less) per acre as well as those using the highest amount (over 40 wheelbarrows) per acre steadily increased with increase in their level of education (Figure 5.9).




Source: Researcher (2015)

***Figure 5.9: Relationship between Smallholders' Education Status and use of manure in Sabatia***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = 0.11) between farmers level of education and use of fertilizer (Figure 5.12). This can be attributed to the fact that the use of manure is also determined by other factors e.g. farming experience.



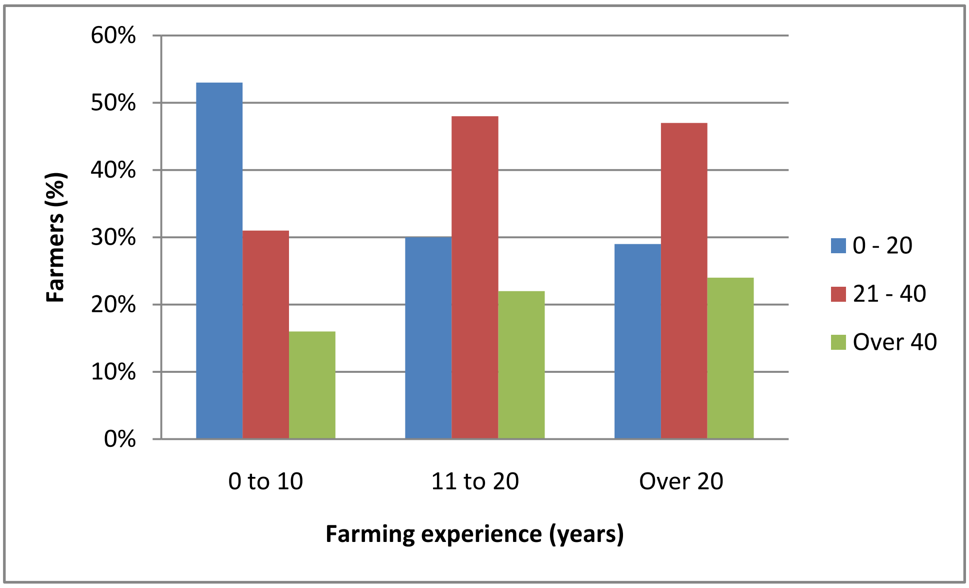

Source: Researcher (2015)
***Figure 5.10: Simple Regression Analysis of the Relationship between Farmers' Level of Education andManure use***

Farmers who had a superior level of education applied slightly more manure per acre than their less educated counterparts (Figure 5.12). This could be attributed to the fact that as a result of education farmers had realized that manure enriched their cropland hence improvement in yields.

This result concurs with Heyi and Mberegwa (2012) who established that educational status of farmers in Tole District, South West Shewa Zone, Oromia National Regional State, Ethiopia had predictive power on use of manure.

**5.3.5.4 Farming Experience and Use of Manure**

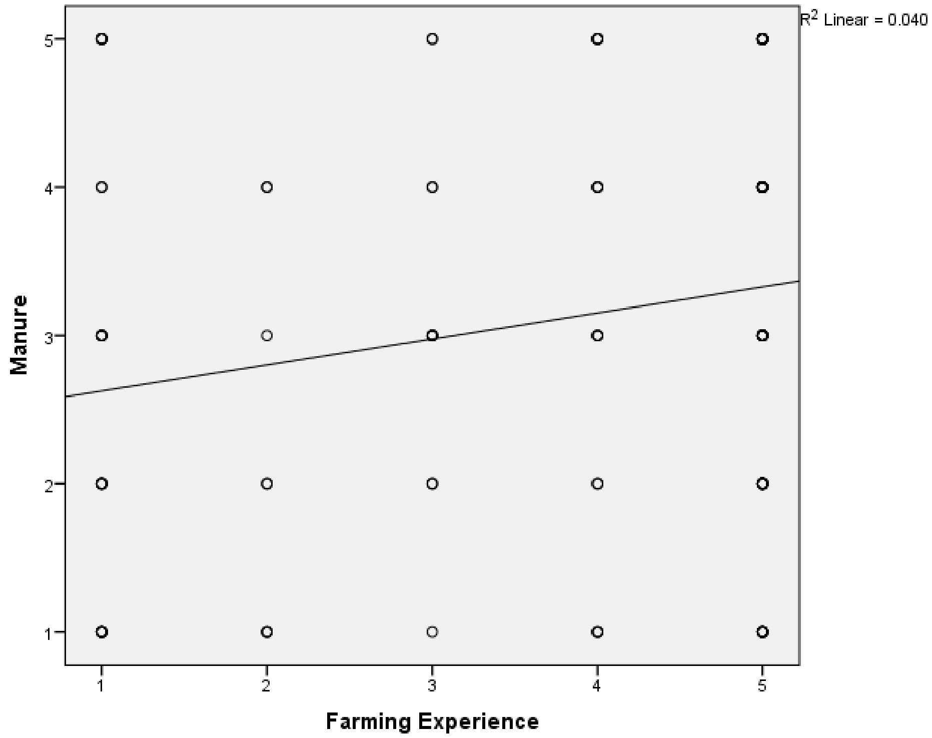
The proportion of farmers who applied the least amount of fertilizer (20 wheelbarrows or less) decreased with increase in farming experience. There was, however, increase in the proportion of farmers who applied the highest amount of fertilizer (more than 40 wheelbarrows) per acre with increase in farming experience (Figure 5.11)




Source: Researcher (2015)

***Figure 5.11: Relationship between manure use and farming experience in Sabatia***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = 0.199) between farming experience and use of fertilizer. $R^2$ = 0.040 indicate that at 4% smallholders' income had little though a positive influence on the use of manure (Figure 5.14). The little weight can be attributed to the fact that the use of manure is also determined by other factors e.g. farmers' income.




Source: Researcher (2015)
***Figure 5.12: Correlation between Smallholders' Farming Experience and Manure Application***

Smallholders with more years of farming applied more manure to their farms than the less experienced farmers (Figure 5.12).

This finding conforms to results of previous studies. Babalola&Olayemi (2013) found out that smallholders farming general and their years of experience in cultivating the current farm holding positively influenced the use of manure and compost in Ogun State, Nigeria.

The weak positive correlation (r = 0.176) existing between smallholders' farming experience and use of manure is attributed to other socio-economic factors as well as institutional factors which also determine the use of fertilizer among smallholders.

#### 5.3.5.5 Hypothesis Testing on Farmers' Education Level and Farming Experience against use of Manure

Stepwise multiple regression analysis was used to test the $H_0$-1 stated in chapter one "that there is no significant relationship between farmers' social attributes (level of education and farming experience) and their use of SLMP (manure). The results were as follows;

***Table 5.8: Summary of Stepwise Regression Analysis on Social Factors and Manure***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| **Manure** | experience | 0.23 | 0.040 | 0.199 | 0.078 | 0.199 | 5.077 | 1 | 3.84 |

Source: Researcher (2015)

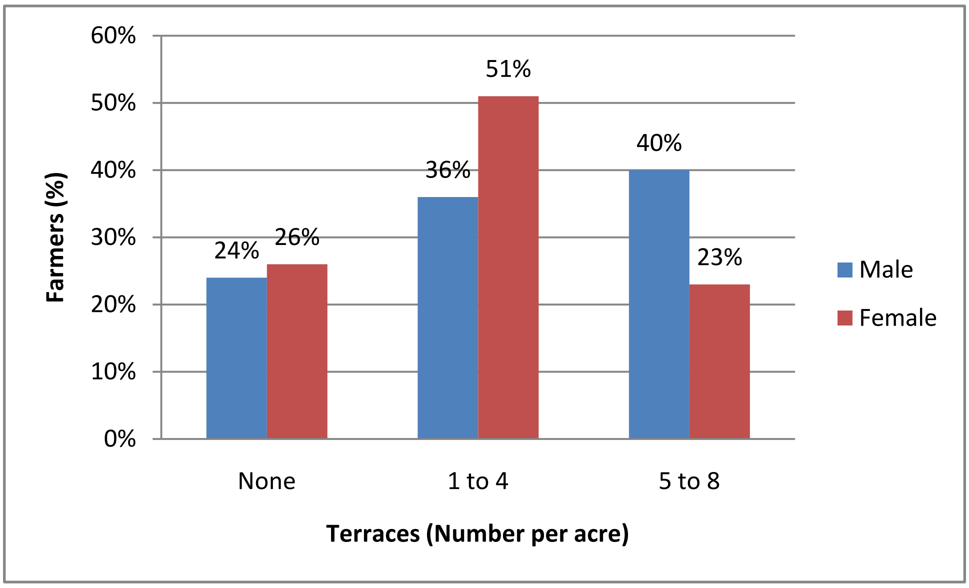
Of the two independent variables, smallholders' farming experience was singled out as the most significant predictor of manure use in Sabatia (Table 5.8).

The calculated F-statistic (5.077) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between farming experience and use of Manure" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

### 5.3.6 Farmers Social Attributes and use of Terraces

#### 5.3.6.1 Smallholders' Gender and use of Terraces

More female (77%) than male (60%) headed households had four terraces per acre or less on their parcels. On the contrary, more males (40%) than females (23%) had five terraces or more per acre (Figure 5.13)




Source: Researcher (2015)

***Figure 5.13: Relationship between Gender and Use of Terraces in Sabatia***

Chi - square analysis was used to test the hypothesis that "There is no relationship between small-scale farmers' gender and the establishment of terraces". The observed counts were greater than the expected frequencies (Table 5.9).

*Table 5.9: Chi-Square Analysis of the Relationship between Gender and Terraces use in Sabatia*

| Terraces (No. per acre) | Gender | | Total |
|---|---|---|---|
| | Male | Female | |
| 0 | 15 (12.8) | 14 (16.2) | 29 |
| 1 - 4 | 23 (28.6) | 42 (36.4) | 65 |
| 5 - 8 | 17 (13.6) | 14 (17.4) | 31 |
| Total | 55 | 70 | 125 |

Source: Researcher (2015)

Note: Figures in brackets e.g. (12.8) are the expected values (computed)

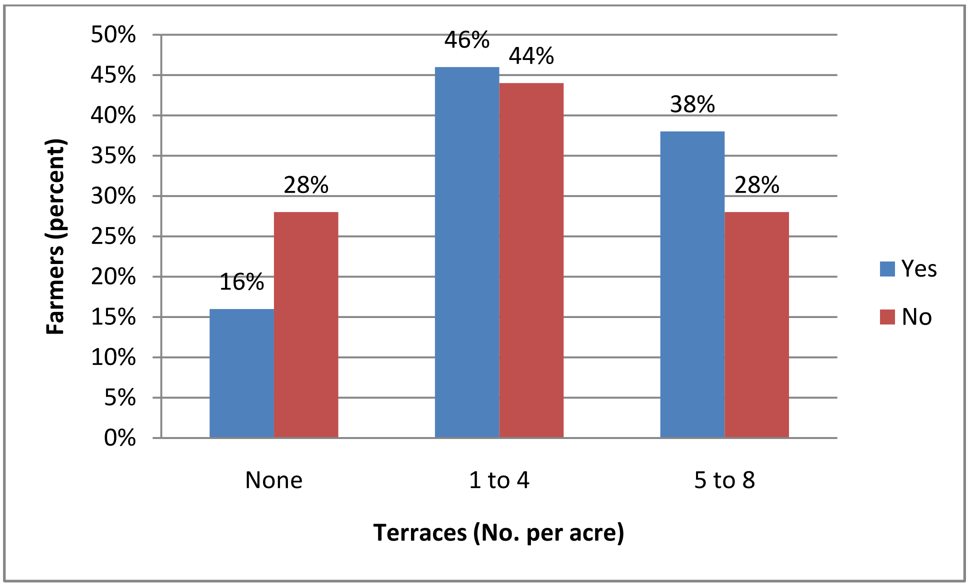
$\chi^2$computed = 4.138 df = 2 Level of Significance = 0.05 $\chi^2$critical = 0.103

The computed chi - $\chi^2$statistic (4.138) was greater than the critical chi - $\chi^2$statistic (0.103) at 0.05 confidence level, the null hypothesis was thus rejected and the alternative hypothesis adopted.

Earlier study by Babalola and Olayemi (2013) established that more male than female headed households had established terraces in Ogun State, Nigeria.

**5.3.6.2 Membership to Farmers' group and use of Terraces**

More farmers' group(s) members (84%) than non-members (72%) had terraces on their plots. On the contrary, fewer farmers' group members (16%) than non-members (28%) did not have terraces on their cropland (Figure 5.14).




Source: Researcher (2015)

***Figure 5.14: Relationship between Smallholders' Membership to Farmers' Group(s) and Terraces Use in Sabatia***

Chi - square analysis was used to test the hypothesis that "There is no relationship between membership to farmers' group and adoption terraces". The observed frequencies were greater than the expected counts (Table 5.10).

***Table 5.10: Chi-Square Analysis of the Relationship between Smallholders' membership to farmers' group and use ofterraces.***

| Terraces (No. per acre) | Membership to Farmers' Group | | Total |
|---|---|---|---|
| | Yes | No | |
| 0 | 5(8.6) | 24(20.4) | 29 |
| 1 - 4 | 19(19.2) | 46(45.8) | 65 |
| 5 - 8 | 13(9.2) | 18(21.8) | 31 |
| Total | 37 | 88 | 125 |

Source: Researcher (2015)

Note: Figures in brackets e.g. (8.6) are the expected values (computed)

$\chi^2$computed = 4.393 df = 2 Level of Significance = 0.05

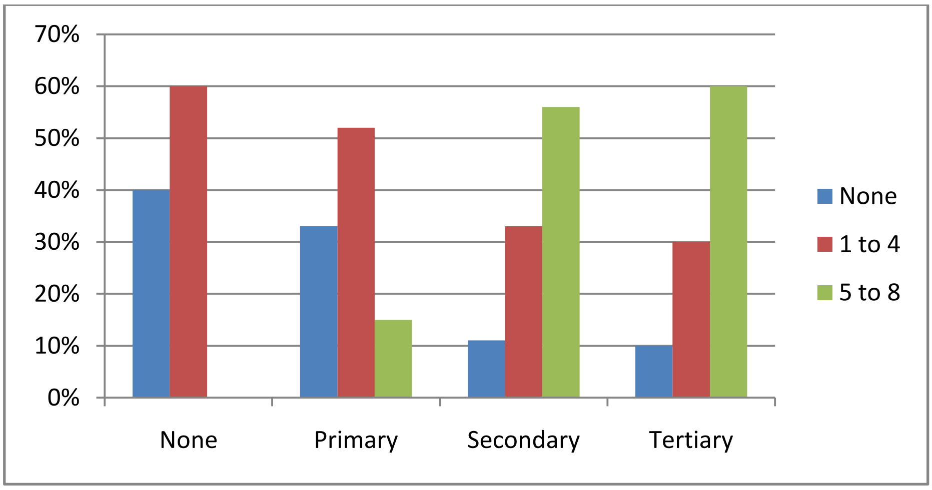
$\chi^2$critical = 0.103

The computed chi - $\chi^2$statistic (4.393) was greater than the critical chi - $\chi^2$statistic (0.103) at 0.05 confidence level. Consequently, the null hypothesis was rejected, and the alternative adopted.

Farmers who belong to farmers' groups have established more terraces than their counterparts who are not members. This result is in conformity with earlier studies. Babalola&Olayemi (2013) established that Membership of Community-Based Organization had a significant and positive relationship with the use of contour bunds among farmers in Ogun State, Nigeria.

