EFFECTS OF LAND FRAGMENTATION ON AGRICULTURAL PRODUCTIVITY IN KISII COUNTY, KENYA

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DECLARATION AND APPROVAL

Declaration

I declare that this thesis is my original work and has not been presented in this or any other university for the award of a degree.

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DEDICATION

This thesis is dedicated to my parents, my siblings, my lecturers and my friends for their determination to make me excel in my studies even when times were hard. I pray that the Lord may reward them abundantly for their guidance and provision.

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ABSTRACT

Land fragmentation is a major problem in most parts of the world as it restricts agricultural development, reduces productivity and opportunities for rural development. Kisii County shows a clear case of land fragmentation due to high population pressure and poverty. This study was conducted with the aim of examining the effect of land fragmentation on agricultural productivity by examining the technical efficiency of households in the area. The specific objectives were to determine factors that influence land fragmentation, to determine the level of technical efficiency in fragmented lands, and to determine the effects of land fragmentation on household income in Kisii County. The study area was purposively selected (Kisii County) with a representative sample of 196 drawn randomly. Primary data was collected using structured questionnaires. The analysis used a Cobb-Douglas production (Stochastic Frontier) function, Tobit model and 3 Stage least squares method. Land fragmentation was found to have negative effect on agricultural productivity, but it may also provide benefits for farm households. On factors that influenced land fragmentation, age of the household head, education level of the household head, number of males and females, generations through land has been transferred, amount of output (maize), tillage method, land size, household income, and membership to a group and access to extension services were found to be significant at different levels. The technical efficiency was found to be 36.82 with more than half of the households falling below 50%. The quantity of planting fertilizer used, certified seeds and fragmentation index were found to influence the level of technical efficiency. On the third objective, crop diversity, labour days, fertilizer use and non-farm income were found to be significant in influencing household farm income. On the other hand, land area, fertilizer use and fragmentation index were significant in influencing the farm's crop diversity. To reduce effects of land fragmentation, appropriate steps like creating awareness on its effects, passing legislature on the contiguous and acceptable land size and promote successful land consolidation in the regions where land fragmentation is an issue, and where an increase in agricultural production capacity is needed.

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LIST OF ACRONYMS

3SLS	3 Stage Least Squares
ASAL	Arid and Semi-Arid Land
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
GDP	Gross Domestic Product
GoK	Government of Kenya
ISK	Institution of Surveyors of Kenya
KNBS	Kenya National Bureau of Statistics
LF	Land Fragmentation
MoA	Ministry of Agriculture
MoL	Ministry of Livestock
SFA	Stochastic Frontier Analysis
SUR	Seemingly Unrelated Regression
TE	Technical Efficiency
UNDP	United Nations Development Programme
VRS	Variable Returns to Scale

CHAPTER ONE
INTRODUCTION

1.0 Background information

In Kenya, 16 per cent of the available land is of high and medium agricultural potential with adequate and reliable rainfall. These areas support agricultural activities such as intensive cropping and dairy production. Moreover, such areas are dominated by commercial agriculture with cropland occupying 31 per cent, grazing land 30 per cent, and forests 22 per cent. The Arid and Semi-arid land (ASALs) occupy the remaining 84 per cent. ASALS are not suitable for rain-fed farming mainly practiced in Kenya due to the low and erratic rainfall. As much as this is the case, it is estimated that 80% of Kenyas' population live and derive their livelihoods in the ASALs. The rest of the population occupies the high to medium land area. This puts a lot of pressure on land resulting to the high and medium potential areas being reduced to small scale farms of up to 0.5 – 10 ha. Consequently, about 81% of small-scale farmers occupy holdings of less than 2 ha (MoA, 2009).

Considering that the population growth rate is 3.2%, the pressure on land is continuously reducing the capacity to sustain food production and cash crop farming. To increase agricultural production, intensive production systems will have to be practiced. This will be through increased use of improved inputs, diversification of value crops, commercialization of smallholder agriculture, and increased value addition through stronger linkages with other sectors. Therefore, for agriculture to reach its full potential, better land use and reclaiming of idle land in the less populated areas has to be undertaken. This will increase agricultural productivity to a great extent (GoK, 2009).

Increasing agricultural productivity can also be achieved through smallholder agriculture commercialization. This transformation can be realized through key institutions in agriculture, livestock, forestry and wildlife, increasing productivity of crops, livestock and tree cover, improving market access for smallholders and introducing land-use policies that advocate for better use of the high and medium potential lands (ASDC, 2010).

Land fragmentation is evident in many areas throughout the world. Although the causes vary from country to country and from region to region, there is an agreement that the four main factors that trigger land fragmentation are: inheritance, population growth, land markets and historical/cultural perspectives (Thapa, 2005; Tan *et al.,* 2006; Van Hung *et al.,* 2007). Other factors noted in more specific situations include: social and administrative decrees (Bentley, 1987); long-established cultivation (Binns, 1950); shortages of land and nucleated settlement (Papageorgiou, 1956) and the conversion of forest lands to arable land (Grigg, 1980).

In Kenya, there are various land tenure systems being practiced. These include communal land, Government trust land, and privately owned land. The communal land ownership system is one that follows the traditional customary rights, where all individuals in a community have a right to use land though they cannot sell it. Government trust land is land held by ministries, state corporations or other public institutions for public use. Privately owned lands are those that have been registered under freehold or leasehold system. The owners of such land can use it as collateral to access credit (MoA, 2009).

Over the years, land ownership that focuses on individual ownership and management of land that allows property inheritance by children has greatly led to land fragmentation. Having a very small piece of land and many children, leads to land being sub-divided into fragments that are not viable for production. Land fragmentation eventually leads to sub-optimal use of factor inputs lowering overall returns expected from a certain parcel of land. The factors that propagate this are loss of time due to traveling to plots, wastage of land along borders, inadequate monitoring, and the inability to use machinery such as tractors and harvesters (ASDC, 2010).

Land is considered as one of the most important resources in agriculture. Lack of access to it is one of the major causes of poverty (UNDP, 2002). Scarcity of agricultural land makes the issue of land use policy a critical one. Policy makers for a long time have been worried by the effect of land fragmentation on agriculture because it is expected to have a negative effect on agricultural production. As such, policies on land consolidation are frequently implemented to soften the degree of land fragmentation.

Existence of fragmented landholdings is regarded a feature of less developed agricultural systems (Van Hung *et al*., 2007; Hristov, 2009). This is regarded as a major obstacle to agricultural development, because it hinders agricultural mechanization, causes inefficiencies in production, and involves large cost to alleviate its effects (Najafi, 2003; Thomas, 2006; Thapa, 2007; Tan *et al*., 2008).

To overcome the effects of land fragmentation, European countries like Netherlands and France and African countries like Kenya, Tanzania and Rwanda have implemented numerous land consolidation and reform policies (Sabates-Wheeler, 2002; Sundqvist and Andersson, 2006). In Kenya, land consolidation and land reform policies have not been fully implemented because the government cannot take a high moral ground in Kenya's land reform issues. This is because the government is solely responsible for the irregular allocation of public land to reward its political supporters (MoL, 2000).

Land fragmentation at the household level depends on factors like external policy, market factors, agro-ecological conditions and farm household socio-economic characteristics. This study will look at land fragmentation as a phenomenon existing in farm level management where people operate a number of owned non-contiguous plots at the same time (Wu *et al.,* 2005; Daniel *et al.*, 2010).

1.1 Statement of the problem

Kisii County is highly dependent on agriculture. The county is characterized by smallholder farming households. Most households occupy holdings that are less than 10 ha. due to the rampant land fragmentation resulting from the ever increasing population which puts pressure on land forcing households to divide their land as they try to balance between agriculture and settlement. This conflict becomes intense to an extent that land allocated to agriculture becomes so small to sustain better agricultural practices hence leading to reduced agricultural productivity as the capacity of the land to sustain food production and cash crop farming is reduced. Although land fragmentation is well recognized, little research in Kisii County has been done to determine how much it has affected productivity.

1.2 Objectives

1.2.1 General objective

The main objective of this study was to contribute to knowledge on land fragmentation in order to enhance agricultural productivity.

1.2.2 Specific objectives

The specific objectives of the study are:

i. To determine factors that influence land fragmentation among households in Kisii County.
ii. To determine the level of technical efficiency in fragmented lands in Kisii County.
iii. To determine the effects of land fragmentation on household income.

1.3 Research questions

i. What are the factors that influence land fragmentation in households?
ii. What is the level of technical efficiency in fragmented lands in Kisii County?
iii. What is the effect of land fragmentation on household income?

1.4 Justification of the study

Agricultural growth is one of the leading ways of reducing poverty in Kenya among the smallholder farmers in rural areas. Increasing the potential of small-scale farmers will alleviate poverty by increasing their incomes. However, since most of the rural people are poor, they sell some parcels of their land to get cash either for food or paying school fees for their children or to build houses but none of the cash is ploughed back to the farms that feed them.

Over the last few years, the Kenyan government has been trying to promote agriculture, but has not looked at the average land sizes in the highly productive areas like Kisii. The population density in these areas is high for instance in Kisii it is 874.7 people per Km^2 and the number of households being 245,029 over an area of 1,317.4 Km^2 (KNBS, 2009).

The population in the high and medium productive areas like Kisii has increased, leading to land being highly subdivided into such small sizes that are uneconomical for farm enterprises. Moreover, families in Kisii still embrace the traditional and cultural values of land inheritance. Boys in the family expect an equal portion of their fathers' land without considering the size of the land. To mitigate this problem, land subdivision should be restricted and farm enterprises intensified (GoK, 2010).

Therefore this study intends to bring out the land fragmentation issue that has for long been quietly discussed among the policy makers. Land fragmentation is an issue that has to be addressed first before tackling the issue of increasing agricultural productivity in the potential areas. With the ever-increasing population, there is increased pressure on land forcing people to compromise between settlement and agriculture. Government policy makers in trying to address the problem of land fragmentation in the high and medium agricultural productive areas will find this research useful in the quest of trying to improve agricultural productivity. In addition, this study will be useful as contribution to the body of knowledge.

1.5 Scope of the study

Kisii County may not be the true measure of land fragmentation situation in the country as there are other counties that maybe in the same situation but measures have been put across to counter the issue of land fragmentation. Also only output of the major crop (maize) and technical efficiencies in the area of study was studied. This may not be the true measure of agricultural productivity that contributes fully to the country's GDP. The study depended on information from recall method which deterred the data collection process.

1.6 Definition of key terms

Land fragmentation

Land fragmentation is defined as a decrease in the size of farms or an increase in the scattering of a farmer's land or a decrease in the size of the plots owned by an individual. This is done by subdividing farm land into undersized units that are so small for rational cultivation. Plots become noncontiguous as they are in form of strips or blocks the make it hard for mechanization and are intermixed with plots operated by other farmers. In this study, Land Fragmentation arises when the household head decides to divide his/her land among the sons.

Technical efficiency

A producer is considered to be technically efficient when an increase of output will need a reduction in one other output or a small increase in one input. Therefore, an ‘efficient farm’ is one that utilizes fewer resources compared to other farms to produce a given quantity of output. This superiority is manifested from having higher efficiency ratios and lower cost per unit of production. Hence, agricultural efficiency is attained if greatest possible product is attained from a given resource.

Agricultural productivity

Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs.

Farm size

Mbowa (1996) suggested that numerous definitions of farm size ranging from acreage, value of farm products sold, days worked off-farm, level of farm income and the level of total family income. The study took farm size to mean farm acreage because it can easily be ascertained and is easy to understand.

Smallholders

These are defined in this study as farmers with at most 2 hectares of arable land used for agriculture and settlement.

CHAPTER TWO
LITERARTURE REVIEW

2.1 Land Tenure system in Kenya

Before colonialism, Kenyan land was owned communally, and governed by customary law, that is, individuals did not own the land. The community owned land with each individual having a right to use it. Colonialists introduced the concept of individual ownership of land, which advocates that an individual owns a piece of land to the total exclusion of all others. English land law introduced the concept of land tenure (freehold, leasehold) to define the kind of interest owned (ISK, 1999). Therefore, interests in land fall into two groups. Rights from traditional African systems and from the English system. The English law also referred to as statutory tenure, secured and expressed through national law, is used in various Acts of parliament for instance Government Land Act (cap 280), Trust Land Act (cap 288) , Registered Land Act (cap 300) and Registration of Titles Act (cap 281) of the Laws of Kenya.

In Kenya, the following land tenure systems exist:

2.1.1 Public tenure

This is a tenure system where the Government owns land for her own purpose. The land is unutilized or un-alienated reserved for future use by the Government or may be available to the general public for various uses. Categories of government land include forest reserves, government reserves, alienated/un-alienated government land, national parks, townships and urban centres and open water bodies (GOK 1996).

2.1.2 Customary land tenure

These are unwritten land laws where ownership is practiced by communities under customary law. Kenya is diverse in terms of its ethnic composition with multiple customary tenure systems. These vary mainly due to agricultural practices, climatic conditions and cultural practices. Most of the customary tenure systems have nearly similar characteristics. First, individuals or groups by virtue of their membership in some social unit of production have guaranteed themselves rights to access land and other natural resources (Ogendo, 1979). Individuals or families thus claim property rights by virtue of their affiliation to the group.

Secondly, rights of control are rested in the political authority of the community. This control comes from sovereignty over the area in which the relevant resources are. Control is to guarantee access to these resources. The administrative component entails having the power to allocate and distribute land and other resources within a group, regulate the use of the land and defend against entry or usage by outsiders (Ogola and Mugabe, 1996).

Thirdly, rights to private property allow individuals to harness, utilize and maintain a resource out of their investment of labour. Thus, the person presently cultivating a piece of land has the greatest rights to it. These rights encompass transmission and in some communities' transfer of land. Lastly, resources do not require extensive labor investment or through their nature, they had to be shared for example, common pasture lands are controlled and managed by the present political authority. Members of that political community have a guaranteed and equal right of access (Ogendo, 1979).

2.1.3 Statutory tenures

Freehold tenure

This tenure confers the greatest interest in land called absolute right of ownership or possession of land as it has an indefinite time period of ownership. The Registered Land Act (RLA) Cap 300 of the Laws of Kenya governs freehold land. Its provision is that the registration of a person as the proprietor of the land rests in that person absolute ownership together with the rights and privileges. Freehold title has no restriction as to the use and occupation but may restrict its use only to agricultural activities or ranching purposes only.

Land individualization was demanded by the colonial settlers who required legal guarantee for the private ownership of land without which they were reluctant to invest. The principle for privatization was hence laid down and implemented as from 1956 mainly in central province. To date most of the high potential agricultural areas such as Western province, Kericho, Uasin Gishu, Embu, Meru, Machakos and Kisii districts have been completely adjudicated and registered (Ogolla and Mugabe, 1996).

In the ASALs, the regime of land registration system has been in place since 1968. Here the registration of group ranches was viewed as a compromise between individual ownership and the need for access to wider resources in dry lands. With this system, communal lands were to be divided into smaller units (ranches) which are then registered in the names of group representatives (three to ten members) elected by the members of the group (Wanjala, 2000).

Every member of the group has rights in the ownership for the group land in undivided shares. The members are entitled to reside therein free of charge with their family and dependants and make exclusive use for the grouped ranches resources. This appears as marriage between the need to have exclusive use of an area of land and the communal ownership and use of land in these areas.

Leasehold tenure

Leasehold is an interest in land for a definite term of years and may be granted by a freeholder usually subject to the payment of a fee or rent. In this system, certain conditions must be observed like developments and usage. Leases are also granted by the government for its land, the local authorities for their trust lands and by individuals or organizations owning freehold land. The government leases land in Kenya for 99 years that is after the promulgation of the new constitution. Previously it was 999 years for agricultural land and 99 years for urban plots. The local authorities grant leases for 50 and 30 years as appropriate (GOK, 1996).

Table 1 shows how the median farm sizes are quite small and declining for most farming households in some countries

Table 1: Arable land per person in agriculture (10-year average) in some countries between 1969 – 2009

	1960-69	1970-79	1980-89	1990-99	2000-09
Ethiopia	0.501	0.444	0.333	0.224	0.218
Zambia	0.643	0.0607	0.398	0.342	0.297
Kenya	0.462	0.364	0.305	0.264	0.219
Uganda	0.655	0.569	0.509	0.416	0.349
Rwanda	0.212	0.213	0.195	0.186	0.174
Nigeria	0.982	0.860	0.756	0.769	0.898
Ghana	0.646	0.559	0.508	0.492	0.565

Source: FAO, 2010

2.2 Land Tenure Distribution by Province

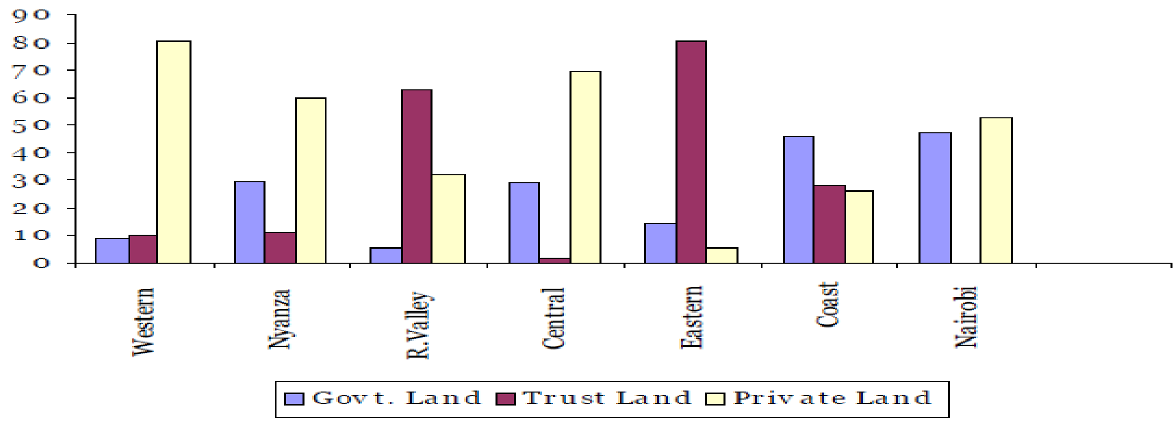

Figure 1: Land tenure distribution by province in Kenya

Source: Republic of Kenya, 2004

Most of the provinces practice private land ownership apart from Eastern province. Western province has the highest percentage of land under private ownership followed by Central and Nyanza provinces. This three provinces exhibit the highest level of agricultural land fragmentation. Rift Valley and Eastern provinces have a higher percentage of their land under Trust ownership. Coast and Nairobi provinces land is government owned. Only Nairobi province does not have land under trust ownership.

With the promulgation of the new Kenyan Constitution on 27 August 2010, some statutes were repealed, that is, The Indian Transfer of Property Act, The Government Lands Act, The Registration of Titles Act, The Land Titles Act, The Registered Land Act, The Way leaves Act, and The Land Acquisition Act. The laws that were not repealed are The Land Control Act, The Landlord and Tenant (Hotels, Shops and Catering Establishments) Act, The Sectional Properties Act and The Distress for Rent Act.

The constitution requires that existing laws on land should not be repealed but applied and adapted to give effect to the new laws. In the absence of formal amendments, the altering and adapting of these new laws to give effect to the new laws will likely cause some inconsistency in the practical application of the law.

Table 2 below shows the land tenure distribution in some districts in all provinces. Under the Swynnerton Plan, land adjudication and registration programme, conversion of the Traditional African tenure system was to be converted to a system based on freehold tenure. Although this was done after independence, by 1995 only 370,000 square kilometers out of the possible 457,000 remained as trust land under customary tenure (Government of Kenya, 2004).

Table 2: Tenure distribution by district

District	%of private land	District	% of trust land
Kisii	94.0	Isiolo	100
Busia	88.4	Turkana	96.3
Laikipia	87.5	Marsabit	94.5
Murang'a	84.0	Baringo	84.3
Kakamega	83.6	Keiyo	78.7
U/Gishu	80.9	Samburu	77.8
T/Nzoia	78.2	Meru	72.2
Kajiado	75.4	Narok	59.2
Kiambu	72.5	Kitui	50.7

Source: UNDP (2005) and district reports

2.2 Measurement of farm size

Getting a universal definition for farm size has been a problem when it comes to efficiency and land size studies (Mbowa, 1996). Their exists numerous farm size definitions ranging from acreage, level of farm income or value of product sold. Depending on the author, farm size is mostly taken synonumously as the farm acreage. It brings out an easier understanding and can be ascertained.

Britton & Hill (1975) stated that acreage is an unsatisfactory indicator of business size. He argued also that the best unit of measuring farm size and size of enterprises depends on the use of the land and requirements by each enterprise. This study will use acreage as a measure of farm size as the area is of the same agricultural productivity potential. The number of acres to measure farm size can only be used if the farm fall in a geographical area with the same soil type, farm type and farm type (Kay 1981).

2.3 Land property rights

Communal land tenure system have been viewed to create incentive problems in land improvements and tenancy arrangements that influence the farm sizes to be used in agricultural activities and end up affecting farm productivity (Lyne & Nieuwoudt, 1991).

The traditional African System that allowed communal land ownership has been viwed by economists as inefficient when land becomes scarce (Johnson, 1972; Barrows & Roth, 1990). Freehold system is viewed as a better option as owners can use the land efficiently and get maximum output thus improve their social wellbeing (Barrows & Roth, 1990). Johnson (1972) argues that when an individual cannot sell land, their tends to be less flexibility by the farmer in converting the land to asset form from fixed-place asset and they tend to invest less. In tjis study, both farmers with legal titles to the land and those without were all considered.

2.4 Causes of land fragmentation

Causes of land fragmentation have been broadly classified into two categories, that is, supply-side and demand-side causes (Bently, 1987; Blarel *et al.*, 1992). The supply-side causes are exogenous imposition of farmers on land in certain areas as a result of inheritance, population pressure and scarcity of land (McPherson, 1982; Blarel *et al*., 1992). The demand-side factors reflect varying degrees of fragmentation chosen positively by farmers in order to reduce risk from natural disasters (such as floods, droughts, fires and other perils), promote crop diversification, as well as to ease allocation of labor over cropping seasons (Fenoaltea, 1976; Ilbery, 1984; Tan, 2005).

Several factors have been cited as contributing to land fragmentation (Blarel *et al.*, 1992). First is the partible inheritance of land. This happens when older farmers have the desire to give each of their children (depending on the number of males) a piece of land. With the ever increasing population, the size of land holdings continues to reduce leading to fragments that are scattered over a wide area (Gebeyehu, 1995). People usually treasure land and hence almost everyone will tend to claim a piece from the parents. Also, the ever increasing population pressure leads to scarcity of land and thus land fragmentation as farmers searching for additional land will tend to accept any available parcel of land within reasonable distance to their homesteads. In addition, land markets and state laws tend to influence land fragmentation as they do not restrict land division.

The second factor is land use. Land use policy determines how land and other natural resources are managed and used (Mwangore, 2002). Land use based on certain rights like ownership and use rights that are either societal or private, determine how land is used and also choices made by the individual land user. Hence people will not be dictated on how to use their lands and end up subdividing it into fragments according to their choices. Different communities have different land use practices based on their socio-economic level and culture.