### 5.3.6.3 Farmers' Education Level and Use of Terraces

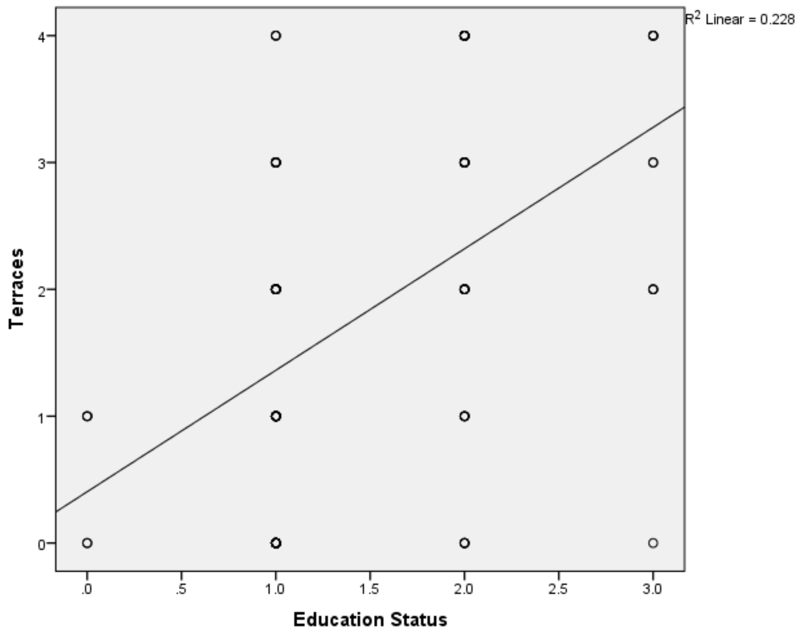
The proportion of farmers with the highest number of terraces (5 – 8) per acre increased with increase in farmers' level of education. On the contrary, the proportion of farmers without terraces decreased with improvement in the level of education (Figure 5.15).




Source: Researcher (2015)

***Figure 5.15: Relationship between Smallholders' Level of Education and use of terraces in Sabatia.***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = 0.478) between smallholders' level of education and use of terraces. $R^2 = 0.228$ indicate that at 22.8% smallholders' level of education had little though a positive influence on the use of manure (Figure 5.16).




Source: Researcher (2015)
***Figure 5.16: Simple Regression Analysis of the Relationship between Farmers' Level of Education and use of Terraces***

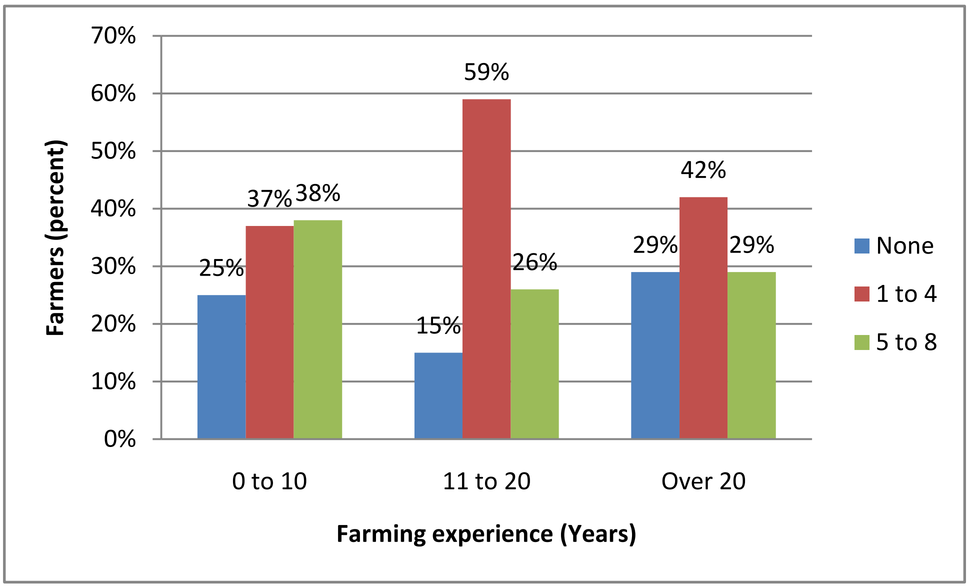
Farmers with a higher level of educational have established more terraces per acre than those with low-level education.

The finding of a positive association between farmers' educational status and terracing is consistent with results of a previous study. Heyi and Mberegwa (2012) found out that higher educational status of farmers had a positive influence on farmers' decision to use terraces.

The weak positive correlation (r = 0.478) between smallholders' education status and their use of terraces could be attributed to the fact that other variables such as farmers'; annual income, membership to farmers' groups and gender among others also determine whether or not they will construct terraces. There is thus a need for the smallholders to improve the status of their other socio-economic attributes so as to improve the significant use and gain from terracing.

### 5.3.6.4 Farming Experience and Use of Terraces

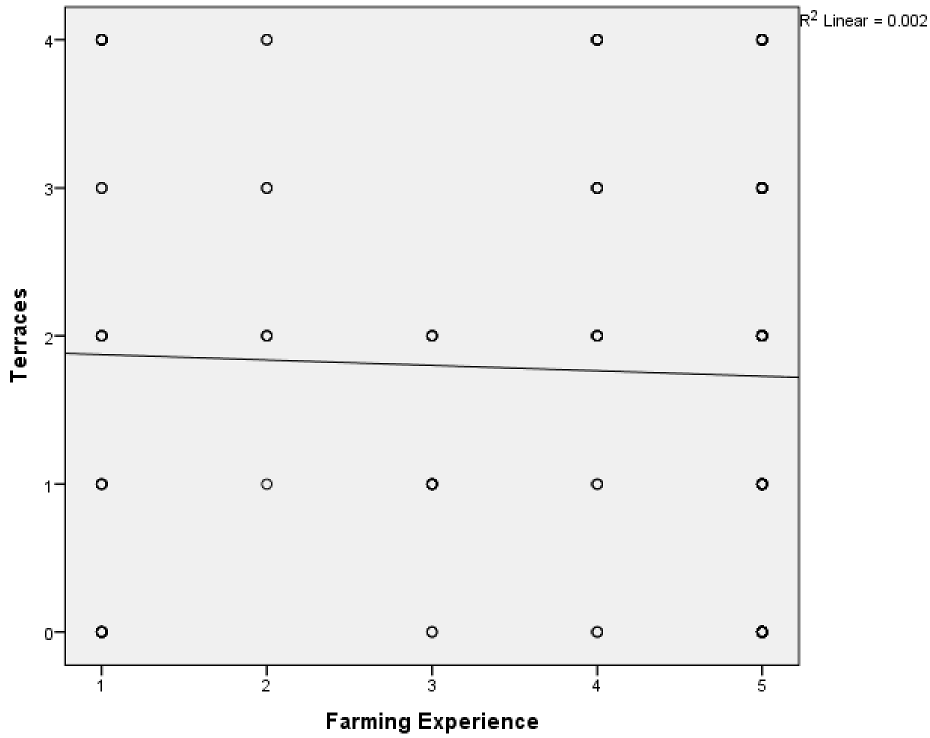
The use of terraces is almost evenly spread across the smallholders their farming experience notwithstanding (Figure 5.17).




Source: Researcher (2015)

***Figure 5.17: Relationship between Farming experience and use of terraces among Smallholders in Sabatia***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = - 0.037) between smallholders' farming experience and use of terraces (Figure 5.18). $R^2$ = 0.002 indicate that at 2% smallholders' farming experience inversely influenced the use of terraces.




Source: Researcher (2015)
***Figure 5.20: Correlation between Smallholders' Farming Experience and use of Terraces***

These results indicate that the less experienced smallholders' have established slightly more terraces per acre than farmers with more years of farming (Figure 5.20).

This finding is contrary to the initial expectation and findings of a previous study. Gitonga (2012) found out smallholders' farming experience had a positive influence on adoption of terraces in Ndabibi Location, Naivasha, Kenya.

#### 5.3.6.5 Hypothesis Testing on Farmers' Education Level and Farming Experience against use of Terraces

Stepwise multiple regression analysis was used to test the $H_0$-1 stated in chapter one that "there is no significant relationship between farmers' social attributes (level of education and farming experience) and their use of SLMP (terraces)." The results were as follows;

***Table 5.11: Summary of Stepwise Regression Analysis on Social Factors and Terraces***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| **Terraces** | education | 0.23 | 0.053 | 0.178 | 1.376 | -0.23 | 36.377 | 1 | 3.84 |

Source: Researcher (2015)

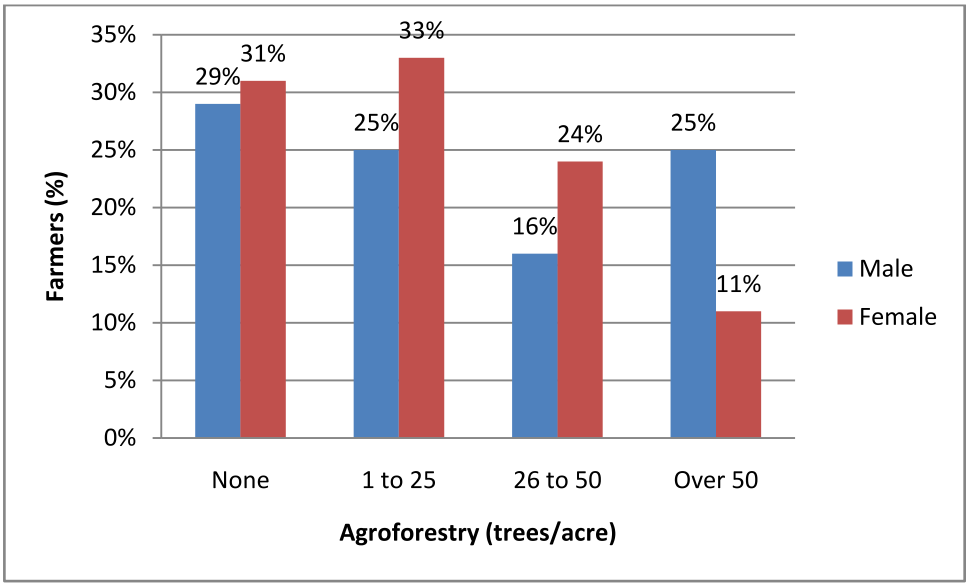
Of the two independent variables, smallholders' level of education was singled out as the most significant predictor of terraces use in Sabatia (Table 5.11).

The calculated F-statistic (36.377) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between farming experience and use of terraces" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

### 5.3.7 Farmers' Social Attributes and use of Agroforestry

#### 5.3.7.1 Smallholders' Gender and use of Agroforestry

More male (40%) than female (36%) managed farms did not have trees on their farms. More female (58%) than male (42%) however had planted between 1 and 50 trees. On the contrary, more male (18%) than female (6%) have planted over 50 trees per acre (Figure 5.19).




Source: Researcher (2015)

***Figure 5.19: Relationship between Gender and Agroforestry in Sabatia***

Chi - square analysis was used to test the hypothesis that "There is no connection between smallholder farmers' gender and use of agroforestry". The observed frequencies were greater than the expected counts (Table 5.12).

***Table 5.12: Chi-Square Analysis of the Relationship between smallholders' gender and use of agroforestry***

| Agroforestry (No. of trees per acre) | Gender | | Total |
|---|---|---|---|
| | Male | Female | |
| 0 | 22(20.7) | 25(26.3) | 47 |
| 1 - 25 | 17(18.9) | 31(24.1) | 43 |
| 26 - 50 | 6(9.2) | 15(11.8) | 21 |
| 51+ | 10(6.2) | 5(7.8) | 14 |
| **Total** | **55** | **70** | **125** |

Source: Researcher (2015)

Note: Figures in brackets e.g. (20.7) are the expected values (computed)

$\chi^2$computed = 6.802 df = 3 Level of Significance = 0.05

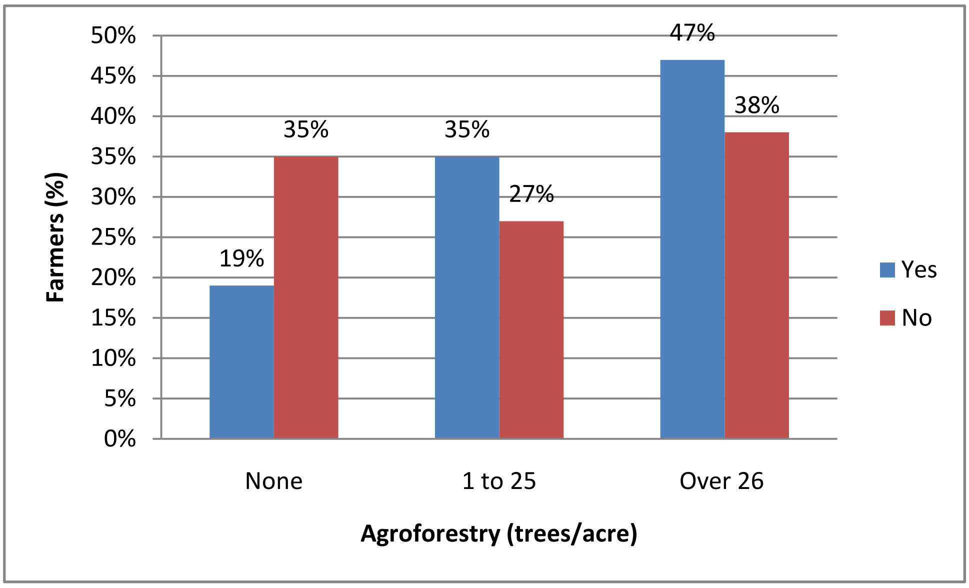
$\chi^2$critical = 0.0.352

The calculated chi - $\chi^2$statistic (6.802) was greater than the critical chi - $\chi^2$statistic (0.352) at 0.05 confidence level. The null hypothesis was therefore rejected, and the alternative adopted.

The result of the current study agrees with those of Gitonga (2010) who established a positive relationship between gender and adoption of agroforestry.

### 5.3.7.2 Membership to Farmers' group and use of Agroforestry

More farmers' group members (77%) than none members (63%) had trees on their farms. On the contrary, fewer farmers' group members (23%) than non-members (37%) did not have trees on their cropland (Figure 5.20).




Source: Researcher (2015)

***Figure 5.20: Relationship between Membership to Farmers' Groups and use of Agroforestry among Smallholders in Sabatia***

Chi - square analysis was used to test the hypothesis that "There is no relationship between membership to farmers' group and adoption agroforestry". The observed counts were greater than the expected frequencies (Table 5.13).

**Table 5.13: Chi-Square Analysis of the Relationship between membership to farmers' group andadoption of agroforestry.**

| Agroforestry (No. of trees per acre) | Membership to Farmers' Group | | Total |
|---|---|---|---|
| | Yes | No | |
| 0 | 10(13.9) | 37(33.1) | 47 |
| 1 - 25 | 15(12.7) | 28(30.1) | 43 |
| 26 - 50 | 12(6.2) | 9(14.8) | 21 |
| 51 + | 5(4.1) | 14(9.9) | 14 |
| Total | 37 | 88 | 125 |

Source: Researcher (2015)

Note: Figures in brackets e.g. (13.9) are the expected values (computed)

$\chi^2$computed = 15.670 df = 3 Level of Significance = 0.05

$\chi^2$critical = 0.352

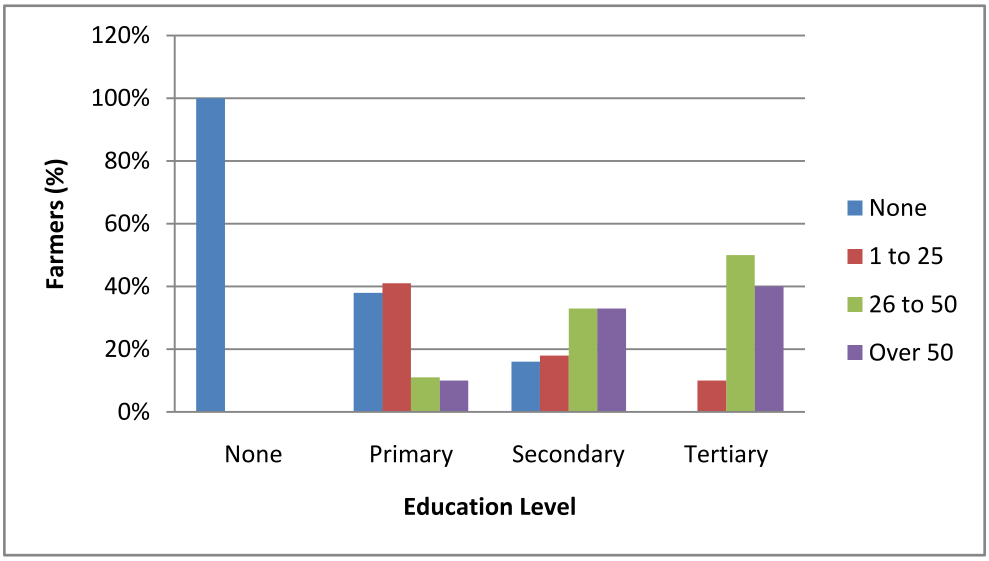
The computed chi - $\chi^2$statistic (15.670) was greater than the critical chi - $\chi^2$statistic (0.352) at 0.05 confidence level. The null hypothesis was subsequently rejected, and the alternative adopted.

Smallholders who are members of farmers' group have planted more agroforestry trees on their farms than farmers who have no membership to such groups.

These results are consistent with the research expectation as well as findings from previous studies. Gitonga (2012) established a positive correlation between smallholders' membership to farmers' associations and adoption of agroforestry in Ndabibi location, Naivasha, Kenya.

### 5.3.7.3 Farmers' Education Level and Use of Agroforestry

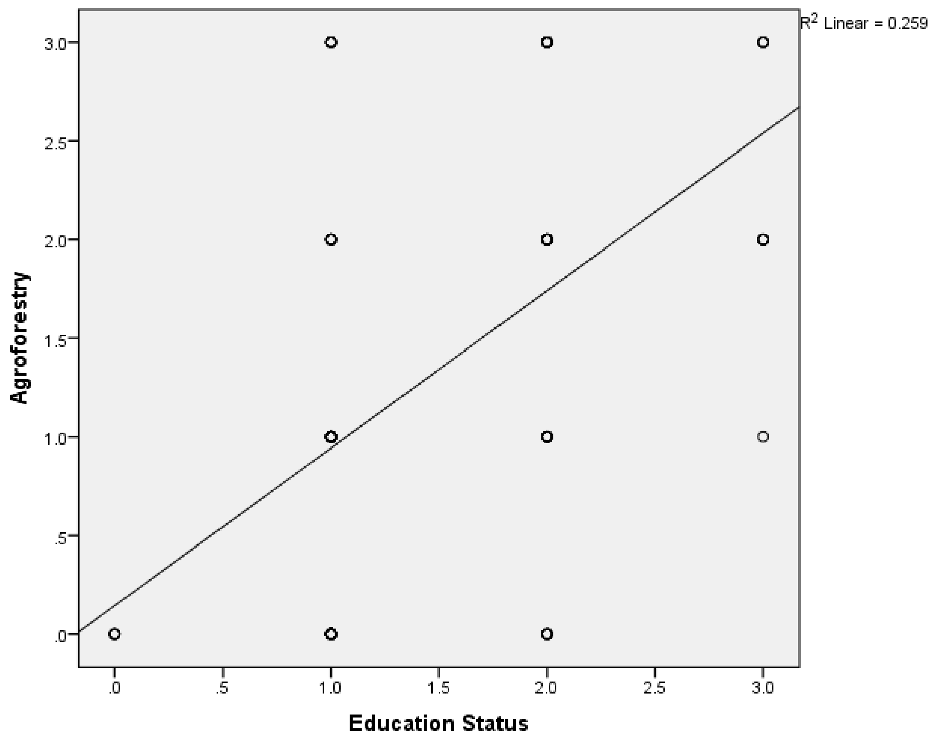
The study established that all farmers with 13 years of education and above (tertiary education) have trees on their farms. At the same time the proportion of farmers who did not have trees on their farms decreased with increase in the level of education (Figure 5.21).




Source: Researcher (2015)

***Figure 5.21: Relationship between Education Status and use of agroforestry among Smallholders in Sabatia.***

Bivariate analysis using simple regression analysis showed a strong positive correlation (r = 0.508) between smallholders' level of education and use of agroforestry. $R^2$= 0.259 indicate that education accounted for 25.9% use of agroforestry (Figure 5.22). The remaining 74.1% was determined by other factors such as farming experience.




Source: Researcher (2015)
***Figure 5.22: Correlation between Farmers' Level of Education and Adoption of Agroforestry***

Small-scale farmers' level of education positively influenced their use of agroforestry. Smallholders who had spent more years in school had planted more trees on their farmland than their counterparts who had not attended school or had fewer years of formal education.

This result is consistent with research expectation andfindings of previous studies. Simon et al (2013) found out that there was a positive relationship between farmers' level of education and use of agroforestry in Northern Part of Taraba State, Nigeria

As established elsewhere in this report, the reason behind the weak positive correlation (r = 0.054) between smallholders' educational status and their use of agroforestry is that other socio-economic factors such as; farm size, income, membership to farmers' group and gender also influence use of agroforestry in Sabatia. Improvement of smallholders' education credentials alone may not be sufficient enough to realize significant use of agroforestry.

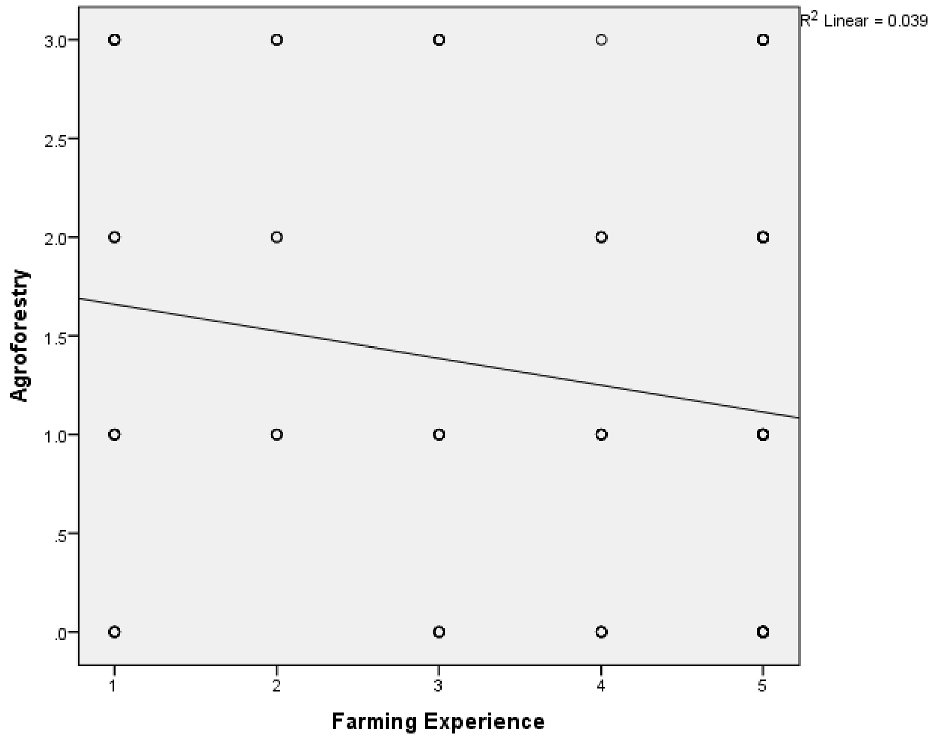
### 5.3.7.4 Farming Experience and Use of Agroforestry

The proportion of farmers with least farming experience increases with increase in agroforestry rate. On the contrary the proportion of farmers with farming experience of at least 11 years decreases with increase in agroforestry (Figure 5.23).


Source: Researcher (2015)

***Figure 5.23: Relationship between Smallholders farming experience and use of agroforestry in Sabatia***

Bivariate analysis using simple regression analysis showed a negative weak correlation (r = -0.137) between smallholders' farming experience and use of agroforestry. The $R^2$= 0.039 obtained indicate that farming experience inversely determined 3.9% use of agroforestry (Figure5.24).




Source: Researcher (2015)
***Figure 5.24: Correlation between Smallholders' Farming Experience and use of Agroforestry***

Findings indicate that less experienced farmers have planted more trees per acre than farmers with more years of farming (Figure 5.24).

The finding of negative relationship between smallholders' farming experience and use of agroforestry is inconsistent with initial expectation and findings by Gitonga (2012) who established that farming experience of smallholders had a positive influence on their decision to apply agroforestry.

#### 5.3.7.5 Hypothesis Testing on Farmers' Education Level and Farming Experience against use of Agroforestry

Stepwise multiple regression analysis was used to test the $H_0$-1 stated in chapter one that "there is no significant relationship between farmers' social attributes (level of education and farming experience) and their use of SLMP (agroforestry)". The results were as follows;

***Table 14: Summary of Stepwise Regression Analysis on Social Factors and Agroforestry***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| Agroforestry | education | 0.23 | 0.053 | 0.771 | 0.127 | 0.491 | 42.890 | 1 | 3.84 |

Source: Researcher (2015)

Of the two independent variables, smallholders' level of education was singled out as the most significant predictor of agroforestry use in Sabatia (Table 14).

The calculated F-statistic (42.890) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between smallholders' level of education and use of agroforestry" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

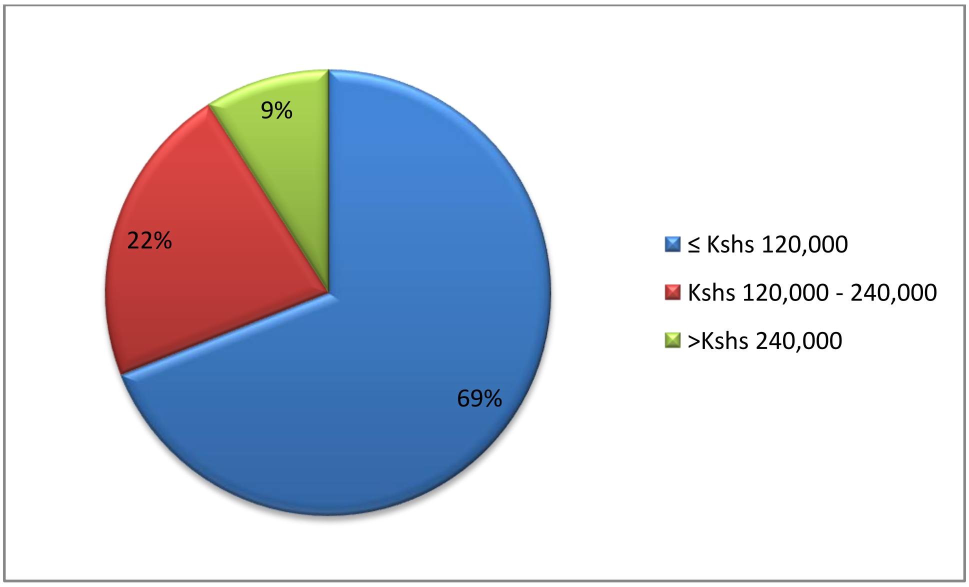
### 5.4 Smallholders' Economic Characteristics and Use of SLMP in Sabatia Sub-County

Pursuant to objective three of this study, smallholders' economic attributes that influence their use of SLMP are discussed here according to field survey results. They include household head's; annual income and the farm size. The household head is targeted as the respondent because they are thought to be the key decision makers concerning major operations on the farm.

### 5.4.1 Income and use of SLMP

Small-scale farmers' income was measured based on the amount of money they receive per month both from on and off-farm activities. Farmers' income was classified into five categories. These included those who earn: less than Kshs 120,000, Kshs 120,001 – 240,000; Kshs 240,001 – 360,000; Kshs 360,001 – 480,000 and those above 480,000 per year.

The study established that smallholders' annual income ranged from Kshs 6000 to Kshs 540,000. Majority of the respondents (69%) had an annual income not exceeding Kshs 120,000. About 22% had an income of between Kshs 120,001 and 240,000 while a paltry 9% had an annual income of between Kshs 240,001 and Kshs 540,000 (Figure 5.25).




Source: Researcher (2015)

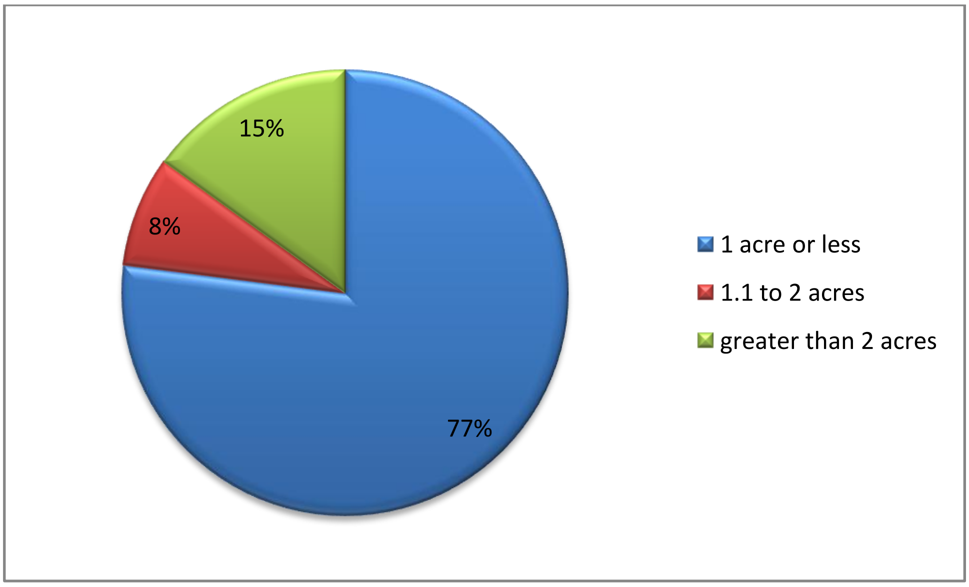
***Figure 5.25: Smallholders Income in Sabatia***

The amount of income may determine whether or not a farmer will implement SLMP. Higher income may enable a farmer to buy manure and tree seedlings as well as hire farm labour to plant trees, dig terraces and apply manure.

### 5.4.2 Farm size and use of SLMP

Farm size was categorized into three classes: less than 1 (one) acre, greater than 1 (one) acre but less than 2 (two) acres and greater than 2 (two) acres. A population density of 1,203 persons per $km^2$ implies serious land fragmentation in Sabatia Sub-County. Fragmentation result from sub-division of ancestral land and/or selling and buying (Wambua, 2008).

Data from the field survey indicate that the smallest cultivated parcel was less than 0.5 acres while the biggest parcel was 4 acres. Majority 96 (76 %) had a farm sized equal or less than 1 (one) acre. Approximately 10(18%) cultivated land greater than 1 (one) acre but less than 2 (two) acres while 19 (15%) farmed land bigger than 2 (two) acres in Sabatia (Figure 5.26).




Source: Researcher (2015)

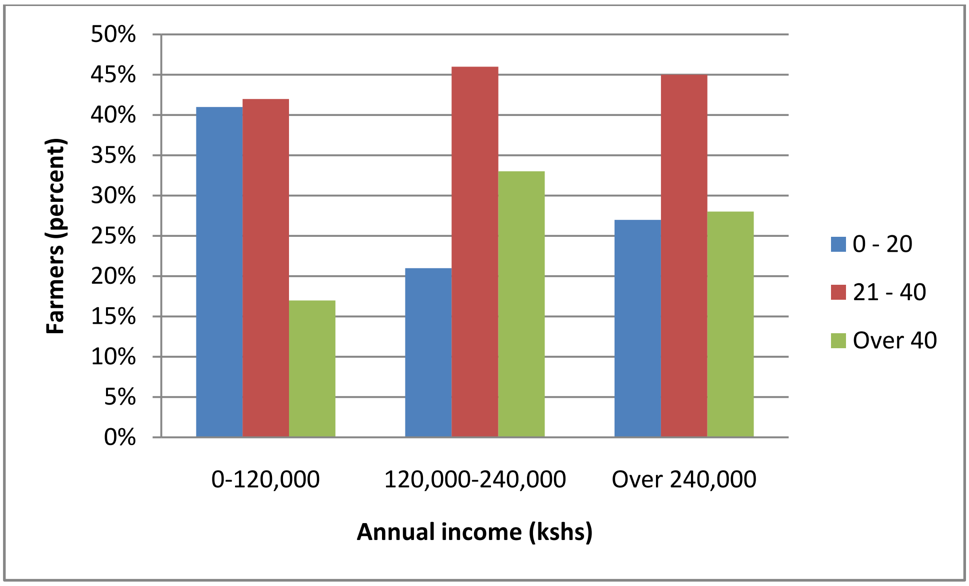
***Figure 5.26: Smallholders' farm size in Sabatia Sub-County***

Heyi and Mberegwa (2012) argue that farmers with larger farm sizes are more likely to implement sustainable land management practices. Larger farms allow space for both crop cultivation and establishment of SLMP.