The ever increasing population puts lots of pressure on diminishing land. Population in Kenya has been on an ever increasing trend. Most people believe in having many children as a form of security in old age. In areas like Kisii where the population density is about 2862 persons per square kilometer, cases of land fragmentation is rampant as people make choices between settlement and agriculture. Each individual family wants to own a piece of land, not considering the size, and have exclusive rights and rights of use. In this region, this has been the major factor that influences land fragmentation with the help of poverty and traditional cultural practices. Land sizes in Kisii have shrunk to an extent that holdings cannot support the population based on traditional land use techniques. The fact is that even if one worked the land to the degree one could, there is not enough land to support the current and future population.

Demand-side causes lead to private benefits of fragmentation to exceed its private costs. Land fragmentation's benefit to farmers is assumed to stem from the understanding that land is not homogenous. This is because land parcels are different in soil type, water retention capability, slope, altitude and microclimate conditions. Through diversifying labor intensive cultures on different plots during peak labor demand times, risks may be reduced. Also it is possible that transaction costs are high in that farmers are unwilling to accept the set of land transaction that would be needed to reduce the degree of fragmentation (Van Hung *et al.*, 2006). In addition, land fragmentation brought about by land reforms has improved food security and equity among households by distributing land plots in terms of soil quality and family size in several countries (Blarel *et al.*, 1992). Land fragmentation helps the farmers to avoid risk. The demand-side reasons for fragmentation show that farmers choose to retain certain levels of fragmentation that they see are beneficial to them.

This brings the question as to whether land fragmentation is either advantageous or disadvantageous. Land fragmentation can either be advantageous or disadvantageous. Land fragmentation has been documented to affect productivity in different ways. First, managing, supervising and securing scattered land is more difficult, time consuming, and costly. The scattered plots become a waste of land requiring more fencing, border constructions and paths. Land fragmentation also increases the risk of disputes between neighbors (Mwebaza and Gaynor, 2002).

Secondly, small fragmented lands lead to difficulties in growing certain crops, thus preventing farmers from changing to high profit crops. Profitable crops, like fruits, require larger plot areas. Therefore, farmers possessing small and fragmented plots are forced to grow non-profit crops (The World Bank, 2005).

Thirdly, land fragmentation hinders economies of scale and farm mechanization. Small and scattered plots reduce the use of machinery or large scale agricultural practices. Operating machines and moving them is a problem or may cause problems. This will discourage development of infrastructure like drainage, communication, transportation, and irrigation. Lastly, it has been observed that banks are unwilling to take small, scattered land holdings as collateral, thus preventing farmers from obtaining credit for investments (Mwebaza and Gaynor, 2002).

2.5 Factors influencing Technical efficiency

In a study by Awudu *et al*., (2001) in Nicaragua, they found that education influenced production efficiency. Educated farmers with larger farms adopted new technologies in production of soybean in the USA (Fernadez-Cornejo *et al.*, 2002). Studies by Owuor *et al.,* (2006) and Akkaya (2007) found an inverse relationship between years of schooling and technical efficiency. A study by Battese *et al.,* (1995) on paddy rice farms in India used panel data for 10 years and also concluded that older farmers were less efficient than the younger ones.

Kakhobwe (2007) in his study on technical efficiency found that age of household head and land fragmentation were determinants of technical efficiency. Also Karanja *et al*., (1998) found that use of fertilizer, education, access to extension services proximity to roads and presence of a male in the household increased efficiency in the production of maize.

2.6 Land fragmentation and efficiency

There exists a lot of literature on the relationship between land fragmentation, land productivity, or efficiency at farm level. However, evidence of this relationship is still inconclusive. Some of the studies have found out that land fragmentation is a source of inefficiency and has a negative relationship with farm profitability (Wu *et al*., 2005; Van Hung *et al*., 2007; Di Falco *et al*., 2010; Corral *et al*., 2011). These studies have been inconclusive on whether there is a significant relationship between land fragmentation and technical efficiency. This is because most farms were considered to be operating on the same production frontier.

Wu, Liu, and Davis (2005) in there study in China found that land fragmentation has no significant impact on productivity. However, another study by Chen, Huffman, and Rozelle (2006) found that technical efficiency is affected by land fragmentation and does result to inefficiency. Using provincial-level data, Carter and Estrin (2001) used cultivated land per capita to capture fragmentation and by using a stochastic frontier, they found that land fragmentation affects technical efficiency negatively.

In a study by Wan and Chen (2001) using the number of plots as a measure of fragmentation, they found that the loss due to fragmentation is less than 4 percent for maize and 17bpercent for wheat. They suggested that by eliminating land fragmentation, agricultural output for grains would increase. Fleisher and Liu (1992) found a gain of around 8 percent with the elimination of land fragmentation. However, Wan and Cheng (2001) note that land consolidation gains are significant, the policy focus should be not be aimed at increasing land holdings but on consolidation because of the small economies of scale that come with it.

Ghose (1979) investigated the contribution of production units to observe the inverse relationship that exists in Indian agriculture. He found out that there is an inverse relationship between farm size and output per acre for all farms in most samples, for peasant tenant and peasant owner farms and employer farms. Ghose (1979) concluded that small farms' technical efficiency was due not to the superiority of peasant organization of production, but relied on primitive technology and undeveloped markets. In the absence of labor saving technologies and developed markets, farms using farmyard manure with abundant labor have the advantage. But he also hypothesized that with technological progress this advantage will end up disappearing.

The inverse relationship between farm size and output per acre is because of the difference in factor use intensity (Newell *et al.*, 1997). A study by Byiringiro and Reardon (1996) discovered that small farms in Rwanda tend to get three times more land yields, use labor four times more and the number of plots per hectare is four times that of larger farms. They concluded that, small farms have a greater average and marginal productivity of land and are less technical and allocatively efficient. The difference in factor use is attributed to imperfection in the labor markets (Verma and Bromley, 1987).

Though land fragmentation limits agricultural production, Hartvigsen (2006) argues “that a high degree of land fragmentation is not always an important problem for development of the agricultural sector”. Agricultural land in some countries is highly controlled by large enterprises (Hartvigsen, 2006), while in other countries little attention has been paid to understand the impact of land fragmentation on productivity, efficient use of resources and profitability (production efficiency). For instance, a high level of productivity does not mean high profitability.

Land fragmentation at the household level depends on factors like external policy, market factors, agro-ecological conditions and farm household socio-economic characteristics. The resulting level of fragmentation affects agricultural production to a great extent.

The costs associated with high levels of fragmentation are seen in terms of inefficient resource allocation (labor and capital) and the resulting cost increase in agricultural production (Shuhao, 2005). According to McPherson (1983) and Simmons (1987), land fragmentation may impose detrimental effects on agriculture like inefficiency, reduced agricultural modernization and mechanization, increased costs of modifying its adverse effects through consolidation schemes. Land fragmentation may also be detrimental to agricultural production in that it causes physical problems, operational difficulties and foregone investment to an individual farmer.

2.7 Theoretical framework

In measuring technical efficiency, one needs to have a great understanding of the decision making behavior of a farmer (producer). Additionally, there is need to recognize the one-sidedness of the production possibilities frontier. Some farms fail to efficiently use their inputs as other farms and fall short of the “best practice” frontier and end up being labeled technically inefficient. Inefficiency can be measured within a sample, though those that are observed to be 100% efficient among their “peers” may not be really efficient compared with farms in other regions.

There are several methods used in measuring technical efficiency with the choice of method often depending on the data and the researcher’s philosophical view of the importance of measurement error. These methods calculate a technical efficiency index (TE score), which measures the distance of the observed firm from a point on the production frontier. Farms lying on the production frontier are considered to be 100% technically efficient (with TE = 1), and the “inefficiency” of the remaining firms increases with the distance from the production frontier.

Two methods that particularly appealed to researchers in the 1980s were stochastic frontier analysis (SFA) and data envelopment analysis (DEA). SFA is a regression-like econometric method that often assumes a Cobb-Douglas production function with constant returns to scale (CRS) and constructs a linear production frontier in the input/output space. DEA is a linear-programming technique that constructs the production frontier as a convex envelope of the observed points in the input/output space without assuming a specific functional form for the production function and thus allows variable returns to scale (VRS).

DEA and SFA also differ in their treatment of errors. DEA is a strictly deterministic technique. It ignores the error term and treats the total deviation from the production frontier as inefficiency. SFA on its own assumes that deviations from the frontier can be split into two components, that is, a symmetrical (“two-sided”) random error with mean zero (classical white noise) and a “one-sided” inefficiency component that takes only positive values from a truncated normal distribution with a positive mean (for instance, the half-normal distribution). Such assumptions create a classical error term with an added one-sided error term. As a result of this difference in the treatment of the error term, none of the observed points can by definition fall outside the DEA production frontier, whereas in the SFA model some points may definitely fall outside (“above”) the production frontier if their classical error term is large enough. These stray points may still have a non-zero inefficiency score, which is determined by their one-sided error component (Coelli, 1998).

As DEA requires no functional form on the input/output relationship, its use by those who believe that imposing any functional relationship on the mix is too restrictive. DEA’s non-parametric approach seems to appear more flexible, SFA has the advantage of explicitly accounting for measurement error in the classical error term, which if not included (as in DEA) means that any measurement error is incorrectly assumed to be technical inefficiency. Therefore, there is no clear or better choice between these two methods that often result in both methods being applied to the same sample (Wang and Schmidt, 2002).

Much of the applied literature stops with the creation of a Technical Efficiency (TE) index while ignoring the idea that such an index really measures "gross" technical efficiency rather than the "pure" TE it purports to measure (Fare *et. al.*, 1985). Ignoring this further distinction may be a problem when, a "whole farm" versus "commodity by commodity" approach to farms are both being considered. Gross TE is composed of pure, scale and congestion TE with such a decomposition easily done only with the DEA method. Scale TE is considered as "social" and not "private" inefficiency as it is outside the farm manager's control. The scale TE can be tested for by comparing TE indices generated with constant returns to scale imposed versus TE indices generated without any returns to scale assumption (Ferrier and Porter, 1991). Congestion TE can result from, a regional government imposing a macroeconomic constraint on a corporate farm such as viewing the farm as an employment center rather than a profit maximizing enterprise leading to an overuse of inputs such as labor that are no longer freely disposable. Such congestion TE has been found in both market and formerly socialist countries (Reiman, 1992) with at least one study finding that congestion TE is the most likely cause of most of the inefficiency measured in a TE index such as we use here (Kemme and Neufeld, 1991). Finally, if one believes in X inefficiency then the TE index may contain both TE and X-inefficiency as separating the two remains problematic (Button and Weyman- Jones, 1992). Thus different levels of aggregation in sample data and the varying institutional environment in which a farm is embedded could lead to TE indexes that appear to contradict each other at different levels of aggregation with one cause being these components of TE found in the literature.

In the 1990s, the technical efficiency literature expanded again with the growing use of Z-variables in the application of SFA. Prior to the 1990s, researchers would take estimates of TE and run auxiliary or "second step" regressions on a wide range of policy variables (so-called Z-variables) that might explain the measured technical inefficiency. The newer SFA method allows for the effect of these Z-variables to be used simultaneously with the calculation of the TE scores in a one-step procedure (Audibert, 1997; Wang and Schmidt, 2002). This method enables analysts to better link technical inefficiency to policy by explicitly including in the estimation both economic variables and other variables (for instance, institutional or sociological factors) that fall outside standard production function analysis. This one-step extension is available for SFA only, while DEA must still use two steps if Z-variables are being considered.

The property rights theory concept

The land resource is a major influence on economic development of a society as it provides livelihood to most households (Swinnen 1999). Land can be accumulated as wealth or transferred from one person or between generations as wealth. Literature on property rights suggest that private property rights provides a way of investment and reduces risks that might affect consumption or income. With change in political power or economic power affects redistribution of wealth and rents.