### 5.4.3 Farmers' Economic Attributes and Use of Manure

#### 5.4.3.1Farmers' Income and Use of Manure

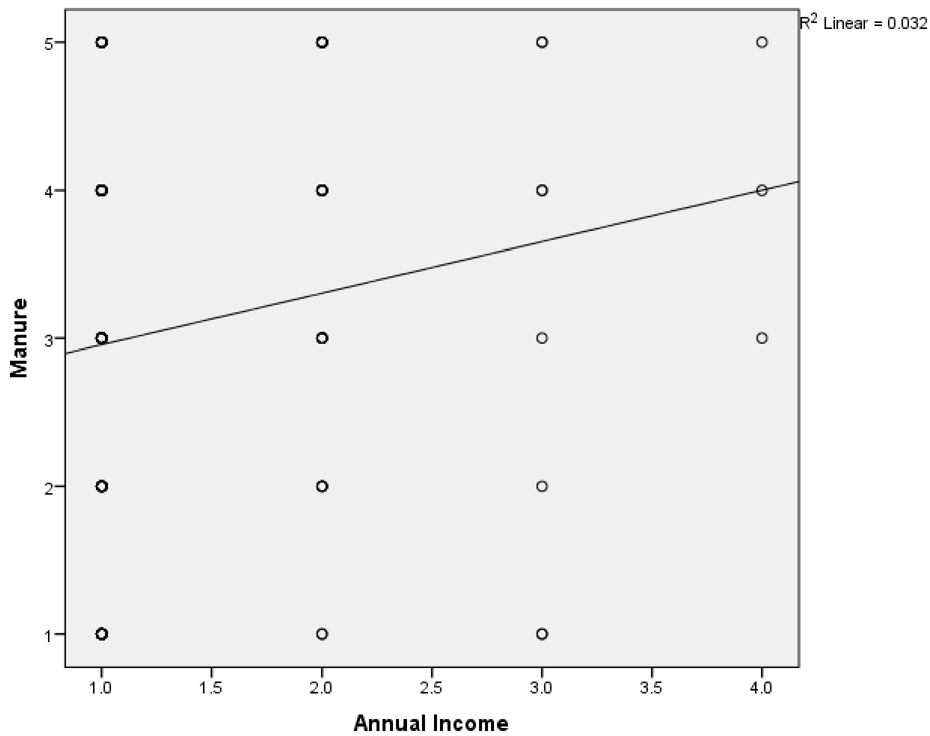
The study established that the proportion of farmers who applied the least amount of manure per acre (0 – 20 wheelbarrows) generally decreased with increase in annual income. On the other hand, the proportion of farmers who applied the highest amount of fertilizer (at least 40 wheelbarrows) generally increased with increase in income (Figure 5.27).




Source: Researcher (2015)

***Figure 5.27: Relationship between smallholders income and manure use in Sabatia.***

Bivariate analysis between farmers income and use of manure using simple regression analysis showed a positive weak correlation (r = 0.179) between smallholders' income and use of manure $R^2 = 0.032$ indicate that smallholders' income accounted for 3.2% of manure use (Figure 5.28). This can be attributed to the fact that the use of manure is also determined by other factors e.g. farming experience.



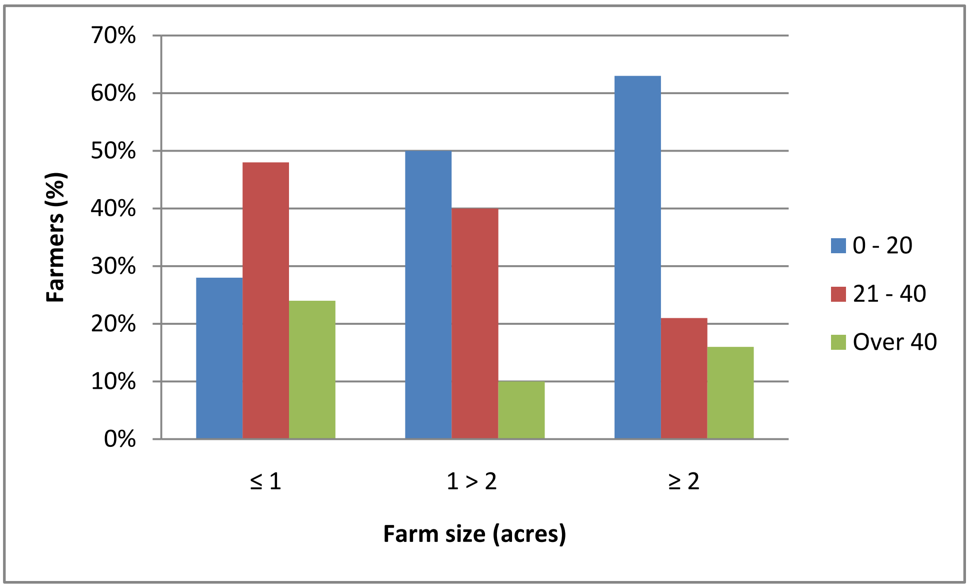

Source: Researcher (2015)
***Figure 5.28: Correlation between Smallholders' Income and Adoption of Manure Application***

These results indicate that farmers with higher annual income applied slightly higher amount of manure per acre than their counterparts who had less income (Figure 5.28). With higher income a farmer is able to buy manure and hire labour to apply.

This finding is consistent with findings of previous studies. Raufu and Adetunji, (2012) found no significant relationship between access to credit (read income) and land management practices (application of manure).

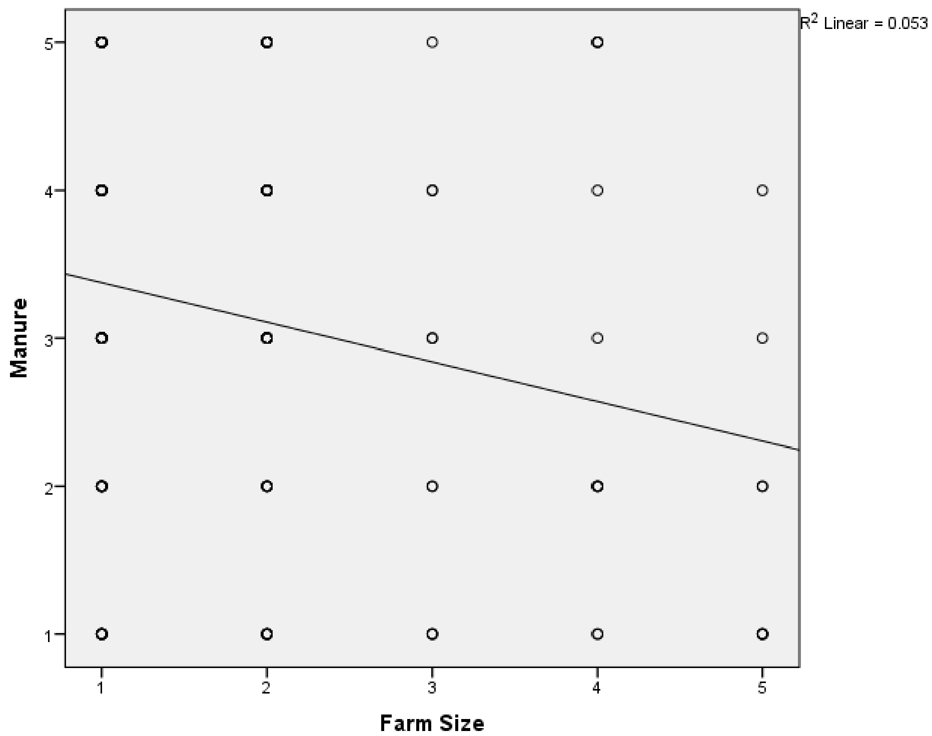
### 5.4.3.2 Farm Size and Use of Manure

The proportion of farmers who applied the least amount of manure per acre generally increased with increase in farm size. However the proportion of farmers who applied over 20 wheelbarrows of manure per acre decreased with increase in farm size (Figure 5.29)




Source: Researcher (2015)
***Figure 5.29: Relationship between farm size and manure use among smallholders in Sabatia.***

Bivariate analysis between farm size and use of manure using simple regression analysis showed a negative weak correlation (r = -0.23) between farm-size and use of manure. $R^2$= -0.053 indicate that farm size inversely accounted for 5.3% of manure use in the study area (Figure 5.30).




Source: Researcher (2015)

***Figure 5.30: Correlation between Smallholders' Farm Size and use of Manure***

This finding indicates that farmers with smaller parcels of land applied more manure per acre compared with their counterparts who had larger pieces of land. Mukhovi (2009) also established an inverse relationship between farm size and use of manure in Western Province of Kenya.

On the contrary, Heyi and Mberegwa (2012) established that there was no significant relationship between farm size and manure use per acre in Tole District, South West Shewa Zone, Oromia National Regional State, Ethiopia.

**5.4.3.3 Test of Hypothesis on Economic Factors and use of Manure**

Stepwise multiple regression analysis was used to test the $H_0$-2 stated in chapter one "that there is no significant relationship between farmers' economic attributes (farm size and annual income) and their use of SLMP (manure). The results were as follows;

***Table 5.15: Summary of Stepwise Regression Analysis on Economic Factors and Manure***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| Manure | Income | 0.33 | 0.111 | 0.23 | 1.338 | 0.25 | 7.607 | 2 | 3.00 |
| | Farm-size | 0.23 | 0.053 | 0.178 | 1.376 | -0.23 | 6.825 | 1 | 3.84 |

Source: Researcher (2015)

Basing on R value of the partial correlation, stepwise multiple regression ranked farmers' annual income above farm size as the most significant determinant of manure use in Sabatia (Table 15).

**(i) Use of Manure and Farm Size**

The calculated F-statistic (6.825) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between farm size and use of Manure" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

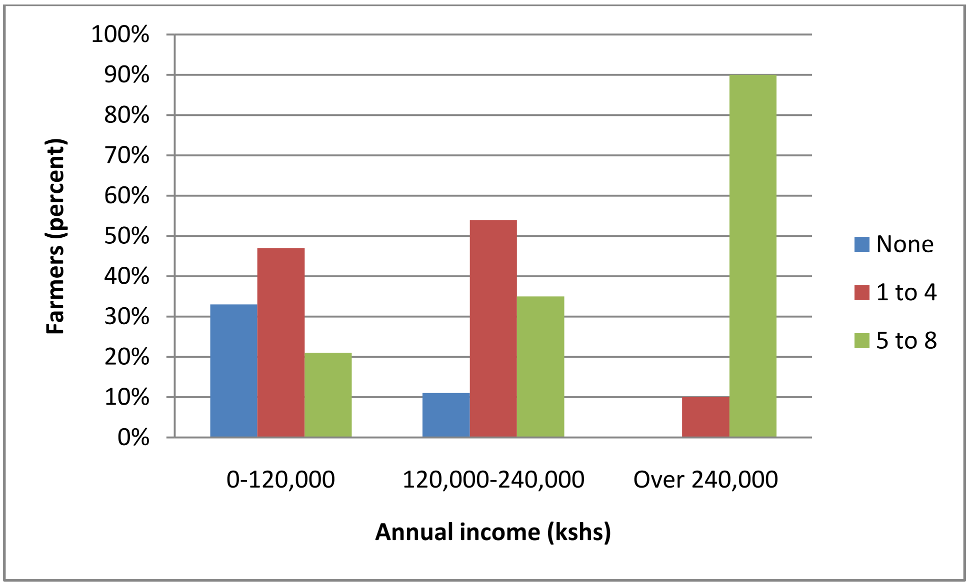
**(ii) Use of Manure and Farmers' Annual Income**

The calculated F-statistic (7.607) was greater than the critical F-statistic (3.00) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between farmers' annual income and use of Manure" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted. Income is an important contributor to use of manure as it enables the farmer to buy and/or hire labour to apply manure in the farm. Farmers with higher income thus applied more manure per acre compared to those with less income.

### 5.4.4 Farmers' Economic Attributes and Use of Terraces

#### 5.4.4.1 Farmers' Income and Use of Terraces

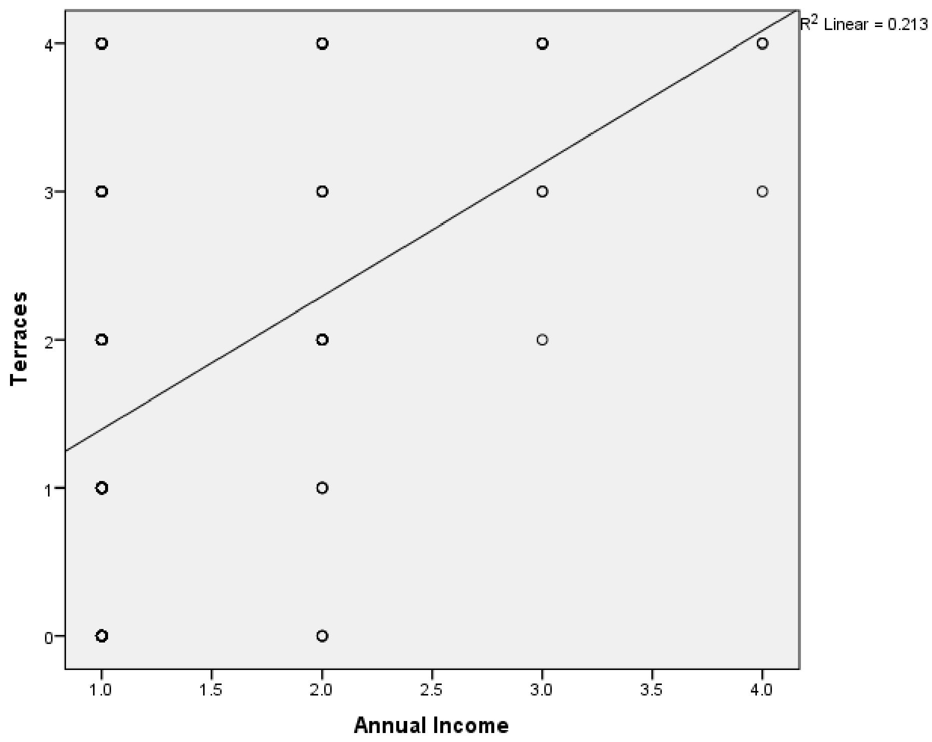
Generally the proportion of smallholders without terraces on their farms is decreasing with increase of income. On the other hand the proportion of farmers with 5 to 8 terraces per acre is increasing with increase in income (Figure 5.31).




Source: Researcher (2015)

**Figure 5.31: Relationship between Smallholders income and use of terraces in Sabatia.**

Bivariate analysis between farm size and use of manure using simple regression analysis showed a positive correlation (r = 0.461) between farmers annual income and use of terraces. $R^2$= 0.213 indicate that smallholders' income accounted for 21.3% of terraces use in the study area (Figure 5.32). Low contribution of farmers' income could be attributed to other socio-economic factors such as gender, membership to farmers' groups and farm size which also determine use of terraces among smallholders.




Source: Researcher (2015)
***Figure 5.32: Correlation between Smallholders' Income and use of Terraces***

This finding indicates that farmers with smaller parcels of land applied more manure per acre compared with their counterparts who had larger pieces of land.

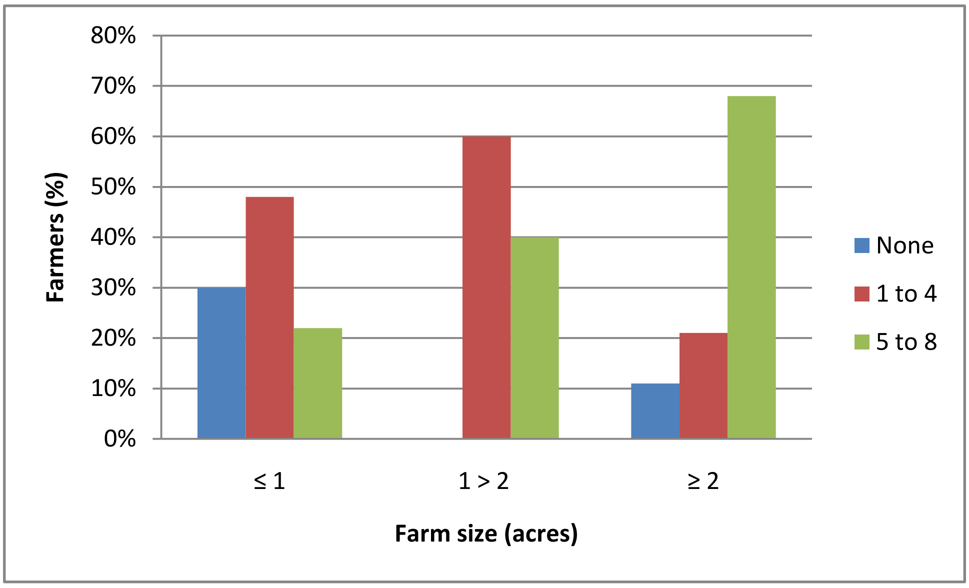
As farmers' annual income increase so is the establishment of more terraces per acre among smallholders in Sabatia Sub-County (Figure 5.32).

This result is in harmony with the initial assumption and finding of a previous study. Heyi and Mberegwa (2012) found out that there was a positive correlation between adoption of terraces and farmers annual income in Tole District, South West Shewa Zone, Oromia National Regional State, Ethiopia.

The hiring of external labour to construct terraces require money. Farmers with higher annual income are more likely to establish terraces on their plots than those with less income (Babalola&Olayemi, 2012).

**5.4.4.2 Farm Size and Use of Terraces**

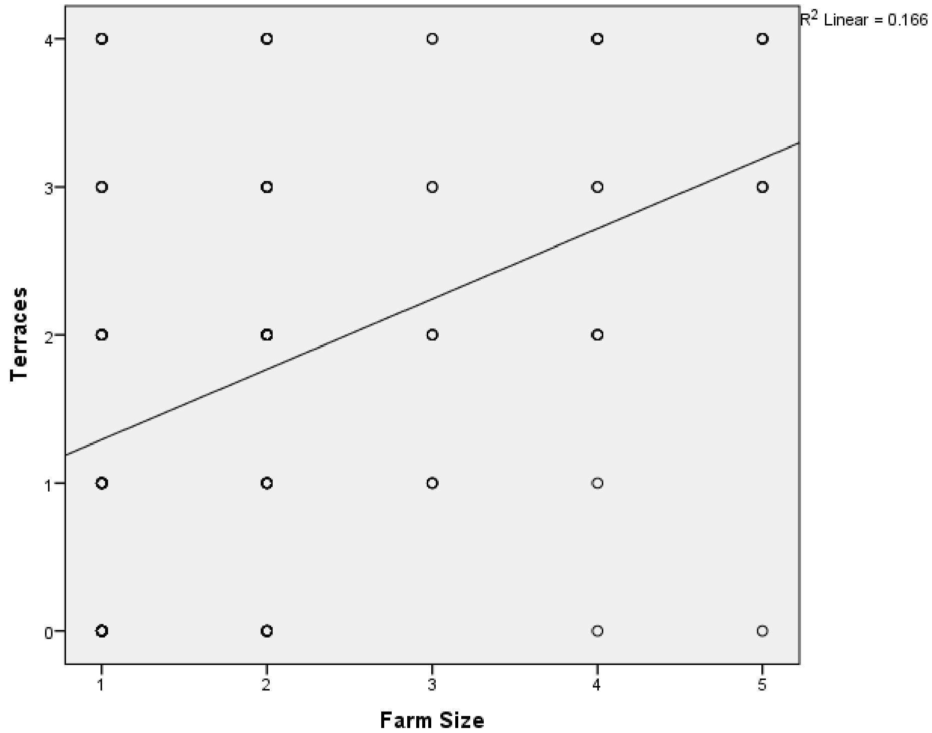
The proportion of smallholders with the highest concentration of terraces (5-8) per acre increased with increase in acreage. On the contrary, the percentage of smallholders who did not have terraces decreased with increased area (Figure 5.33).




Source: Researcher (2015)

***Figure 5.33: Relationship between Farm Size and use of Terraces in Sabatia***

Bivariate analysis between farm size and use of manure using simple regression analysis showed a weak negative correlation (r = 0.408) between farm-size and use of terraces. $R^2$ = 0.166 indicate that farm size accounted for 16.6% of terraces utilization in the study area (Figure 5.34). The small contribution of farm size could be attributed to other socio-economic factors such as educational status and farm size which also determine the use of terraces among smallholders.




Source: Researcher (2015)
***Figure 5.34: Correlation between Farm Size and Use of Terraces in Sabatia***

This finding indicates that farmers with smaller parcels of land applied more manure per acre compared with their counterparts who had larger pieces of land.

Farmers with relatively bigger land had established more terraces than those with smaller parcels. Terraces were perceived as occupying land that would otherwise be used for crop production.

The findings of this study are in conformity with those of Smith, (2004) who established that farmers with larger plot and farm sizes in Southern Province of Zambia are more capable of undertaking investments in SLMP because they can spare land areas for terraces while putting larger portions of their lands under cultivation

**5.4.4.3 Test of Hypothesis on Economic Factors and use of Terraces**

Stepwise multiple regression analysis was used to test the $H_0$-2 stated in chapter one "that there is no significant relationship between farmers' economic attributes (farm size and annual income) and their use of SLMP (manure). The results were as follows (Table 5.16);

***Table 5:16: Summary of Stepwise Regression Analysis on Economic Factors and Terraces***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| **Terraces** | Farm size | 0.553 | 0.306 | 0.408 | 0.090 | 0.315 | 26.903 | 2 | 3.84 |
| | Income | 0.416 | 0.213 | 0.132 | 0.155 | 0.461 | 33.280 | 1 | 3.00 |

Source: Researcher (2015)

According to R-value of the partial correlation, stepwise multiple regression ranked farmers' farm size above annual income as the most significant determinant of terraces use in Sabatia (Table 5.16).

**(i) Use of Terraces and Farm size**

The calculated F-statistic (26.903) was greater than the critical F-statistic (3.00) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between farm size and use of terraces" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

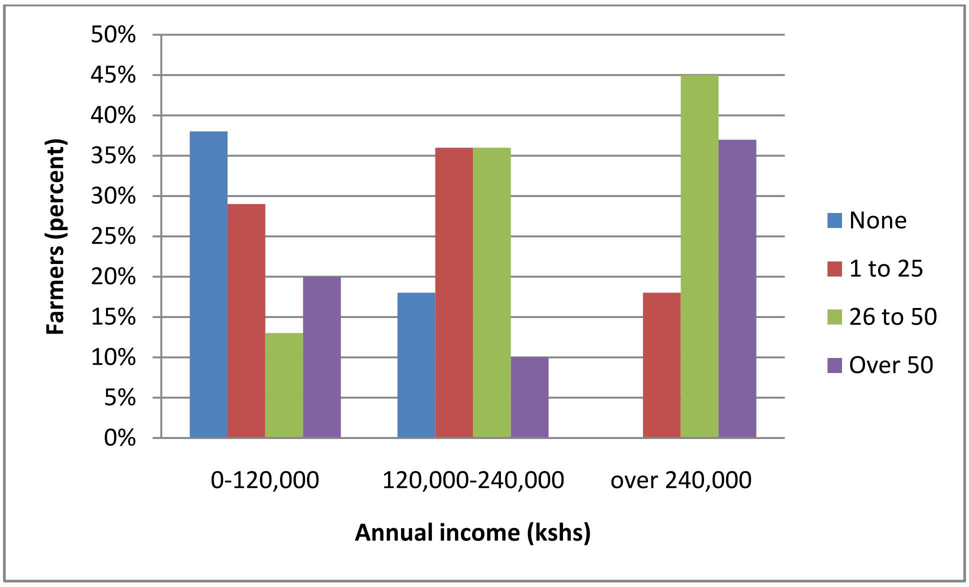
**(ii) Use of Terraces and Farmers' income**

The calculated F-statistic (33.280) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated "there was no significant relationship between income and use of terraces" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

### 5.4.5 Farmers' Economic Attributes and Use of Agroforestry

#### 5.4.5.1 Farmers' Income and Use of Agroforestry

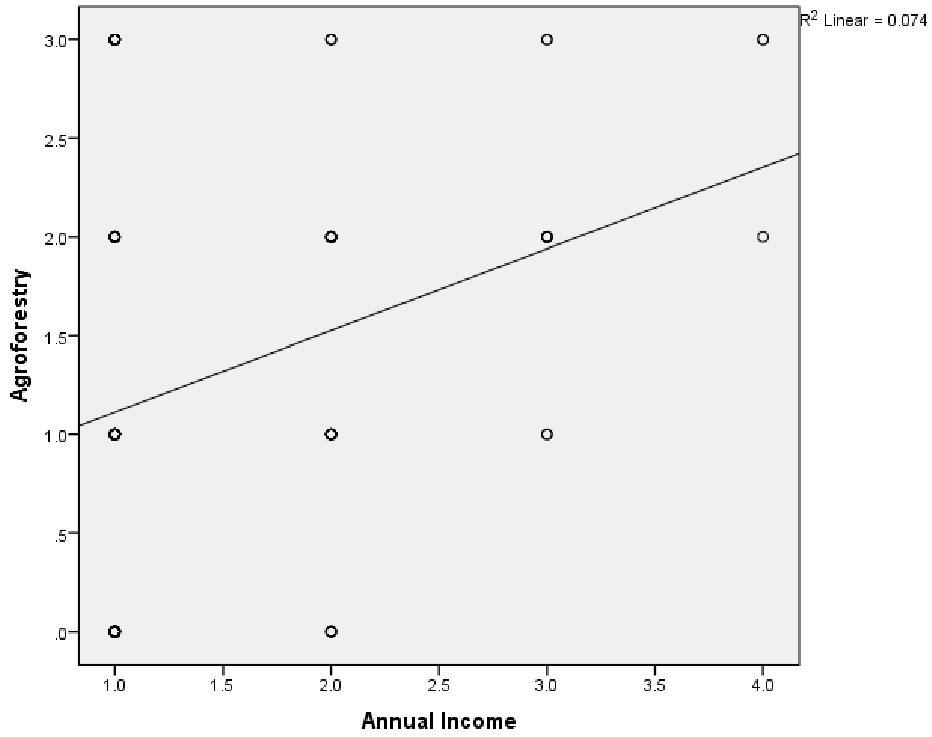
The proportions of farmers with over 26 trees per acre increase with an increase in annual income. On the contrary, the proportions of smallholders without trees on their cropland decrease with increase in annual income (Figure 5.35).




Source: Researcher (2015)

***Figure 5.35: Relationship between Smallholders income and use of Agroforestry on Sabatia.***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = 0.272) between smallholders' revenue and use of agroforestry. $R^2$ = 0.074 indicate that income accounted for 7.4% of agroforestry use in the study area (Figure 5.36). Low contribution of annual income to agroforestry use could be attributed to other socio-economic factors such as educational status and farm size which also determine the use of agroforestry among smallholders.



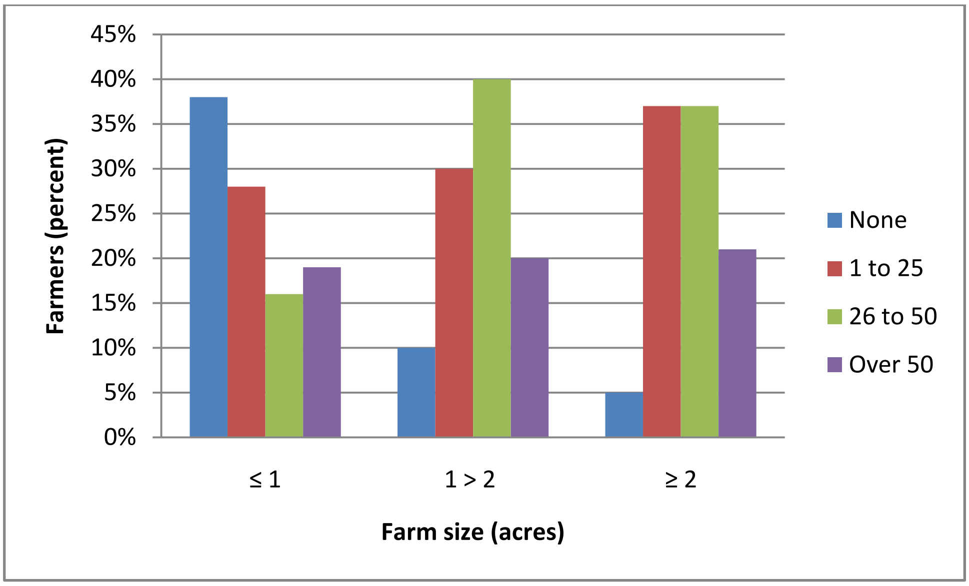

Source: Researcher (2015)
***Figure 5.36: Correlation between Smallholders' Annual income and Adoption of Agroforestry***

This finding indicates that the use of agroforestry among farmers in Sabatia increased with improvement in their annual income (Figure 5.36). Farmers with higher annual income can afford to buy seedlings and hire labor to plant the trees.

These results are in conformity with the initial assumption as well as past research findings. Gitonga (2012) found out that smallholders' annual income was significantly related to the adoption of agroforestry.

### 5.4.5.2 Farm Size and Use of Agroforestry

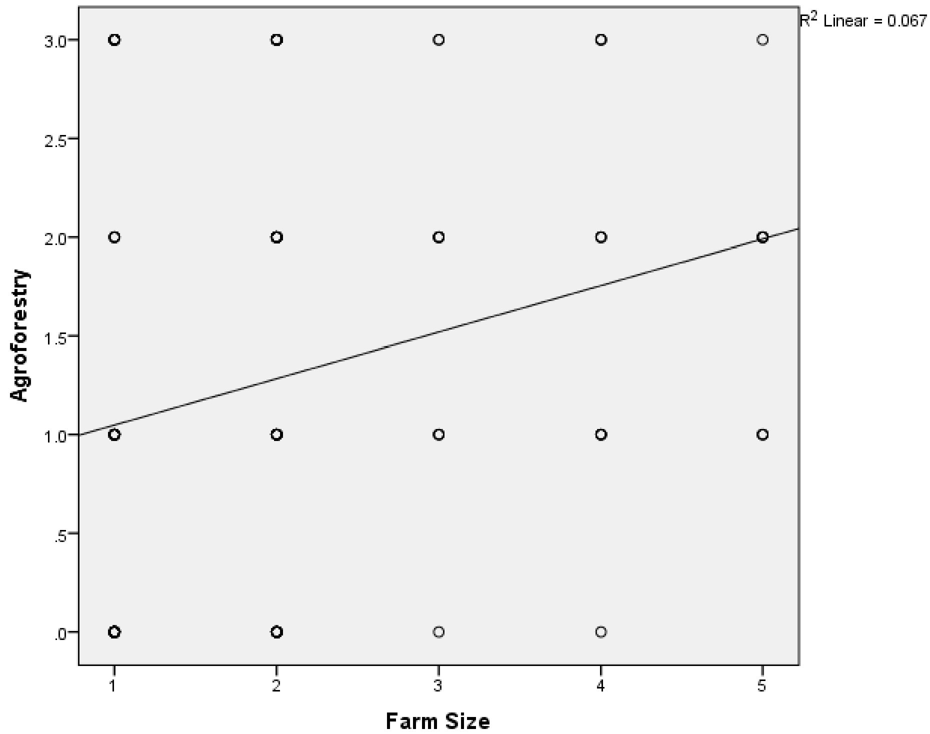
The proportion of farmers with trees on their cropland increased with the increase of farm size. On the contrary, the percentage of smallholders without agroforestry trees on their farms decreased with increase in farm size (Figure 5.37).