Property rights of assets like land allows landlords to get income and have power in managing it. The ownership gives individuals discretionary power over the resource and provides a basis for a competitive market. The property owner has a right to utilize the asset, lease it out or sell it. Transfer of ownership becomes easier from one person to another. Land being a nearly scarce resource, its ownership influence economic status or the owners and transfer in the land market is always to the highest bidder (Pejovich 1972).

2.8 Conceptual framework

The relationship between farm size and efficiency has major implications to policy options for agricultural production in Africa. Previous studies carried out bring out conflicting results on the best land acreage for farming to be efficiently productive. Large-scale farms are considered more productive than small-scale farmers. On the other hand, small-scale farmers face a lot of restrictions in terms of lack of capital to adopt better technology and better inputs in terms of seeds and also labor. Other socio-economic characteristics of these small scale farmers also determine how their agricultural performance is affected to a great deal (Mwebaza and Gaynor, 2002).

The factors shown in Figure 2 contribute differently towards land fragmentation. Socio-economic factors of the farmer tend to affect land fragmentation differently. Age of the household head is hypothesized to influence land fragmentation positively. This is because they tend to divide their land to the male children and the fact that most of them are risk averse, they tend to sub-divide the land into plots so as to plant different crops. Gender of the household head also is another factor that is hypothesized to influence land fragmentation positively. Female heads are faced with more pressure from the children to sub-divide the land more than the male heads. Also occupation of the household head is hypothesized to influence land fragmentation both positively and negatively. Those under formal occupation will tend to shy away from farming leaving their land either unused or if they practice farming then it will be in small scale. Also from the income they get they are able to rent in other plots and able to finance farming activities. Those whose main occupation is farming have a lower efficiency and tend to sub-divide their lands less. Off-farm income also influence land fragmentation and efficiency. With their extra income, they can be able to use it to acquire farm inputs in time hence improving productivity. Education level of the household head is hypothesized to have mixed effects on land fragmentation. Educated household heads that are committed to farming are able to take up new technologies faster hence tend to maintain land tracts of land to practice mono cropping. Also they may be able to practice other income generating activities that require them to be done separately from other activities and in turn end up increasing land fragmentation. When households have a low income, they tend to practice some activities that greatly contribute to land fragmentation like relying on traditional practices of land inheritance due to lack of alternative forms of income. Consequently, they concentrate on agriculture in their small farms though they do not have the manpower and resources to better the way they farm like access to quality inputs.

Farm inputs like fertilizers, land size, pesticides and seeds are some of the main inputs in production. For households to have access to them, the correct and best policy framework has to be in place and this in turn determine productivity. It is assumed that the more farm inputs used, the higher the productivity assuming that the farms have to reach diminishing returns.

Institutional factors like group membership, tenure system, access to credit, access to information and access to extension services are hypothesized to influence land fragmentation. Credit access provides funds for farmers to buy required inputs in time and be able to rent in land from other households and also pay for hired labour. Membership to groups is seen to help farmers to access new insights and be able to practice new ideas in agriculture. Access to extension services provides farmers with better information on best farming methods and technologies thus help them improve their productivity and this can influence land fragmentation positively.

A technically efficient farm is expected to have higher output compared to the less efficient ones. They are hypothesized to have lower production costs leading to higher income from the farming activities.

This leads to improved welfare of the household and hence increased access to production inputs. Therefore a farmer to experience higher farm income, they need to be more technically efficient and hence higher agricultural production.

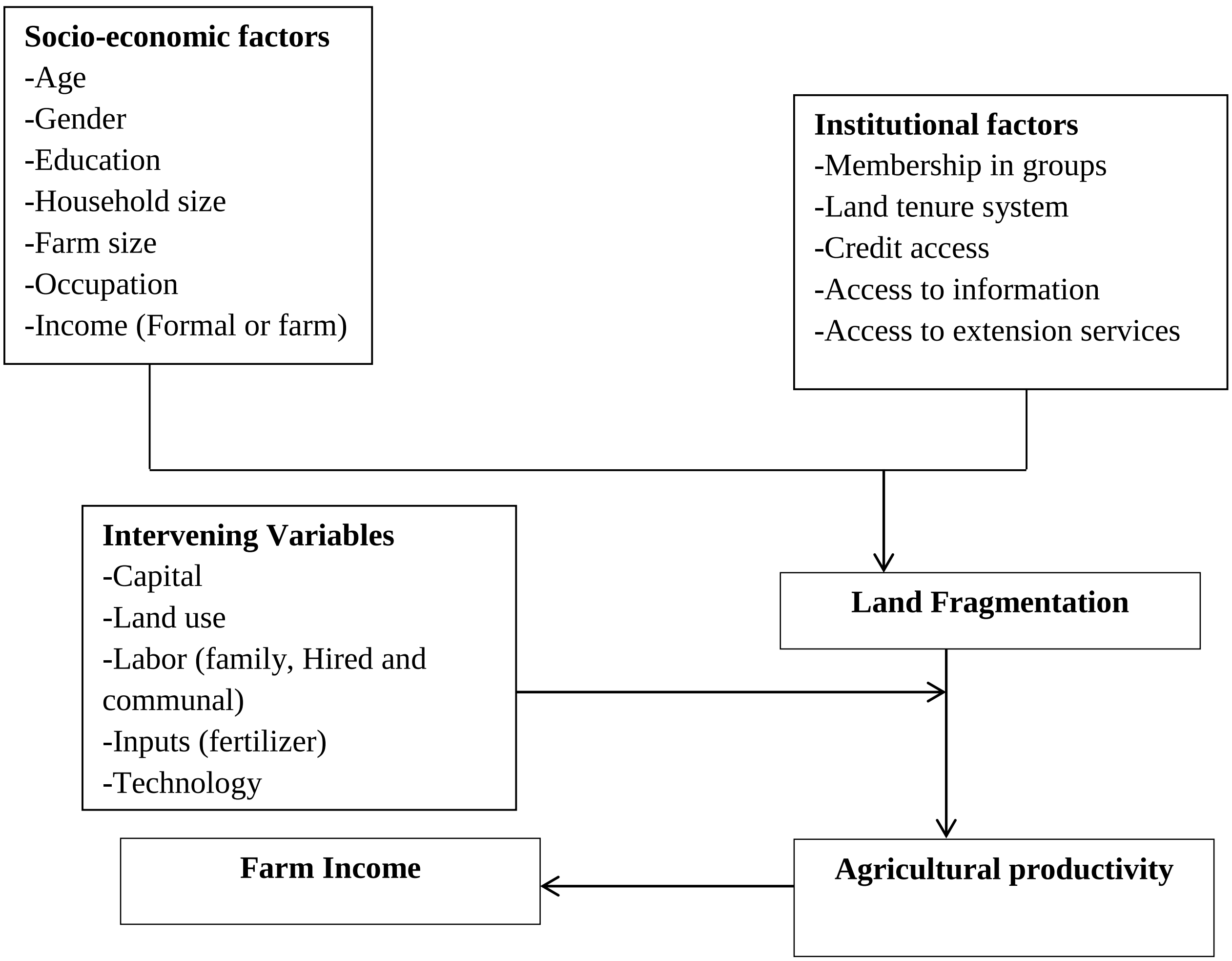

Figure 2: Contributing factors to Agricultural Land Fragmentation and Productivity

Source: Authors conceptualization

CHAPTER THREE
METHODOLOGY

3.1 Study area

The study was conducted in Kisii Central District in Kisii County (Figure 3), which is a highly productive area in the western region of Kenya. The district was purposively selected because of its high population and productivity. The residents still embrace the traditional cultural ways of children inheriting land from their parents. This leads to high fragmentation of land making people have strips of land that might be uneconomical. The district receives rain almost throughout the year, although there are two rainy seasons (February to June and September to November). The average rainfall is over 1500 mm and is quite reliable, helping to support cash crops (such as coffee, tea and pyrethrum) and subsistence crops (maize, beans, millet and potatoes). Temperatures can range from 16^{o}C to 27^{o}C.

Kisii County is located to the south east of Lake Victoria and is bordered by six counties with Narok to the south, Migori to the west, Homa Bay to the north west, Kisumu to the north, Bomet to the south east and Nyamira to the east. It has an average area of 1,317.4 Km^2.

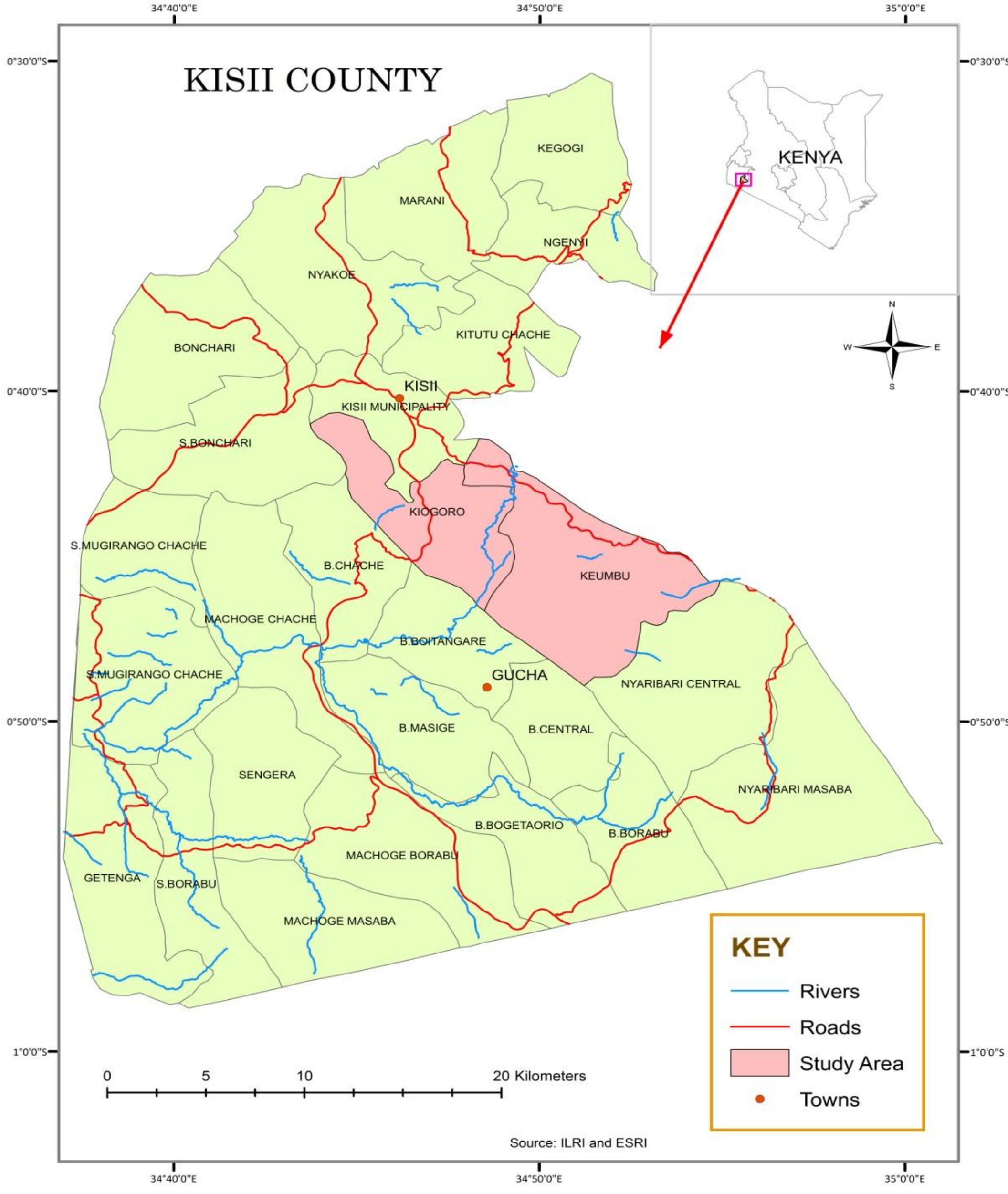

Figure 3: Map of Kisii County

Source: Karani (2014).

The county has a population of 1,152,282 (Male – 48 %, Female – 52%), population density of 874.7 people per Km^2 making a national percentage of 2.9 %. This gives the county an annual growth rate of 2.75% (KNBS, 2010). The age distribution is 0-14 years (45%), 15-64 years (51.6 %), 65+ years (3.4%). The total number of households is 245,029 (KNBS, 2010).

Table 3: Administrative divisions

Division	Population	Urban Population
Suneka	86,030	3,723
Keumbu	109,837	8,843
Kisii town	183,000	83,000
Kiogoro	89,215	5,423

Source: KNBS 2009

The main sources of livelihood are subsistence agriculture, vegetable farming, small-scale trade, dairy farming, tea and coffee growing, businesses and soapstone carvings, with major crops being tea, coffee, bananas, tomatoes, vegetables, dairy products, maize and sugarcane.

3.2 Sampling procedure and sample size

The sample unit for this study consisted of all smallholder farming households in Kisii County. Kisii County has 245,029 households (KNBS, 2010). Multi-stage sampling procedure was used to select the sample for the study. First, Kisii Central district was purposively selected because of its high productivity and high population. Secondly, stratified random sampling was done to select Kiogoro and Keumbu divisions. The two divisions were chosen because land fragmentation was prominent than in the other divisions in the CountyIn the third and final stage, simple random sampling approach was used to select smallholder farmers that comprised the sampling units.

Sampling size

The required sample size was determined by proportionate to size sampling method (Kothari, 2004).

$$n = \frac{Z_{\alpha 2}\, \hat{P}\left(1 - \hat{P}\right)}{e^2}$$

Where n = sample size, $\hat{P}$ = proportion of the population containing the major interest, Z= confidence level (α = 0.05), δ = acceptable/allowable error. Since the number of household that have fragmented their land is not known, $\hat{P}$ =0.5, Z = 1.96 and e = 0.05. This results to a sample of 196.

3.3 Data collection

Primary data was collected using a structured questionnaire to gather information on the family setup, land sizes of the household, education level of parents and their dependents, the produce from farms, farm and non-farm incomes, distance to input buying places, access to extension services, group membership, credit access, quantities of seeds, planting and top dressing fertilizer, certified seeds, labour man-days and cropping area.

3.4 Validation of the instrument

Prior to the full study, a pre-test study was conducted in one village in Masimba division. This locality was chosen because it has similar characteristic with study area. 10 questionnaires were chosen for the pre-test basing on Kathuri and Pals (1993), suggestion that it is the smallest number that yields meaningful results in data analysis in a survey research.

The pre-test was subjected to the spilt-half analysis technique according to Cronbach's formula

$$\alpha = \left(N \text{x} r \big/ 1 + (N-1) \text{x} r \right)$$

Where:

N is the number of items and **r** is the average inter-item correlation among the items.
The study will use Cronbach alpha as the reliability coefficient of at least 0.7, which is accepted (Santos and Reynaldo, 1999). The questionnaire will be pre tested to ensure data collected is reliable, valid and accurate.

3.5 Data analysis

To analyze data, Tobit model was used for the first objective, stochastic frontier model for the second objective and 3 Stage Least Squares model for the third objective. First, the fragmentation index was calculated using the Januszewki index.

3.5.1 Measuring fragmentation

The Januszewki (JI) index was adopted in measuring land fragmentation. This index is located within the range of 0 to 1. The smaller the JI value, the higher the degree of land fragmentation. The JI value combines information on the number of plots, average plot size and the size distribution of the plots (Jha *et al*., 2005). The index was computed as:

$$k = \frac{\sqrt{\sum a}}{\sum \sqrt{a}}$$

Where 'a' represents the parcel size and *k* represents the Januszewki index.

3.5.2 Specification of econometric model for objective 1.

The Tobit model was used on objective 1 which was to assess the factors that influence land fragmentation among households in Kisii Central district, Kisii County. The Tobit model is a regression model with a dependent variable that is either left-censored (censored at a low threshold) or right-censored (censored at a high threshold)), (Tobin, 1958). For land fragmentation, the data are left-censored at zero (high level of land fragmentation).

When the dependent variable of the model is limited in its range, using ordinary least squares (OLS) may result in biased and inconsistent parameter estimates even asymptotically. The Tobit regression model is used to overcome such problems. In this study, the value of the dependent variable is calculated by Januszewki index for each household as shown above and ranges between 0 and 1. Thus, a two-limit Tobit model (Rosett and Nelson, 1975), is appropriate in such cases. This is give as given by equation 1.

$$Y_i^* = \beta' X_i + \varepsilon_i \qquad \text{.........} 1$$

Where Y_i^* is a vector of the latent variable that is not observed for values less than zero and greater than one.

X_i, represents vector of the independent variables,

β is vector of the unknown parameters,

ε_i is vector of the error terms that are distribute normally with mean 0 and variance σ^2

i=1, 2, 3. . .n represents the number of observations.

If Y_i is the observed variable representing the level of fragmentation, its value is censored from below at L=0 and from above at U= 1. Thus, giving rise to equation 2.

$$\left\{ \begin{array}{l} Y_i = 0 \; if \; Y_i^* \leq L \\ \quad = Y_i^* \; if \; L \leq Y_i^* \leq U \\ \quad = 1 \; if \; Y_i^* U \end{array} \right\} \qquad \text{.......2}$$

The expected value of the latent variable Y_i^* is given by equation 3

$$E\left(Y_i^* / X \right) = \beta' X \qquad \text{.......3}$$

As the values of the level of land fragmentation Y, is truncated from below at 0 and from above at 1, its conditional expected value is given by equation 4.

$$E\left(Y/X, L < Y^* < U \right) = \beta X + \sigma \frac{\phi(Z_L) - \phi(Z_U)}{\Phi(Z_U) - \Phi(Z_L)} \qquad \text{.......4}$$

Where,

$$Z_L = \frac{L - \beta X}{\sigma} \text{ and } Z_U \; \frac{U - \beta X}{\sigma}$$

ϕ (·) and Φ (·) are the density function and cumulative distribution of a standard normal variable respectively. In the absence of the limits, $Z = \frac{\beta X}{\sigma}$.

However, the Tobit coefficients do not directly give the marginal effects of the independent variables on the dependent variable. But their signs show the direction of change in probability and intensity of fragmentation as the respective explanatory variables change (Amemiya, 1984; Maddala, 1985; Goodwin, 1992). By extending McDonald and Moffit (1980) decomposition of the Tobit model, the total marginal effect of an explanatory variable on the extent of fragmentation in a household and can be disaggregated into three components:

1. The effect of an independent variable on the level of land fragmentation among households is given by:

$$\frac{\partial \Phi(Z_L)}{\partial X_i} = \phi(Z_L)\left(\frac{\beta_i}{\sigma}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.5$$

2. The change in the fragmentation level with respect to a change in an explanatory variable among different households is given by:

$$\frac{\partial E\left({}^{Y}\!/_{X}, L<Y^*<U\right)}{\partial X_i} = \beta_i\left[1 + \frac{Z_L\emptyset(Z_L)-Z_U\emptyset(Z_U)}{\Phi(Z_U)-\Phi(Z_L)} - \frac{[\emptyset(Z_L)-\emptyset(Z_U)]^2}{[\Phi(Z_U)-\Phi(Z_L)]^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

   The probability of change in the level of fragmentation as an explanatory variable changes by a unit is given by equation 7

$$\frac{\partial E\left({}^{Y_i^*}\!/_{X}\right)}{\partial X_i} = \beta_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.7$$

3. The probability of change in the level of land fragmentation with respect to a change in an explanatory variable is:

$$\frac{\partial \Phi(Z_U)}{\partial X_i} = \emptyset(Z_U)\left(\frac{\beta_i}{\sigma}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

The level of land fragmentation in a household could be affected by socio-economic, social capital and institutional characteristics faced by that household. The variables are hypothesized to affect level of fragmentation differently.

Tobit Model Specification

A Tobit model was used to determine the factors that influence land fragmentation among households in Kisii Central district, Kisii County.

The Tobit model was specified as,

$Y_i^* = \alpha + \beta_0 X_1 + \beta_1 X_2 + \beta_2 X_3 + \beta_3 X_4 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ \beta_n X_n + \varepsilon$

Level of land

$fragmentation(Y_i^*) = \alpha + \beta_1 AHH + \beta_2 GHH + \beta_3 EHH + \beta_4 HSZ + \beta_5 LSize + \beta_6 member + \beta_7 accext + \beta_8 Nfi + \beta_9 generation + \beta_{10} areamaize + \beta_{11} HHI + \beta_{12} amountmaize + \varepsilon$

3.5.3 Specification of econometric model for objective 2

For the second objective, the study used the stochastic frontier model approach to estimate the production function and determinants of technical inefficiency among smallholder farmers. With the stochastic frontier approach, unlike the other parametric frontier measures, there is an allowance for stochastic errors from statistical noise or measurement errors. The stochastic frontier model decomposes the error term into a two-sided random error that captures the random effects outside the control of the firm.

With the given potential estimation biases of the two-step procedure for estimating technical efficiency scores and analysing their determinants, the study will use the one-stage procedure suggested by Battese and Coelli (1995).

$$\ln(y_i) = f(x_{ij}, \beta) + \varepsilon_j \qquad \text{....................9}$$

Where *y* is the level of output on the j^{th} plot, *x* is the value of input *i* used on plot *j*, $\varepsilon_i = v_j - u_j$ is the composed error term, and v_j is the two-sided error term while u_j is the one-sided error term.

The random component v_j is assumed to be identically and independently distributed as $N(0, \sigma^2_v)$ and is also independent of u_j. The random error represents random variations in the economic environment facing the production units.

The inefficiency component distribution can take different forms, but is distributed asymmetrically. The inefficiency component is a representation of features reflecting inefficiency such as farm-specific knowledge, the will, skills and effort the farmers, work stoppages, material bottlenecks and other disruptions to production (Aigner *et al.*, 1977; Lee and Tyler, 1978). Meeusen and van den Broeck (1977) assume that u_j has an exponential and a half-normal distribution, respectively.