Source: Researcher (2015)

***Figure 5.37: Relationship between Farm Size and Use of Agroforestry in Sabatia.***

Bivariate analysis using simple regression analysis showed a weak positive correlation (r = 0.259) between farm-size and use of agroforestry. $R^2$ = 0.067 indicate that farm size accounted for 6.7% of agroforestry use in the study area (Figure 5.38). Low contribution of farm size to agroforestry use could be attributed to other factors such as farmers' income which also influence the use of agroforestry.




Source: Researcher (2015)
***Figure 5.38: Correlation between Smallholders' Farm Size and Adoption of Agroforestry***

This finding indicates that farmers with smaller parcels of land applied more manure per acre compared with their counterparts who had larger pieces of land.

Farmers cultivating relatively smaller parcels have not planted agroforestry trees as those with bigger pieces of land. This can be explained by smallholders' perception that trees would occupy cropland hence reduce yield.

These research findings are consistent with the initially assumption and results of earlier researchers. Asrat et al. (2004) found out that farmers with larger portions in the southeastern highlands of Ethiopia had planted more agroforestry trees than those with relatively smaller parcels.

#### 5.4.5.3 Test of Hypothesis on Economic Factors and use of Agroforestry

Stepwise multiple regression analysis was used to test the $H_0$-2 stated in chapter one that “there is no significant relationship between farmers’ economic attributes (farm size and annual income) and their use of SLMP (agroforestry)." The results were as follows (Table 5.17);

***Table 5.17: Summary of Stepwise Regression Analysis on Economic Factors and Agroforestry***

| Dependent Variable | Independent Variable | Multiple R | R Square | Simple R | Standard Error | Beta | Calculated F | d.f | Critical F |
|---|---|---|---|---|---|---|---|---|---|
| **Agroforestry** | Income | 0.337 | 0.113 | 0.272 | 0.080 | 0.205 | 7.803 | 2 | 3.84 |
| | Farm-size | 0.272 | 0.074 | 0.259 | 0.132 | 0.272 | 9.834 | 1 | 3.00 |

Source: Researcher (2015)

According to R-value of the partial correlation, stepwise multiple regression ranked farmers’ annual income above farm size as the most significant determinant of agroforestry use in Sabatia (Table 5.17).

**(i) Income and agroforestry use**

The calculated F-statistic (7.803) was greater than the critical F-statistic (3.84) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated “there was no significant relationship between income and use of agroforestry” was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

**(ii) Farm size and agroforestry use**

The calculated F-statistic (9.834) was greater than the critical F-statistic (3.00) at 0.05, significance level. The null hypothesis, ($H_0$: $\beta = 0$) that stated “there was no significant relationship between farm size and use of agroforestry" was rejected and the alternative hypothesis ($H_1$: $\beta \neq 0$) adopted.

### 5.5 Impact of SLMP uses on Agricultural Productivity

In line with objective four of the study, impact of SLMP (manure use, terraces, and agroforestry) on agricultural production in Sabatia Sub-County is discussed in this section according to field survey findings.

Nyangena and Kohlin (2008) observe that the use of SLMP can affect farm production positively in at least two ways. First, there could be an increase in farm yields per hectare through increased soil depth and water retention capacity. Second, adoption of SLMP may reduce input costs. For instance, increased soil fertility through accumulated soil organic matter could decrease the need to apply fertilizers.

The majority of smallholders in the study area were using SLMP although the intensity of use varied from one household to another.

The variable, agricultural production was inferred from the smallholders' net yield which was obtained by subtracting farm input cost from the output (Yields) at the prevailing market price. Both input and output were expressed in kshs. Agricultural production per acre was categorized into four distinct classes; Very low, Low, Average, and High (Table 5.18).

*Table 5.18: Categorization of Agricultural Production in Sabatia*

| Agricultural Production | Net yields per acre (Kshs) | No. of Farmers |
|---|---|---|
| **Low** | 20,000 or less | 78 |
| **Average** | 20,001 – 30,000 | 42 |
| **High** | 30,001 – 40,000 | 5 |

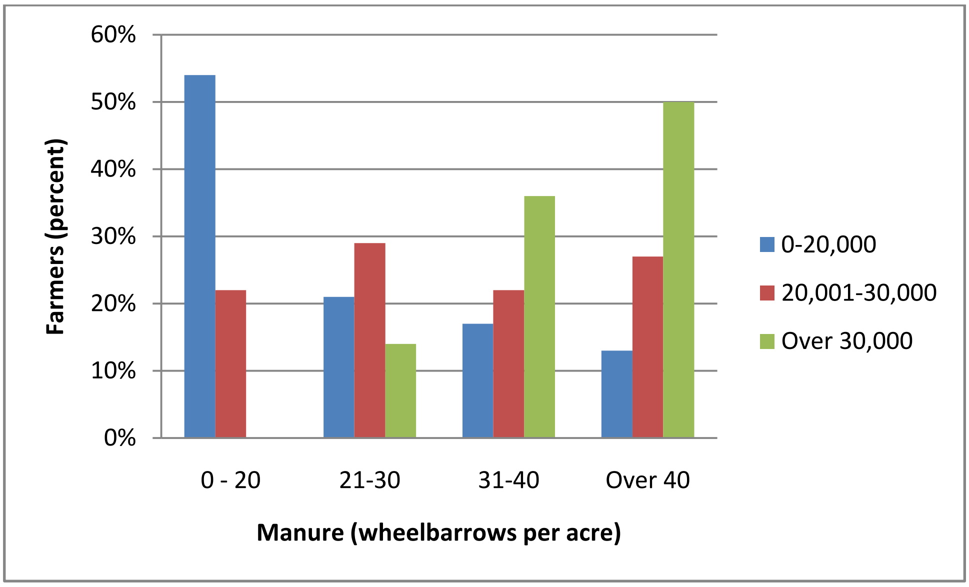
Source: Researcher (2015)

Field study revealed that agricultural production per acre in Sabatia during the year 2014 ranged between kshs -3000.00 and kshs 36,000.00. Most of the farmers 78 (62%) recorded production of 20,000.00 or less. Production per acre ranging between kshs 20,001.00 and 30,000.00 had 42 (34%) farmers, while 5 (4%) farmers had a production exceeding kshs 30,000.00 respectively (Table 5.8).

Bivariate analysis using simple regression analysis was used to establish the relationship between agricultural productivity and use of SLMP. The outcome was as follows;

### 5.5.1 Manure use and Agricultural Production

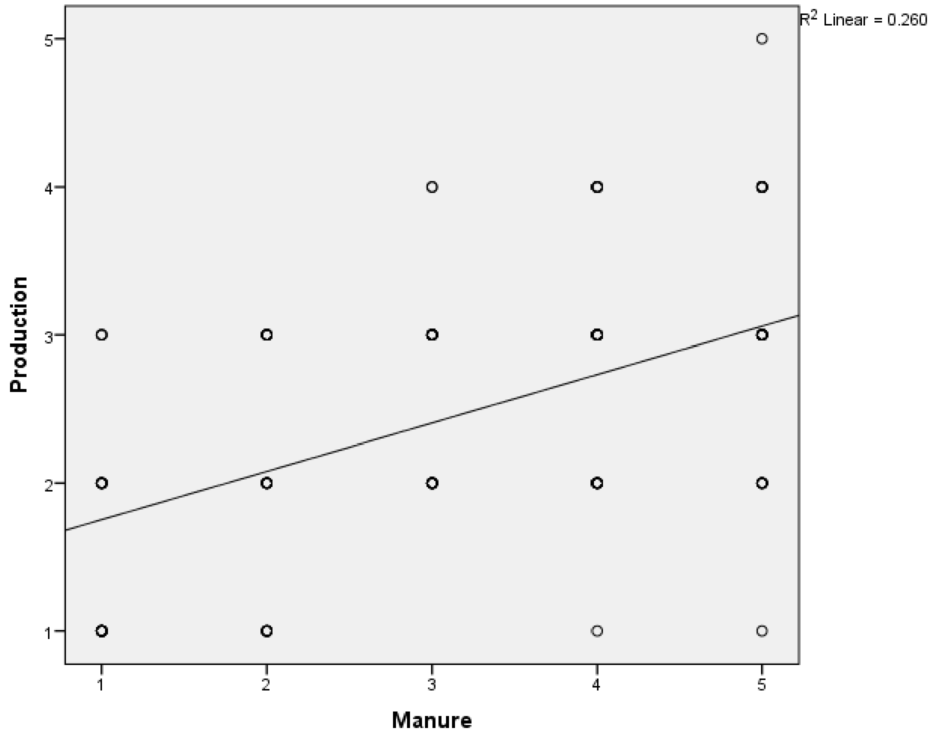
The proportion of smallholders with farm productivity per acre not exceeding kshs 20,000 decreased with the increase of manure use. On the contrary, the percentage of farmers with productivity per acre over Kshs 30,000 increased with the greater use of fertilizer (Figure 5.40).




Source: Researcher (2015)

***Figure 5.40: Relationship between Manure use and Agricultural Productivity in Sabatia.***

Bivariate correlation using simple regression analysis showed the positive correlation (r = 0.510) between the use of manure and farm production. $R^2$ = 0.260 indicate that fertilizer use in the study area accounted for 26% of agricultural production (Figure 5.41). Small contribution of manure use to farm production could be attributed to other factors such as the use of agroforestry and terraces which also determine production.




Source: Researcher 2015

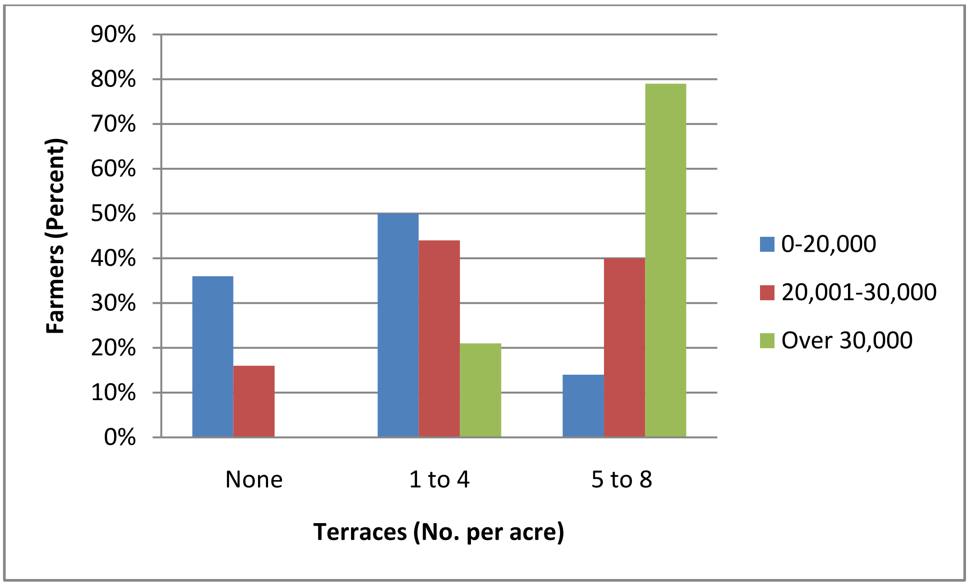
***Figure 5.41: Correlation between manure use and farm production in Sabatia.***

Farmers who applied more fertilizer per acre had better yields than those who applied less manure.

Onim et al. (1990) found out that farmers using goat manure had a superior harvest when compared with those using DAP fertilizers in Kibos near Kisumu, Kenya. Musikoyo (2012) also established that smallholders in Bungoma County who were using manure were more food secure than their counterparts who were not.

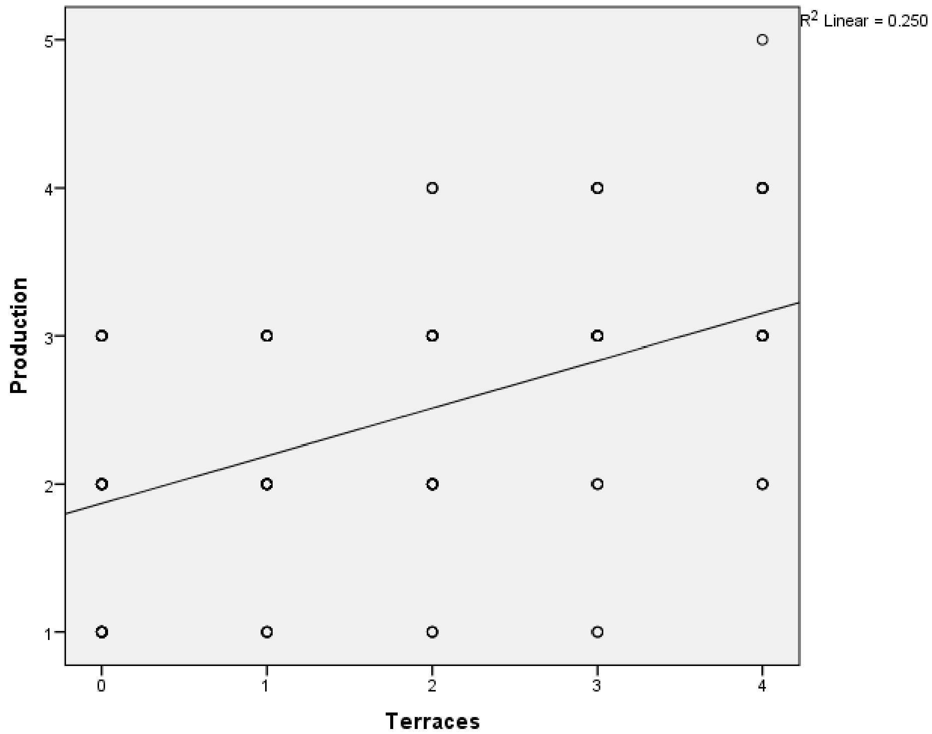
### 5.5.2 Terraces use and Agricultural Productivity

The proportion of farmers with production per acre over Kshs 30,000 increased with the greater use of terraces. On the contrary, the percentage of smallholders with farm productivity per acre not exceeding kshs 20,000 decreased with the increased terraces use (Figure 5.42).




Source: Researcher (2015)
***Figure 5.42: Relationship between Terraces use and Agricultural Productivity in Sabatia.***

Bivariate correlation using simple regression analysis showed the positive correlation (r = 0.500) between the use of terraces and farm production. $R^2$ = 0.250 indicate that terraces utilization in the study area accounted for 25% of agricultural production (Figure 5.43). Low contribution of terraces use to farm production could be attributed to other factors such as the use of agroforestry and manure which also determine production.




Source: Researcher (2015)

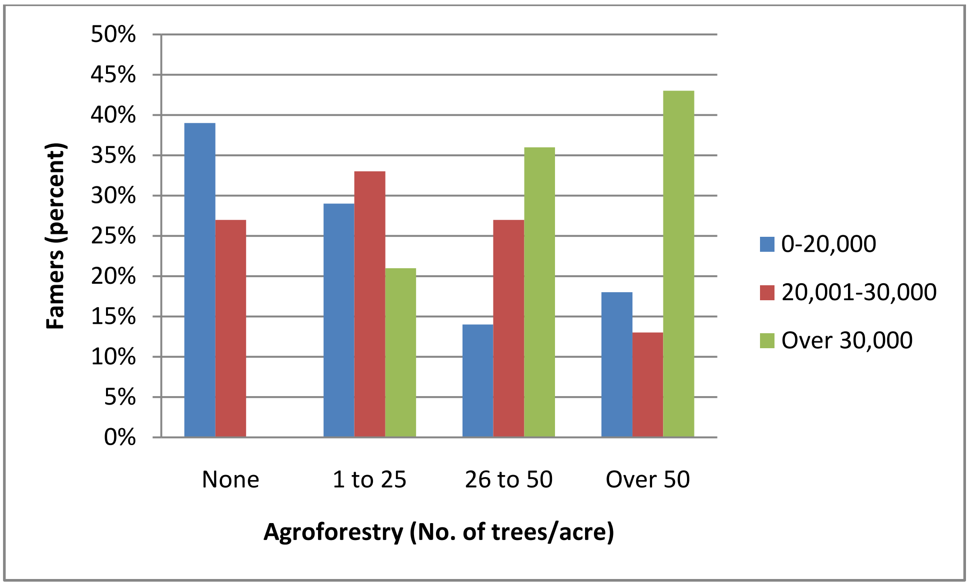
***Figure 5.43: Correlation between terraces utilization and farm production in Sabatia.***

Farmers who had more terraces per acre had better yields than those who had less.