The stochastic model can be estimated by 'corrected' ordinary least squares (COLS) method or the maximum likelihood method. We follow the Battese and Coelli (1988) and Battese and Coelli(1995) using Battese and Corra (1977) parameterization. The maximum likelihood (ML) estimates of the production function (1) are obtained from the following log likelihood function.

$$\ln L = \frac{N}{2}\ln(\frac{\pi}{2}) - \frac{N}{2}\ln \sigma^2 + \sum_{j=1}^{N} \ln\left[1 - F\left(\frac{\varepsilon_j\sqrt{\gamma}}{\sigma\sqrt{(1-\gamma)}}\right)\right] - \frac{1}{2\sigma^2}\sum_{j=1}^{N}\varepsilon_j^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

where ε_j are residuals based on ML estimates, *N* is the number of observations, *F*( ) is the standard normal distribution function;

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\gamma = \sigma_u^2 / \sigma^2$$

Assuming a half normal distribution of *u*, the mean technical efficiency is measured by:

$$E\left[\exp(-u_j)\right] = 2\left[\exp(-\gamma\sigma^2/2)\right]\left[1 - F\left(\sigma\sqrt{\gamma}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

Where *F* is the standard normal distribution function. Measurement of farm level inefficiency requires the estimation of nonnegative error *u*. Given the assumptions on the distribution of *v* and *u*, Jondrow et al. (1982) first derived the conditional mean of *u* given ε. Battese and Coelli (1988) derived the best predictor of the technical efficiency of plot or farm *j*, is $TE_j = exp(-u_j)$ as:

$$\mathrm{E}\left[I\exp(-u_j|\varepsilon_j)\right] = \left[\frac{1 - F(\sigma_A + \gamma\varepsilon_i/\sigma_A)}{1 - F(\gamma\varepsilon_i/\sigma_A)}\right]\int \exp(\gamma\varepsilon_i + \sigma_A^2/2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 12$$

Where:

$$\sigma_A = \sqrt{\gamma(1-\gamma)}\sigma^2$$

Table 4: Description of Variables for the Tobit model

Variable	Description	Unit of measurement	Expected sign
Dependent variable			
Land fragmentation	Level in the household	Index of 0-1 (Januszewki Index)	
Independent variables			
Socio-economic characteristics			
AHH	Age of household head	Number of years	+/-
EHH	Education level	Number of years	+/-
HSZ	Household size	Number	+/-
GHH	Gender of household head	1=Male, 0=Female	+/-
LSize	Land size	Ha	+/-
HHI	Household income	Kshs	+/-
Generation	Number of generations land has been transferred	Number	+/-
Yield	Amount of output	Kgs	+/-
Areamaize	Area used for maize cultivation	Ha	+/-
Institutional Factors			
NFI	Availability of non-farm Income	1=Yes 0=No	+/-
accext	Access to extension services	1=Yes 0=No	+/-
member	Membership to a group	1 = Yes 0 = No	+/-

The maximum likelihood estimates of the production function in equation (1) are automated in a computer program, FRONTIER Version 4.1, written by Coelli (1996). FRONTIER provides estimates of *β,*

$$\sigma^2 = \sigma_u^2 + \sigma_v^2$$

$$\gamma = \sigma_u^2 / \sigma^2$$

And average technical efficiencies and plot or farm level efficiencies. FRONTIER also provides the estimate for μ when the symmetric error term follows a truncated normal distribution $u_j \sim N(\mu,\sigma^2_u)$.

3.5.4 3 Stage Least Squares (3SLS)

The 3SLS model was used to determine how land fragmentation has affected the income of households. This is to explain the impact of land fragmentation with other factors on farm income. Given that crop diversity is itself affected by land fragmentation, it will assume that farm income is affected, among other things, by crop diversity and fragmentation, thus:

$$Farm\ Income = \beta_0 + \beta_1 cropdiversity + \beta_2 Fragmentationindex + \beta_3 Fertilizeruse + \beta_4\ non\text{-}farmincome + \beta_5 Knowledge + \beta_6 LandSize + \beta_7 farmilysize + \varepsilon_1 \quad \text{……13}$$

Equation 13 identifies the role of fragmentation, and other determinants including the amount of crop diversity on farm income.

The second equation shows the effect of land fragmentation and other factors on crop diversity. Crop diversity is measured by both Entropy index and Herfindahl index and both will be used separately in regression to show there outcomes and the results compared.

$$Farm\ crop\ diversity = \alpha_0 + \alpha_1 fragmentationnindex + \alpha_2 experience + \alpha_3 land\ size + \alpha_4 fertilizer\ use + \varepsilon_2 \quad \text{……14}$$

Because the error terms might be correlated, seemingly unrelated regression is used alongside the 3SLS. Seemingly Unrelated Regression (SUR) has a cross-equation error correlation. Also Durbin-Wu-Hausman test was done to test for endogeneity of the crop diversity index.

Farm crop diversity

Crop diversity is the explanatory variable in equation (13) and a dependent variable in equation (14) that needs to be calculated. This is done using Entropy index and/or Herfindahl index

Entropy Index

This index weights the shares of a farm's activity by a log term of the inverse of the respective shares. It takes then the value of zero when the farm is completely specialized, and it will approach its maximum when diversification is perfect. Thus, for increasing diversification the index should increase. This index gives less weight to larger activities than the Herfindahl index.

Herfindahl index

The Herfindahl index (Pattayanayak, 2006), was computed by squaring the shares of a farm's activities, gives particular weight to the farm's principal activities. It means that a farm's secondary activities are given only limited weight in calculating the index. The weakness of this index is that it is insensitive to minor secondary activities. This is desirable since it focuses attention on the major activities of the farm. This index takes the value of one, when a farm is completely specialised in its primary activity, and should approach zero as N gets large. Thus, for increasing diversification Herfindahl index should decrease. The index was first used to measure the regional concentration of industries (Theil, 1967).

Let Z_i be the crop acreage in activity *i*

Then $\sum Z_i$ = total farm acreage cropped

$P_i = Z_i \Big/ \sum_{i=1}^{N} Z_i$ will show the proportions

Therefore:

Entropy index= $\sum_{i=1}^{N} P_i \log \frac{1}{P_i}$ ……………………………………………………………...15

Herfindahl index = $\sum_{i=1}^{N} P_i^2$ ………………………………………………………………16

Where N is the total number of crops and P_i represents area proportion of the *i-th* crop in total cropped area.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The mean age of the sample was 46.14 which shows that most of the respondents fall within the productive age bracket. Most household heads were less than 45 years and this shows that most families are young.

When it comes to land size, the mean land holding was 2.06 acres per household. This shows that most people are smallholder farmers concurring with the countries estimation of 87% owning 2.5 acres or less (KNBS, 2010). From the sample, 37.2% of the households were female headed compared to 62.7% being headed by males. In the country, the male headed households are about 70% (KNBS, 2010)

The average educational level of the household head was 9.5 years of schooling. This shows that most of them had only basic education of up to primary level with very few completing their secondary education. The countries national average literacy level is about 87.2% (KNBS, 2012).

In all the families the land acreage, before it was divided from the parents, had a mean of 7.6 acres. Comparing with the household that were interviewed which had a mean of 2.06 acres, showing that land fragmentation has been done extensively. In the next few years, this mean will be much lower because of land inheritance as the children mature. On average, the households grew 2 varieties of crops in their farms either by inter-cropping or on different plots.

Table 5: Household Characteristics

Variable name	Mean	Std. Deviation	Std. Error Mean
Age	46.14	14.72	1.05
education	9.50	4.50	.32
household size	5.14	2.27	.16
Land size	2.06	3.02	.22
original acreage	7.65	10.88	.80
variety of crops grown	2.65	1.28	.09
amount of maize harvested	428.16	381.49	27.46
Planting fertilizer used (kgs)	25.78	27.13	1.94
Top dressing fertilizer used	14.54	20.64	1.47
Certified seeds used	3.98	7.86	0.56
Amount of credit	13530.10	67085.89	4791.85
Non-farm income	81737.79	1.69	12118.98
Farm income	26353.30	51259.98	3661.43
Labour cost	4034.85	8318.71	594.19

The mean age of my sample was 46 years old. Most of the household heads much older than the young age members. Most of the respondents had managed to reach class 8 or form one as shown by the man of the education level. They had attained the basic level of education while others had even reached the tertiary level of education.

The average output from the farms is about 8 bags each of 90 kgs. This is a bit low compared to other areas. Land has been heavily subdivided to as low as 2 acres per household. Most of the households try to use high amounts of fertilizer to improve their productivity with approximately 25 kgs use during planting and 14 kgs for top dressing. The amount of income from the farms is low though also the cost of paying hired labour is also low. Averagely, each farming household gets about Shs. 26,353 and incurred a labour cost of Shs. 4034. This means they were profitable.

4.2 Factors that influence land fragmentation among households

In the context of this study, the first objective was to determine factors that influence the land fragmentation among households. Hence, the JI results were regressed on specific household characteristics using the Tobit model in STATA software. The limited dependent variables (results of JI are bounded between 0 and 1) were used in the regression. Since the Tobit model parameter estimation is by maximum likelihood, it provides consistent and asymptotically efficient estimators for parameters and variance (Greene, 1997). This implies validity of standard inference procedures, such as t statistics and F tests.

For the dependent variable, the JI index calculated was chosen as it shows clearly the level of fragmentation. Thus, the overall fragmentation level was regressed against the different explanatory variables.

Table 6 shows results of the factors influencing land fragmentation among households in Kisii County. This was achieved by use of censored Tobit model as the limit of the Januszewki Index lies between 0 and 1. The smaller the fragmentation index value, the higher the degree of land fragmentation.

Among the sampled households, the factors identified as significant influencers of land fragmentations were age and education level of the household head, generation, farm income, land size and number of women.

Table 6: **Factors that influence land fragmentation among households.**

Level of land fragmentation (Januszewki Index)	Coefficient	Std. Err.
Age	0.0046**	0.0019
Education	0.010**	0.0050
Number of men	0.018	0.0168
Number of women	0.027*	0.0161
Number of generations	-0.058*	0.0306
Yield	0.017	0.0286
Land size	0.081***	0.0075
Farm income	0.016***	0.0051
Group membership	0.086	0.0634
Access to extension	0.035	0.0658
Constant	-3.868***	0.2217
Sigma	0.278	0.0156

Number of Obs =161, LR chi^2 (12) = 132.49, Pseudo R^2 = 0.7359, Log likelihood = -23.780327, Prob>chi2= 0.0000

*** Significant at 1%; ** significant at 5%; and * significant at 10%

A year increase in age of a household head increases land fragmentation index by 0.0046. This was significant at 5% among households especially if the household head is female (0.027 times). This implies that the older a household head becomes, he is less likely to subdivide his land holding to his children. Older members of the household tend to be less involved in agriculture, depending more on their children who are more energetic. With the absence of a male head, the children tend to demand a share of their land because the female head cannot hold the land for them. Kisii has a more traditional cultural setup where women are not landowners.

Number of years of schooling had positive influence on household's decision to fragment land into smaller portions for either his children or selling portions for upkeep purposes. An extra year of schooling for the household head increases fragmentation index by 0.07 times and this was significant at 5%. This implies that a well-educated household head is less likely to subdivide his his land but rather centralize homesteads leaving a large portion for production purposes.

Land size of the household a significant factor in decision making with regard to land fragmentation. Increase in size of land holding will increasing land fragmentation index by 0.081 times, which implies a reduction in probability of fragmenting available land resource. This can be explained by the fact the less fragmented land allow for cultivation of crops on large scale thus allowing economies of scale to exist. However, most families want to increase their produce so to have enough for consumption and others to have surplus for sale in the market and this often results in crop intensification. Some farmers are trying to make most out of the small parcels of land to produce more. With a small piece of land, when it comes to inheritance of the land by male children, the level of fragmentation will tend to increase more and household land end up being less than the standard land size of 2 hectares.

An extra generation in a family lineage decreases the land fragmentation index by 0.058 times. This implies that additional generation will increase land subdivision making land that was once large belonging to one household would be subdivided into smaller portions for a number of households. This means that with one more generation coming of age, land fragmentation will increase. This is because the new generation will also want to own property of their own especially land in their ancestral homes. With each generation fragmentation will tend to increase and will reach a point no more of it will take place.

Household farm income had significant influence on farm fragmentation among households in Kisii County. Extra Shilling in household income increases land fragmentation index by 0.016 times implying a reduction in probability to subdivide land into small portions as incomes improve overtime. This was significant at 1%. An increase in land size, that is below 0.5 hectares per capita, is influenced by increase in household income. Because most smallholder farms are below 2.5 hectares, it is likely that promotion measures to access land will reap high payoff (Jayne *et al.,* 2012).

4.3 Determinants of technical efficiency/inefficiency

The average total production of the main crop in the study area was 298.16 kgs of maize per acre for one harvest season which represents a yield of 478.826 kgs per ha. This is approximately 5 bags of maize for each household (Table 8). Most of the households use approximately 26 kilograms of planting fertilizer during every planting season. This will not change with increase in acreage. Due to their poverty status, they prefer the subsidized priced fertilizer from the Ministry of Agriculture. The fragmentation index also shows that land in Kisii County is highly fragmented. Land was subdivided to cater for different crops as most households are practicing intensive agriculture to fulfill household food requirements as well as creating space for development of new homes. Few households use certified seeds of about 4kgs per ha. This waslow compared to other areas because most smallholder households use previous year's harvest as seeds for planting in subsequent planting season. In addition, households used approximately 14.5 kgs of top dressing fertilizer per ha to improve crop productivity.