This finding concurs with that of Nyangena&Kohlin, (2008) who established a positive relationship between use of bench terraces and agricultural productivity on steep slopes in Kiambu, Meru, and Machakos districts in Kenya.

### 4.5.3 Agroforestry use and Agricultural Productivity

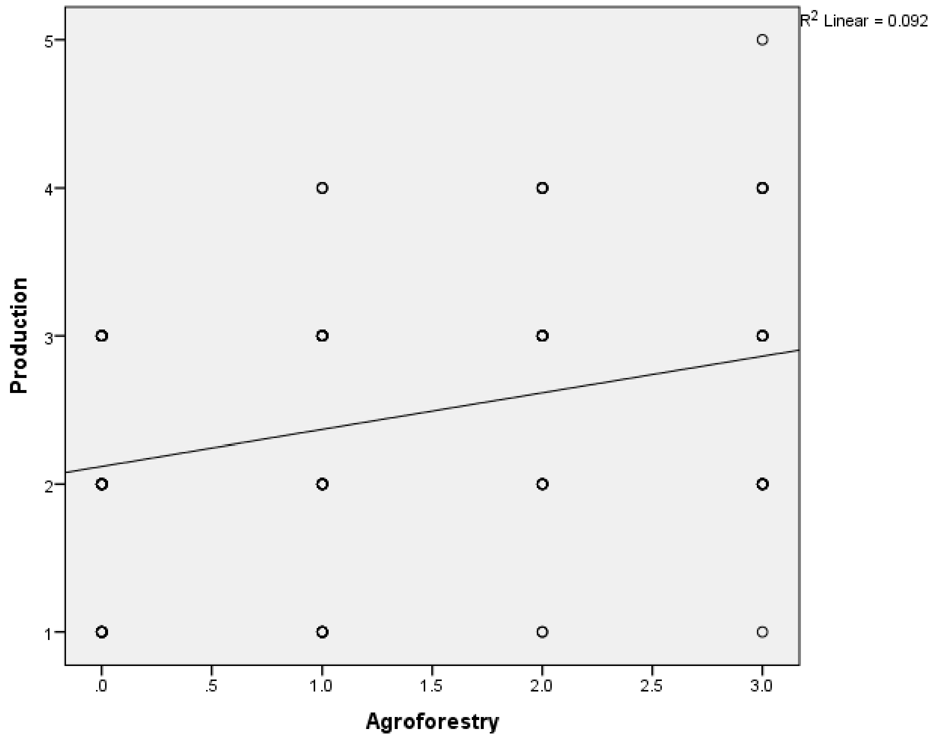
The proportion of smallholders with production per acre not exceeding Kshs 20,000 decreased with increase in agroforestry rate. On the contrary, the proportion of smallholders with farm production more than Kshs 30,000 increased with increased use of agroforestry in Sabatia (Figure 5.44).




Source: Researcher (2015)

***Figure 5.44: Relationship between Agroforestry use and Farm Productivity in Sabatia.***

Bivariate correlation using simple regression analysis showed the positive correlation (r = 0.303) between the use of agroforestry and farm production. $R^2$ = 0.092 indicate that agroforestry in the study area accounted for 9.2% of agricultural production (Figure 5.45). Low contribution of agroforestry use to farm production could be attributed to other factors such as the use of terraces and manure which also influence farm production.




Source: Researcher (2015)

***Figure 5.45: Correlation between agroforestry use and farm production in Sabatia.***

Farmers who had more agroforestry trees per acre had better yields than those who had less. Musikoyo (2012) also established that there is a positive relationship between use of agroforestry and food security in Bungoma County.

# CHAPTER SIX

# SUMMARY OF KEY FINDINGS, CONCLUSION AND RECOMMENDATIONS

## 6.1 Introduction

This study aimed at addressing the socio-economic determinants of sustainable land management practices adoption among smallholder farmers in Sabatia Sub-County, Kenya. The summary of the key findings is organized along the specific objectives outlined in chapter one. Finally, recommendations for policy makers and future researchers are suggested.

## 6.2 Summary of Key Findings

Soil erosion, as well as loss of soil fertility, have been established as the most prevalent forms of land degradation among smallholders in Sabatia Sub-County. These are as a result of less use of land management practices. The hilly terrain of land as well as the high annual rainfall (1900mm) is also to blame. The result of this is low farm productivity in this area.

To mitigate the impact of land degradation, small-scale farmers have adopted some sustainable land management practices, notably; manure application, use of terraces, and planting of agroforestry trees. They have also established grass strips apart from applying chemical fertilizers – Diammonium Phosphate (D.A.P), Urea and Calcium Ammonium Nitrate (C.A.N) – to their farms.

The rate of SLMP use mainly terraces and agroforestry is low. Despite the sloping nature of land in the study area, about 38 and 23 percent of smallholders have not adopted agroforestry and terracing respectively.

Farmers' social attributes that were hypothesized to influence their use of SLMP were; the level of education, farming experience, gender and membership to farmers' group. Stepwise multiple regression and Simple regression analysis were used to analyze the relationship of household heads'; the level of education and farming experience to the adoption of SLMPs – manure application, terracing, and agroforestry. On the other hand chi-square test was used to analyze the relationship of smallholders' gender and membership to farmers group with the adoption of SLMP.

From the analysis of the field data, it was established that; farmers' level of education did not influence their adoption of manure application. More educated farmers, however, had adopted terracing and agroforestry than their less educated counterparts.

The farming experience of smallholders did not have a bearing on adoption of terracing and agroforestry. It, however, favored adoption of manure application. The more experienced farmers over time had raised more livestock which is a primary source fertilizer applied to farms.

It was further established that smallholders' gender did not have any relationship with their use of fertilizer in the study area. However, chances of male supervised households creating terraces and agroforestry were higher compared to female managed homes in Sabatia.

Smallholders' membership to farmers' group positively influenced their adoption of; manure application, terracing, and agroforestry.

Smallholders' economic attributes considered for this study were; annual income and farm size Simple regression analysis was used to analyze the relationship of household heads'; annual revenue and farm size to the adoption of SLMPs – manure application, terracing, and agroforestry.

Field observation established that farmers' annual income did not affect their adoption of manure application. On the contrary, annual revenue had an influence on adoption of terraces and agroforestry. Farmers with higher annual income were more likely to establish terraces and plant agroforestry trees on their farms.

Farmers with smaller parcels of land applied more manure per acre than their counterparts who had larger pieces of land. Farm size also had an influenced on the use of terraces and agroforestry among small-scale farmers in the study area. Farmers with bigger parcels had adopted terracing and agroforestry more than those with smaller parcels.

Although adoption of SLMP among smallholders in Sabatia is dismal, analysis of field observation showed that the few farmers who were using substantial; manure, terraces and agroforestry had higher farm productivity.

### 6.3 Conclusion

Feeding the ever growing population is perhaps the greatest challenge facing the agriculture sector today. This is as a result of land degradation among other factors. Various forms of degradation have not only resulted in low agricultural productivity per hectare but also facilitated the loss of formerly agricultural land in several regions of the world.

To ensure agricultural sustainability, reduction of hunger and malnutrition, as highlighted in the Sustainable Development Goals (SDGs), it has become necessary to focus policies on enhancing sustainable land management, especially in vulnerable areas. Sustainable land management practices have been with us for quite a while, but the rate at which they have been adopted by farmers is unsatisfactory particularly in sub-Sahara Africa.

For the efficient and sustainable implementation of programmes on sustainable land management practices just like any other innovation, the characteristic of farmers and their perception must be carefully evaluated and incorporated into planning framework such as highlighted in this study.

## 6.4 Recommendations

The study came up with various recommendations aimed at improving the use of SLMP (manure application, terraces, and agroforestry) among the smallholder farmers.

### 6.4.1 Recommendations to Policy Makers

Land degradation if not checked may incapacitate agriculture from meeting its obligation of feeding the ever-growing population in not only Sabatia but the world as a whole. Although smallholders are yet to embrace SLMP entirely, it is promising to raise the agricultural productivity of the study area by lowering farm input costs while at the same time increasing farm yield. Specific policy issues that need to be addressed so as to improve adoption include;

a) Since agriculture is a devolved function of the county government, the minister in charge should encourage smallholders to use terraces and agroforestry irrespective of their farm size as it has been established that the two practices increase agricultural productivity.

b) Vihiga County Government Minister in charge of Agriculture, Livestock, Fisheries and Cooperatives, should mobilize both female and male household heads in the uptake of manure, agroforestry, and terracing. Ideally, there should be no difference between male and female headed households concerning SLMP use

c) Farmers' educational status positively influences the use of terraces and agroforestry. The study thus encourages the need for parents to send their children to school as this enhances SLMP use. Farmers should also actively participate in farmer field schools to increase their uptake of SLMP

d) Smallholders who were members of farmers' groups were better adopters of SLMP than those who were not. Small-scale farmers thus should be encouraged to form and join farmers' associations to improve their SLMP adoption.

e) Farmers who have higher annual income have embraced agroforestry and terraces more than the relatively low-income earners. The study suggests that smallholders should engage more in income generating activities which will then translate to improved use of SLMP.

### 6.4.2 Suggestion for Further Research

In the course of conducting this study, a number of related issues that could not be addressed arose. Future research could focus on them. They include;

a) SLMP adoption in various agro-ecological zones – the current study was conducted in an area that falls under agroecological zone I. the findings may not apply to areas in other agro-ecological zones.

b) Institutional determinants of SLMP adoption – This study investigated smallholders' socio-economic attributes that influence their use of SLMP. Future research could look into institutional factors as sustainable agriculture is too large to be left to individual farmers alone. There is a need to assess the role of government and non-government agencies in the adoption of SLMP.

c) The Impact of adoption of SLMP on socio-economic wellbeing of smallholders could be investigated as this research looked into the influence of farmers' socio-economic characteristics on their use of SLMP.

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# APPENDICES

## Appendix I: Household Survey Questionnaire

Dear respondent,

My name is William A. Andahi, a postgraduate student undertaking M.A – Agricultural Geography degree at the University of Nairobi. I am conducting research as a requirement in partial fulfillment for the degree course. The aim of this questionnaire is to collect data on socio-economic determinants of sustainable land management practices among smallholder farmers in Sabatia Sub-County. The research is for academic purpose only. Your honest answers to the question posed will be highly appreciated and that any information provided will be treated with strict confidentiality.

Thank you.

### I. DEMOGRAPHICS

1. Name of respondent: ………………………………………….

2. Address of respondent

    (a) Division: ……………………………………………………

    (b) Location: ……………………………………………………

    (c) Sub-Location: ………………………………………………

    (d) Village: …………………………………………………….

3. Sex of respondent:

    Male [ ]

    Female [ ]

4. How old are you?

    (a) 20-30 Years [ ]

    (b) 31- 40 Years [ ]

    (c) 41-50 Years [ ]

    (d) 51-60 Years [ ]

    (e) Over 61Years [ ]

5. Educational level

(a) Primary Level [ ]

(b) Secondary Level [ ]

(c) Tertiary Level [ ]

6. Who makes the major decision regarding farming in your household?

Husband [ ]

Wife [ ]

Other (specify) [ ]

7. What is your occupation?

(a) Farmer [ ]

(b) Casual Labourer [ ]

(c) Business [ ]

(d) Others (Specify) [ ]

8. What is your average income per month in Kshs?

(a) 0-10,000 [ ]

(b) 10,001-20,000 [ ]

(c) 20,001-30,000 [ ]

(d) 30,001-40,000 [ ]

(e) Over 40,000 [ ]

10. Did you take any credit for SLMP - purchase of manure/ Agroforestry/ terraces e.t.c. on your farm in the last 12 months?

Yes [ ]

No [ ]

11. If yes, from which source did you borrow?

(a) Bank [ ]

(b) Cooperatives [ ]

(c) Private money lenders [ ]

(d) Others (Specify) [ ]

12. How much did you borrow?

……………………………………………………………………………………..

13. Do you think that engagement in SLMP on your farm would be an important measure in improving your income level?

(a) Strongly agree [ ]

(b) Agree [ ]

(c) Undecided [ ]

(d) Disagree [ ]

(e) Strongly disagree [ ]

14. For how long have you been farming?

(a) 0 – 5 Years [ ]

(b) 6 – 9 Years [ ]

(c) 10 – 14 Years [ ]

(d) 15 – 20 Years [ ]

(e) Over 21 Years [ ]

14. Type of Land ownership

(a) Individual [ ]

(b) Communal [ ]

(c) Rented [ ]

(d) Others (specify) ………………………….. [ ]

15. What is the size of your land in acres?

(a) 0.5 [ ]

(b) 1 [ ]

(c) 1.5 [ ]

(d) 2 [ ]

(e) 2.5 [ ]

(f) Other (specify) [ ]

16. Do you belong to any farmers' group?

Yes [ ]

No [ ]

17. If yes which ones?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

18. Which activities does your group engage in?

..........................................................................................................................

.............................................................................................................................

...........................................................................................................................

19. In what ways has your association contributed towards SLMP adoption?

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

20. How often do you meet?

………………………………………………………………………………….

**II: SUSTAINABLE LAND MANAGEMENT PRACTICES**

22. Is your farm affected by land degradation?

Yes [ ]

No [ ]

23. If yes which form(s) of land degradation do you face?

(a) Soil erosion

(b) Leaching

(c) Loss of soil fertility

(d) Other (Specify)

24. How do you address the challenges of land degradation on your farm?

(a) Terraces [ ]

(b) Manure application [ ]

(c) Agroforestry [ ]

(d) Other (Specify) …………………………………. [ ]

25. Do you have terraces on your farm?

Yes [ ]

No[ ]

26. If yes how many terraces have you established per acre?

(a) 1-2 [ ]

(b) 3-4 [ ]

(c) 5-6 [ ]

(d) 7-8 [ ]

27. What is the importance of terraces to your farming?

(a) Reduction of soil erosion [ ]

(b) Conservation of water [ ]

(c) Improve Soil fertility [ ]

(d) Improve agricultural productivity [ ]

(e) Other (Specify) ……………………………………… [ ]

28. Do you use manure on your farm?

Yes [ ]

No [ ]

29. If yes what amount do you apply per season per acre?

(a) 1 – 10 Wheelbarrows [ ]

(b) 11 – 20 Wheelbarrows [ ]

(c) 21 – 30 Wheelbarrows [ ]

(d) 31 – 40 Wheelbarrows [ ]

(e) Over 41 Wheelbarrows [ ]

30. Why do you apply manure to your farm?

(a) Reduction of soil erosion [ ]

(b) Conservation of water [ ]

(c) Improve Soil fertility [ ]

(d) Improve agricultural productivity [ ]

(e) Other (Specify) ……………………………………… [ ]

31. Do you Practice agroforestry on your farm?

Yes [ ]

No [ ]

32. If yes how many trees have you planted on your cropland?

(a) 1 - 25[ ]

(b) 26 - 50[ ]

(c) Over 50 [ ]

(d) None [ ]

33. Which tree species have you planted alongside crops?

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

34. Why do you practice agroforestry?

(a) Reduction of soil erosion [ ]

(b) Conservation of water [ ]

(c) Improve Soil fertility [ ]

(d) Improve agricultural productivity [ ]

(e) Other (Specify) ………………………………………… [ ]

**III: AGRICULTURAL PRODUCTIVITY**

35. List the crops you produced last year

| Crop | Total production (kgs, bags, etc.) | Total Production (kshs) | Farm input cost (kshs) | Deviation |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| Total | | | | |

36. What do you think are the factors that affect the production of food by your household?

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

37. In your opinion do you think that adoption of SLMP – terracing, manure application or agroforestry can enhance your farm productivity?

(a) Strongly agree [ ]

(b) Agree [ ]

(c) Undecided [ ]

(d) Disagree [ ]

(e) Strongly disagree [ ]

# Appendix II: F-test Table

***Critical values of F for the 0.05 significance level:***

| df | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 161.5 | 199.5 | 215.7 | 224.6 | 230.2 | 233.99 | 236.77 | 238.88 | 240.54 | 241.88 |
| **2** | 18.51 | 19.00 | 19.16 | 19.25 | 19.30 | 19.33 | 19.35 | 19.37 | 19.39 | 19.40 |
| **3** | 10.13 | 9.55 | 9.28 | 9.12 | 9.01 | 8.94 | 8.89 | 8.85 | 8.81 | 8.79 |
| **4** | 7.71 | 6.94 | 6.59 | 6.39 | 6.26 | 6.16 | 6.09 | 6.04 | 6.00 | 5.96 |
| **5** | 6.61 | 5.79 | 5.41 | 5.19 | 5.05 | 4.95 | 4.88 | 4.82 | 4.77 | 4.74 |
| **6** | 5.99 | 5.14 | 4.76 | 4.53 | 4.39 | 4.28 | 4.21 | 4.15 | 4.10 | 4.06 |
| **7** | 5.59 | 4.74 | 4.35 | 4.12 | 3.97 | 3.87 | 3.79 | 3.73 | 3.68 | 3.64 |
| **8** | 5.32 | 4.46 | 4.07 | 3.84 | 3.69 | 3.58 | 3.50 | 3.44 | 3.39 | 3.35 |
| **9** | 5.12 | 4.26 | 3.86 | 3.63 | 3.48 | 3.37 | 3.29 | 3.23 | 3.18 | 3.14 |
| **10** | 4.97 | 4.10 | 3.71 | 3.48 | 3.33 | 3.22 | 3.14 | 3.07 | 3.02 | 2.98 |
| **11** | 4.84 | 3.98 | 3.59 | 3.36 | 3.20 | 3.10 | 3.01 | 2.95 | 2.90 | 2.85 |
| **12** | 4.75 | 3.89 | 3.49 | 3.26 | 3.11 | 3.00 | 2.91 | 2.85 | 2.80 | 2.75 |
| **13** | 4.67 | 3.81 | 3.41 | 3.18 | 3.03 | 2.92 | 2.83 | 2.77 | 2.71 | 2.67 |
| **14** | 4.60 | 3.74 | 3.34 | 3.11 | 2.96 | 2.85 | 2.76 | 2.70 | 2.65 | 2.60 |
| **15** | 4.54 | 3.68 | 3.29 | 3.06 | 2.90 | 2.79 | 2.71 | 2.64 | 2.59 | 2.54 |
| **16** | 4.49 | 3.63 | 3.24 | 3.01 | 2.85 | 2.74 | 2.66 | 2.59 | 2.54 | 2.49 |
| **17** | 4.45 | 3.59 | 3.20 | 2.97 | 2.81 | 2.70 | 2.61 | 2.55 | 2.49 | 2.45 |
| **18** | 4.41 | 3.56 | 3.16 | 2.93 | 2.77 | 2.66 | 2.58 | 2.51 | 2.46 | 2.41 |
| **19** | 4.38 | 3.52 | 3.13 | 2.90 | 2.74 | 2.63 | 2.54 | 2.48 | 2.42 | 2.38 |
| **20** | 4.35 | 3.49 | 3.10 | 2.87 | 2.71 | 2.60 | 2.51 | 2.45 | 2.39 | 2.35 |
| **21** | 4.33 | 3.47 | 3.07 | 2.84 | 2.69 | 2.57 | 2.49 | 2.42 | 2.37 | 2.32 |
| **22** | 4.30 | 3.44 | 3.05 | 2.82 | 2.66 | 2.55 | 2.46 | 2.40 | 2.34 | 2.30 |
| **23** | 4.28 | 3.42 | 3.03 | 2.80 | 2.64 | 2.53 | 2.44 | 2.38 | 2.32 | 2.28 |
| **24** | 4.26 | 3.40 | 3.01 | 2.78 | 2.62 | 2.51 | 2.42 | 2.36 | 2.30 | 2.26 |
| **25** | 4.24 | 3.39 | 2.99 | 2.76 | 2.60 | 2.49 | 2.41 | 2.34 | 2.28 | 2.24 |
| **26** | 4.23 | 3.37 | 2.98 | 2.74 | 2.59 | 2.47 | 2.39 | 2.32 | 2.27 | 2.22 |
| **27** | 4.21 | 3.35 | 2.96 | 2.73 | 2.57 | 2.46 | 2.37 | 2.31 | 2.25 | 2.20 |
| **28** | 4.20 | 3.34 | 2.95 | 2.71 | 2.56 | 2.45 | 2.36 | 2.29 | 2.24 | 2.19 |
| **29** | 4.18 | 3.33 | 2.93 | 2.70 | 2.55 | 2.43 | 2.35 | 2.28 | 2.22 | 2.18 |
| **30** | 4.17 | 3.32 | 2.92 | 2.69 | 2.53 | 2.42 | 2.33 | 2.27 | 2.21 | 2.17 |
| **31** | 4.16 | 3.31 | 2.91 | 2.68 | 2.52 | 2.41 | 2.32 | 2.26 | 2.20 | 2.15 |
| **32** | 4.15 | 3.30 | 2.90 | 2.67 | 2.51 | 2.40 | 2.31 | 2.24 | 2.19 | 2.14 |
| **33** | 4.14 | 3.29 | 2.89 | 2.66 | 2.50 | 2.39 | 2.30 | 2.24 | 2.18 | 2.13 |
| **34** | 4.13 | 3.28 | 2.88 | 2.65 | 2.49 | 2.38 | 2.29 | 2.23 | 2.17 | 2.12 |
| **35** | 4.12 | 3.27 | 2.87 | 2.64 | 2.49 | 2.37 | 2.29 | 2.22 | 2.16 | 2.11 |
| **36** | 4.11 | 3.26 | 2.87 | 2.63 | 2.48 | 2.36 | 2.28 | 2.21 | 2.15 | 2.11 |
| **37** | 4.11 | 3.25 | 2.86 | 2.63 | 2.47 | 2.36 | 2.27 | 2.20 | 2.15 | 2.10 |
| **38** | 4.10 | 3.25 | 2.85 | 2.62 | 2.46 | 2.35 | 2.26 | 2.19 | 2.14 | 2.09 |
| **39** | 4.09 | 3.24 | 2.85 | 2.61 | 2.46 | 2.34 | 2.26 | 2.19 | 2.13 | 2.08 |
| **40** | 4.09 | 3.23 | 2.84 | 2.61 | 2.45 | 2.34 | 2.25 | 2.18 | 2.12 | 2.08 |
| **41** | 4.08 | 3.23 | 2.83 | 2.60 | 2.44 | 2.33 | 2.24 | 2.17 | 2.12 | 2.07 |
| **42** | 4.07 | 3.22 | 2.83 | 2.59 | 2.44 | 2.32 | 2.24 | 2.17 | 2.11 | 2.07 |
| **43** | 4.07 | 3.21 | 2.82 | 2.59 | 2.43 | 2.32 | 2.23 | 2.16 | 2.11 | 2.06 |
| **44** | 4.06 | 3.21 | 2.82 | 2.58 | 2.43 | 2.31 | 2.23 | 2.16 | 2.10 | 2.05 |
| **45** | 4.06 | 3.20 | 2.81 | 2.58 | 2.42 | 2.31 | 2.22 | 2.15 | 2.10 | 2.05 |
| **46** | 4.05 | 3.20 | 2.81 | 2.57 | 2.42 | 2.30 | 2.22 | 2.15 | 2.09 | 2.04 |
| **47** | 4.05 | 3.20 | 2.80 | 2.57 | 2.41 | 2.30 | 2.21 | 2.14 | 2.09 | 2.04 |
| **48** | 4.04 | 3.19 | 2.80 | 2.57 | 2.41 | 2.30 | 2.21 | 2.14 | 2.08 | 2.04 |
| **49** | 4.04 | 3.19 | 2.79 | 2.56 | 2.40 | 2.29 | 2.20 | 2.13 | 2.08 | 2.03 |
| **50** | 4.03 | 3.18 | 2.79 | 2.56 | 2.40 | 2.29 | 2.20 | 2.13 | 2.07 | 2.03 |
| **51** | 4.03 | 3.18 | 2.79 | 2.55 | 2.40 | 2.28 | 2.20 | 2.13 | 2.07 | 2.02 |
| **52** | 4.03 | 3.18 | 2.78 | 2.55 | 2.39 | 2.28 | 2.19 | 2.12 | 2.07 | 2.02 |
| **53** | 4.02 | 3.17 | 2.78 | 2.55 | 2.39 | 2.28 | 2.19 | 2.12 | 2.06 | 2.02 |
| **54** | 4.02 | 3.17 | 2.78 | 2.54 | 2.39 | 2.27 | 2.19 | 2.12 | 2.06 | 2.01 |
| **55** | 4.02 | 3.17 | 2.77 | 2.54 | 2.38 | 2.27 | 2.18 | 2.11 | 2.06 | 2.01 |
| **56** | 4.01 | 3.16 | 2.77 | 2.54 | 2.38 | 2.27 | 2.18 | 2.11 | 2.05 | 2.01 |
| **57** | 4.01 | 3.16 | 2.77 | 2.53 | 2.38 | 2.26 | 2.18 | 2.11 | 2.05 | 2.00 |
| **58** | 4.01 | 3.16 | 2.76 | 2.53 | 2.37 | 2.26 | 2.17 | 2.10 | 2.05 | 2.00 |
| **59** | 4.00 | 3.15 | 2.76 | 2.53 | 2.37 | 2.26 | 2.17 | 2.10 | 2.04 | 2.00 |
| **60** | 4.00 | 3.15 | 2.76 | 2.53 | 2.37 | 2.25 | 2.17 | 2.10 | 2.04 | 1.99 |
| **61** | 4.00 | 3.15 | 2.76 | 2.52 | 2.37 | 2.25 | 2.16 | 2.09 | 2.04 | 1.99 |
| **62** | 4.00 | 3.15 | 2.75 | 2.52 | 2.36 | 2.25 | 2.16 | 2.09 | 2.04 | 1.99 |
| **63** | 3.99 | 3.14 | 2.75 | 2.52 | 2.36 | 2.25 | 2.16 | 2.09 | 2.03 | 1.99 |
| **64** | 3.99 | 3.14 | 2.75 | 2.52 | 2.36 | 2.24 | 2.16 | 2.09 | 2.03 | 1.98 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **65** | 3.99 | 3.14 | 2.75 | 2.51 | 2.36 | 2.24 | 2.15 | 2.08 | 2.03 | 1.98 |
| **66** | 3.99 | 3.14 | 2.74 | 2.51 | 2.35 | 2.24 | 2.15 | 2.08 | 2.03 | 1.98 |
| **67** | 3.98 | 3.13 | 2.74 | 2.51 | 2.35 | 2.24 | 2.15 | 2.08 | 2.02 | 1.98 |
| **68** | 3.98 | 3.13 | 2.74 | 2.51 | 2.35 | 2.24 | 2.15 | 2.08 | 2.02 | 1.97 |
| **69** | 3.98 | 3.13 | 2.74 | 2.51 | 2.35 | 2.23 | 2.15 | 2.08 | 2.02 | 1.97 |
| **70** | 3.98 | 3.13 | 2.74 | 2.50 | 2.35 | 2.23 | 2.14 | 2.07 | 2.02 | 1.97 |
| **71** | 3.98 | 3.13 | 2.73 | 2.50 | 2.34 | 2.23 | 2.14 | 2.07 | 2.02 | 1.97 |
| **72** | 3.97 | 3.12 | 2.73 | 2.50 | 2.34 | 2.23 | 2.14 | 2.07 | 2.01 | 1.97 |
| **73** | 3.97 | 3.12 | 2.73 | 2.50 | 2.34 | 2.23 | 2.14 | 2.07 | 2.01 | 1.96 |
| **74** | 3.97 | 3.12 | 2.73 | 2.50 | 2.34 | 2.22 | 2.14 | 2.07 | 2.01 | 1.96 |
| **75** | 3.97 | 3.12 | 2.73 | 2.49 | 2.34 | 2.22 | 2.13 | 2.06 | 2.01 | 1.96 |
| **76** | 3.97 | 3.12 | 2.73 | 2.49 | 2.34 | 2.22 | 2.13 | 2.06 | 2.01 | 1.96 |
| **77** | 3.97 | 3.12 | 2.72 | 2.49 | 2.33 | 2.22 | 2.13 | 2.06 | 2.00 | 1.96 |
| **78** | 3.96 | 3.11 | 2.72 | 2.49 | 2.33 | 2.22 | 2.13 | 2.06 | 2.00 | 1.95 |
| **79** | 3.96 | 3.11 | 2.72 | 2.49 | 2.33 | 2.22 | 2.13 | 2.06 | 2.00 | 1.95 |
| **80** | 3.96 | 3.11 | 2.72 | 2.49 | 2.33 | 2.21 | 2.13 | 2.06 | 2.00 | 1.95 |
| **81** | 3.96 | 3.11 | 2.72 | 2.48 | 2.33 | 2.21 | 2.13 | 2.06 | 2.00 | 1.95 |
| **82** | 3.96 | 3.11 | 2.72 | 2.48 | 2.33 | 2.21 | 2.12 | 2.05 | 2.00 | 1.95 |
| **83** | 3.96 | 3.11 | 2.72 | 2.48 | 2.32 | 2.21 | 2.12 | 2.05 | 2.00 | 1.95 |
| **84** | 3.96 | 3.11 | 2.71 | 2.48 | 2.32 | 2.21 | 2.12 | 2.05 | 1.99 | 1.95 |
| **85** | 3.95 | 3.10 | 2.71 | 2.48 | 2.32 | 2.21 | 2.12 | 2.05 | 1.99 | 1.94 |
| **86** | 3.95 | 3.10 | 2.71 | 2.48 | 2.32 | 2.21 | 2.12 | 2.05 | 1.99 | 1.94 |
| **87** | 3.95 | 3.10 | 2.71 | 2.48 | 2.32 | 2.21 | 2.12 | 2.05 | 1.99 | 1.94 |
| **88** | 3.95 | 3.10 | 2.71 | 2.48 | 2.32 | 2.20 | 2.12 | 2.05 | 1.99 | 1.94 |
| **89** | 3.95 | 3.10 | 2.71 | 2.47 | 2.32 | 2.20 | 2.11 | 2.04 | 1.99 | 1.94 |
| **90** | 3.95 | 3.10 | 2.71 | 2.47 | 2.32 | 2.20 | 2.11 | 2.04 | 1.99 | 1.94 |
| **91** | 3.95 | 3.10 | 2.71 | 2.47 | 2.32 | 2.20 | 2.11 | 2.04 | 1.98 | 1.94 |
| **92** | 3.95 | 3.10 | 2.70 | 2.47 | 2.31 | 2.20 | 2.11 | 2.04 | 1.98 | 1.94 |
| **93** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.20 | 2.11 | 2.04 | 1.98 | 1.93 |
| **94** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.20 | 2.11 | 2.04 | 1.98 | 1.93 |
| **95** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.20 | 2.11 | 2.04 | 1.98 | 1.93 |
| **96** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.20 | 2.11 | 2.04 | 1.98 | 1.93 |
| **97** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.19 | 2.11 | 2.04 | 1.98 | 1.93 |
| **98** | 3.94 | 3.09 | 2.70 | 2.47 | 2.31 | 2.19 | 2.10 | 2.03 | 1.98 | 1.93 |
| **99** | 3.94 | 3.09 | 2.70 | 2.46 | 2.31 | 2.19 | 2.10 | 2.03 | 1.98 | 1.93 |
| **100** | 3.94 | 3.09 | 2.70 | 2.46 | 2.31 | 2.19 | 2.10 | 2.03 | 1.98 | 1.93 |
| ∞ | 3.84 | 3.00 | 2.60 | 2.37 | 2.21 | 2.10 | 2.01 | 1.94 | 1.88 | 1.83 |

NB: If the obtained value of F is equal to or larger than this critical F-value, then the result is significant at that level of probability.