Table 7: Descriptive statistics of variables used in the stochastic frontier production

Variable name	n=196			
	Minimum	Maximum	Mean	Std. Deviation
Amount of maize harvested (kg/ha)	0	3953	478.8300	513.0790
Quantity of planting fertilizer used	.00	200.00	25.7832	27.1289
Quantity of certified seeds used	.00	100.00	3.9796	7.8630
Quantity of top dressing fertilizer used	.00	125.00	14.5357	20.6440
JI(Fragmentation index)	.000	.303	.0638	.0322

4.3.1 Sources of Technical Efficiency

The efficiency sources are differentiated if observed among farms. This is due to difference in roles played by farm and characteristics of farmers. Cobb-Douglas production function is used to estimate the efficiency and inefficiency levels of the households using some production inputs and farm characteristics on the output of crop production. In the efficiency equation, the quantity of planting fertilizer used, quantity of certified seeds used and fragmentation index were statistically significant at 1% level.

Households in Kisii County practice intensive agriculture with very little mechanization. Most households prefer using human labour in cultivating their land because of cost. Hiring oxen or tractors is much expensive beyond the reach of most households, and with pooling of labour with neighbours, it becomes much cheaper for them. For them to increase productivity, they rely on inputs such as fertilizer application as the only way of trying to improve the productivity. Lands are highly cultivated year in year out without leaving it to regenerate or even doing crop rotation. The amount of fertilizer used during planting is common and it is statistically significant at 1 percent. A 1 percent increase in the amount of planting fertilizer used increases output by 23.6 percent. Unlike use of top dressing fertilizer, which is not significant, planting fertilizer plays a significant part in increasing efficiency of these farms.

Table 9 below shows the Maximum likelihood estimates of parameters of the frontier production/efficiency and inefficiency functions. Fragmentation index was statistically significant at 1 percent. This suggests that fragmentation has a significant impact on crop production. This is consistent with Fleisher and Liu (1992) and Wan and Cheng (2000). On the other hand, these findings are different from those of Heston and Kumar (1983) in South Asian countries. Their insignificance may be twofold. Efficiency improvements maybe through saving labour as an input. Crop production relies mainly on labour instead of use of machinery. Farming households engage more in diversified production rather than specialized production which tends to increase fragmentation. These small scale units of production hinder the effective use of machinery.

Land has always remained the most important factor of production. With the ever increasing technologies, it becomes uneconomic to increase productivity with the highly fragmented lands in Kisii County. This is because land does not increase in size. The kind of technology in Kisii County is fixed at use of hoes and oxen ploughs. Uneconomic sub-division of land as experienced in Kisii, leads to land fragmentation affecting productivity.

The dummy variable for amount of planting fertilizer used is statistically insignificant. According to other studies, fertilizer was found to be a major factor in production of major crops especially those grown by smallholder farmers. Reardon *et al.,* (1997) in his case studies in Rwanda, Senegal, Zimbabwe and Burkina Faso found that there is a positive effect of fertilizer on productivity.

The amount of output increased was not affected by use of certified seeds. In other studies, the use of certified seeds increased the total output from farms. However, it was also found that farmers tend to recycle seeds especially during planting by mixing the seeds or setting aside an area for that. This is because most of them find it costly to buy certified seeds. Also seed unavailability during planting season and scarcity due to ineffective distribution force most farmers to use uncertified seeds (Reardon *et al.*, 1997).

Land fragmentation effects on Technical efficiency

Table 9 gives the results of stochastic frontier production function. From these results, land fragmentation index is negative and statistically significant at 1%. This indicates that land in Kisii County is highly subdivided. A decrease in land fragmentation level by 1% will induce 13.56% increase in agricultural output. This result is the same with that of Djokoto (2012), who estimated stochastic frontier model for Ghana using household data from 1961 to 2010.

Land fragmentation has been considered by many authors (Yates, 1960; Thompson, 1963; Karouzis, 1971; DeLisle, 1982; Jabarin and Epplin, 1994; Blaikie and Sadeque, 2000), as a big obstacle to agriculture. It hinders its development by hindering mechanization, causing inefficient agricultural production and it will require a lot of costs to alleviate its adverse effects, resulting in a reduction in farmers' net incomes. This is made worse by the ever increasing agricultural market and industrialization of agricultural sector (Demetriou *et al.*, 2013).

There are different problems that arise with land fragmentation. Some of the main ones are dispersion of the parcels, small sizes and irregularly shaped. In Kisii County, land has been subdivided into strips that are stretched downhill. This reduces access by road to the parcels of households because of their irregular shapes and many are on hilly sides. According to a study by Bentley (1987), discussions on land parcel dispersion of given households while considering the distance travelled to reach them began in 1826 by Johan Von Thunen in a publication entitled *'The Isolated State'*, who argued that the cost of farming increases with distance. This is because costs of moving labour, other farm inputs and machines from one parcel to another are increased due to increased travel time (Karouzis, 1977; Bentley 1987, Burton, 1988; Niroula and Thapa, 2005), and therefore parcels far from the homestead are monitored and cultivated less intensively (Van Dijk, 2003). Also small sized parcels of land and irregularly shaped hinder use of modern machinery and may require use of manual work in the corners and along the boundaries (Karouzis, 1977 and 1980; Bentley 1987). This is the case experienced by many households in Kisii County who depend on use of hoes and little use of animal traction method.

Table 8: Regression results Stochastic Frontier production function

Efficiency variables	Parameter	Coeff.	Std. Err.
Planting fertilizer (kg Ha^{-1})	β_1	0.2361	0.0667
Certified seeds (kg Ha^{-1})	β_2	0.4048	0.1224
Top dressing fertilizer (kg Ha^{-1})	β_3	0.1375***	0.02416
Fragmentation index	β_4	-14.0276***	0.43845
Intercept	β_0	7.8980***	0.1988
Inefficiency variable			
HH size	δ_1	-0.3934	0.2601
Education level of HH	δ_2	-0.1383	0.2556
Access to extension	δ_3	-0.2343	0.2489
Land size (Ha)	δ_4	-0.0744	0.08332
Intercept	δ_0	2.9224***	0.8116
Variance parameters			
Sigma-squared	σ^2	-1.998***	0.3779
Marginal Technical efficiency		36.82	
Log Likelihood		-238.172	

Wald chi2(4)	154.17
Prob>chi2	0.000
Number of observations	148

*** significant at 1% , ** significant at 5%, * significant at 10%

The land fragmentation's negative influence on technical efficiency could be arising due to economies of scale factors. The smaller the land size being held by households, the more unlikely the household will use mechanization. This is due to their low income, and high chances that they will reuse the seeds or mix with quality seeds and minimal use of fertilizer leading to low output.

It can be argued that farmers occupying large farms use their land sparingly thus reducing depleting the soils off its nutrients making them more productive in the longrun. The small scale farmers cultivate their lands year in year out leading to reduced productivity hence increasing technical inefficiency. A study by Fernandez *et al.,*. (2009) on sugarcane farmers in Philippines concurs with this study. The findings of this study re-emphasize that land fragmentation has a negative impact on agricultural productivity.

In the inefficiency function, access to extension services, household size, education level of the household head and land size were not significant. Although from their signs, the dummy for access to extension services had a negative impact on technical inefficiency. A review on several studies done by Ali and Byerlee's (1991), shows that when farmers had accessed extension services, there was a negative influence to inefficiency. The coefficient for dummy for education level of the household head had a negative sign showing that with a higher level of education it would result to lower technical inefficiency. Household size dummy was presumed to have a positive effect on inefficiency. With availability of family labour, labour constraints would likely reduce on the farm. They would be able to finish farming activities in time making production more efficient.

Approximately 63% of the total output is lost due to inefficiency. The study show that the marginal technical efficiency is about 36.82% as shown in table 9.

The predicted farm technical efficiency was estimated using stochastic frontier function. The mean technical efficiency was 42.53%. The technical efficiency score are summarized in Table 10.

Table 9: Technical efficiency level of sampled households

Technical efficiency level	Frequency	Percentage	Cumulative
Highly Inefficient (0-0.24)	70	35.71	35.71
Fairly inefficient (0.25-0.49)	41	20.92	56.63
Moderately Efficient (0.50-0.74)	53	27.04	83.67
Efficient (0.75-1)	32	16.33	100.00
Total	196	100.00	
Mean		42.53	
Std deviation		33.17	
Minimum		0	
Maximum		89.6	

The most efficient farm had a score of 89.6% and the least had 1.3%. This shows the gap that exists between farming households in the same area in terms of technical efficiency. Farms that are averagely technically efficient can be able to save up to 52.53% of yield loss if they try and achieve what most efficient farms manage. From Table 11, the highest percentages of farmers (35.71%) were highly inefficient (less than 25%). 16% of the farms were above 75% efficiency level. More than half of the sampled households were less than 50% efficient. This shows that most farms need to improve on their efficiency to reach an average of above 50%.

4.4 Effect of Land Fragmentation on Farm income

This objective uses the 3 stage least squares model to find the effect of land fragmentation on farm income using a two equation system. Crop diversity is affected by land fragmentation, potentially bringing out a recursive system.

Farm Income $= \beta_0 + \beta_1 cropdiversity + \beta_2 Fragmentationindex + \beta_3 Fertilizeruse +$

$\beta_4\ non\text{-}farmincome + \beta_5 farmingexperience + \beta_6 LandSize + \beta_7 farmilysize + \varepsilon_1$

The second equation shows the effect of land fragmentation and other factors on crop diversity. Crop diversity is measured by both Entropy index and Herfindahl index and both will be used in the regression to show there outcomes and compared.

Farm crop diversity = $\alpha_0 + \alpha_1$fragmentationnindex + $\alpha_2$experience + $\alpha_3$land size + $\alpha_4$fertilizer use + ε_2

Because the error terms might be correlated, seemingly unrelated regression is used alongside the 3SLS. The SUR has a cross-equation error correlation. Also Durbin-Wu-Hausman test is done to test for endogeneity of the crop diversity index and it was found not to be endegeneic.

$Z=0$, $F(1,168) = 0.00$, $Prob > F = 1.0000$

The 3SLS and SUR were used to calculate the effect of land fragmentation and farm crop diversity on farm income.

Table 10: Summary Statistics

Variable	Mean	Std Deviation	Min	Max
Education	9.5	4.501	1	16
Family size	5.140	2.271	1	12
Herfindahl Index	0.544	0.244	0	1
Entropy Index	0.7053	0.429	0	1.473
JI	0.064	0.032	0	0.303
Fertilizer use	25.783	27.129	0	200
Non-farm income	81737.790	169665.800	0	1570000
Household income	26353.300	51259.980	0	432000
Land size	2.064	3.022	0	37.1

From Figure 4 below, most household plant approximately two types of crops in their farms. This is mostly by intercropping or on different plots.

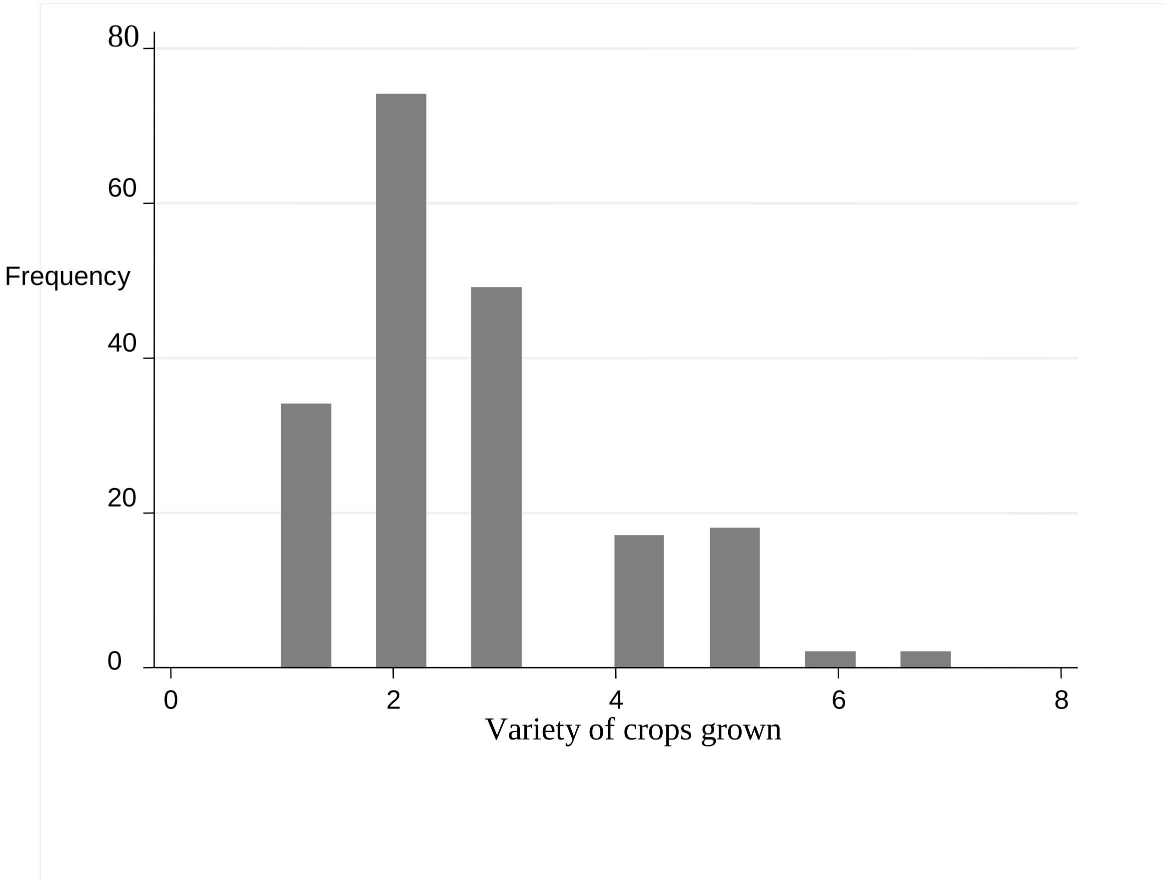

Figure 4: Distribution of variety of crops grown

3 SLS regression results

Table 12 shows the results from the Three Stage Least Squares (3SLS) analysis and Seemingly Unrelated Regression (SUR) to show consistency of the regression results.

Table 11: Regression using Entropy Index

Variables	3SLS (A)		SUR (B)	
	Coeffs	Std Errors	Coeffs	Std Errors
Dependent variable: Farm Income				
Crop diversity	3.95**	5.31	4.28***	0.75
Experience	-0.11	0.07	-0.10	0.07
Family size	0.04	0.15	0.04	0.14
Fragmentation	19.58	13.88	17.54	12.08
Labour(days)	0.05*	0.03	0.04**	0.02
Fertilizer	1.07**	0.41	1.07**	0.32
Land area	-0.31	0.93	-0.25	0.35
Non-farm income	-0.14*	0.08	-0.14**	0.07
_cons	1.92	4.43	1.75	1.41
Dependent variable – Farm crop diversity				
Experience	-0.01	.01	-0.01	0.01
Land area	-0.07***	0.02	0.16***	0.03
Fertilizer use	-0.04	0.03	-0.06**	0.03
Fragmentation	8.98***	2.25	-0.90	1.15
_cons	0.45***	0.14	0.81***	0.11

N=177; signifance levels: * at 10%, ** at 5% and *** at 1%,

Table 12 shows the regression results of the 3SLS and SUR analysis. They both used the same variables for consistency of the regression results. Results of the SUR show that, farm crop diversity is significant at 1% level. This shows that farm crop diversity is correlated with farm income. Farms that manage to grow different crops on separate fragments of land tend to earn more than those that don't. This is consistent with Di Falco and Perrings (2005) and indicate the economic benefits that are associated with crop diversification. Also on the 3SLS column, farm crop diversity is also significant at 5% level. Growing a variety of crops to match the different agro-ecological conditions of the area will tend to be more beneficial than growing only one type of crop. This also can help reduce production risks and price fluctuations as farmers can be able to trade throughout the year on the different crops grown.

Fertilizer use is also significant indicating that it affects farm income. This result gives a different perspective on the intra-specific crop diversity (Di Falco and Chavas, 2006). Increasing the number of crops increases the use of fertilizer and pesticides and in the long run more income is expected from sale of the farm products. Fertilizer use tends to improve productivity of farms and farmers get more produce.

Labour days were also significant at 10% and positively affect farm income. For most of the farmers their income tends to increase when they work on their own farms with the help of the family members. The more days they spend on their farms, the more farm income they get.

Non-farm income is also significant at 10% level on the 3SLS and 5% level in the SUR equations. As the total non-farm income increase in the household, the total farm income will end up reducing. This is because non-farm income may influence the farmers not to engage themselves in farming activities. This is mainly because in Kenya, the income obtained from the farming sector is comparatively lower and inconsistent than that from the non-farming sector.

On the second equation, land area of the households is correlated to the farm crop diversity. In the 3SLS column, land area is shown to have a negative influence on the farm crop diversity. Having a bigger piece of land will tend to decrease the crop diversity as more farmers prefer to do large scale farming of commercial potential crops like maize of beans.

Land fragmentation also has an effect on crop diversity as shown by the 3SLS results The 3SLS coefficient is largely different from that of the SUR which is statistically insignificant. The wide spread level of land fragmentation has led to increased crop diversity in the area and most parts of the country. Farm input use is also significant as shown in the SUR column. Increased use of fertilizer will lead to a decrease in the level of crop diversification.

Table 12: Regression using Herfindahl Index

Variables	3SLS (A)		SUR (B)	
	Coeffs	Std Errors	Coeffs	Std Errors
Dependent variable: Farm Income				
Crop diversity	-5.8949**	7.9209	-7.0549***	1.3353
Experience	-.1108	.0688	-.1055	.0671
Family size	.0249	.1529	.0235	.1407
Fragmentation	16.2322	12.4624	14.2665	12.1766
Labour(days)	.0411*	.0217	.0400**	.0185
Fertilizer	1.0359**	.3905	1.0624**	.3267
Land area	-.0281	.6083	-.0061	.3384
Non-farm income	-.1191	.0940	-.1238*	.0677
_cons	7.9452*	4.0885	8.6112***	1.4517
Dependent variable – Farm crop diversity				
Experience	.0033	.0037	.0033	.0037
Land area	.0431**	.0125	.0431**	.0125
Fertilizer use	.0284	.0175	.0284	.0175
Fragmentation	-5.1268***	1.2357	-5.1284***	1.2356
_cons	.6820***	.0746	.6820***	.0746

N=177, R-sq=0.2839, Chi-sq=41.28, p-value=0.000

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This study was undertaken to find out the effects of land fragmentation on agricultural productivity among households in Kisii County. This was after realizing that lands have been so much subdivided to an extent that some households could not provide for themselves in the same land that fed them year in year out. Kisii county was purposively selected with two division (Keumbu and Kiogoro) providing the sample for the study. A total of 196 households were selected using multistage sampling procedure. Questionnaires were administered to collect the information needed from mainly the household heads. A stochastic frontier model was used to estimate the technical efficiency levels while a censored Tobit model was used to estimate the factors the promote land fragmentation among households. A 3 stage least squares estimation was used to determine how land fragmentation and crop diversity affect farm incomes of households.

5.2 Conclusion

The main objective was to determine how land fragmentation affects agricultural productivity among smallholder farming households in Kisii County. The analysis established that agricultural productivity was significantly influenced by fragmentation index, use of certified seeds and use of planting fertilizer with land fragmentation index being negative.

Technical efficiency in Kisii County, was found to be about 36.82%. Less than half the interviewed households were technically efficient and these households could easily improve to be fully efficient. The technical inefficiency was not significantly influenced by any of the variables used. For agricultural production to improve, the households need to be sensitized on importance of improving soil fertility and better ways of maintaining acceptable land sizes. Farmers need to be sensitized on diseconomies of land fragmentation and costs that come with their continued practice of land inheritance. This will help reduce technical inefficiency.

Farm crop diversity also contributed to how the smallholder farmers were performing. Increasing farm income is the major intention by all farmers as they try to change from agriculture to agribusiness. Farm crop diversity, labour days, use of fertilizer and non-farm income all contributed differently towards farm income. Thus for smallholder farmers to manage such change in their farms, they need to increase the number of crops grown in their farms. This will help them diversify their source of income and protect them from risks in case some crops fail. Also maintaining small pieces of lands mostly helps to increase crop diversity, hence, increasing farm incomes. Subdividing land can be beneficial in terms of increasing income. Agriculture is quiet dependent on uncontrollable environmental factors and diversification is important factor to consider when it comes to starting up agribusinesses.

5.3 Recommendations

For agricultural production to improve, the households need to be sensitized on importance of improving soil fertility and better ways of maintaining acceptable land sizes. KEPHIS should also ensure that there is proper channels of disseminating new seed varieties all over the country. Farmers can also be advised to start thinking of land consolidation as it will ensure that there is enough land for cultivation as currently a lot of land is wasted in boundaries and dispersed settlement. Also cost of moving from place of living to parcels of land will be minimized and also pooling of labour will help improve productivity.

Production efficiency can also be improved by reducing land fragmentation. The government through the Ministry of Lands can determine the minimum land size to be registered and those having lands below that size to be advised on doing land consolidation. Farmers need to be sensitized on diseconomies of land fragmentation and costs that come with their continued practice of land inheritance. This will help reduce technical inefficiency. Farmers need also to be taught on turning their farms in to agribusinesses in order to for them to be entrepreneurs. They will invest more on their farms, be able to generate more profits thereby increasing their farm incomes. This will help to create employment of youths who have shunned away from agriculture.

Land consolidation can be done within the study area and most high potential areas. Allocating land to farmers that are more proficient be done through local institutions and policies to promote efficiency and efficient land market. The Rwandan government passed a policy to reallocate larger land holdings to farmers as a way of reducing land fragmentation (MINAGRI, 1997). Having small farms has bigger implications in rural development as more resources are allocated to improve the human capital thus involve more of the extension personnel and information.

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APPENDIX

Technical Efficiency of sample Households

.7694214	.5369051	.7006377	.7741371	.59086	.4508828	.8501123
.7427372	.8012545	.6921721	.8017403	.4598129	.7580591	.0137891
.8655424	.455502	.6113266	.6040989	.8176584	.4374932	.4383225
.3660305	.3917497	.4269284	.6894863	.2770566	.7291266	.2290189
.7972336	.8058115	.7132275	.5375937	.4858653	.5482101	.6838942
.6507318	.4028899	.7281522	.6095228	.7396444	.1866769	.7833626
.7425656	.8049961	.797226	.8419609	.7971585	.6933354	.0413195
.5056682	.735703	.8749995	.6009321	.7403616	.7765492	.2067075
.3006021	.4682544	.5953495	.063622	.8959784	.7896626	
.8145061	.2852282	.8443153	.2684291	.8134494	.7487363	
.3370734	.7245797	.8721323	.8138813	.806857	.5534877	
.6673675	.2154674	.6986203	.5909212	.4123378	.8577007	
.59004	.2270884	.7075373	.4501639	.7675413	.6197701	
.79653	.4622912	.2597951	.6544843	.7675413	.7741981	
.2805364	.8186249	.0308377	.6546133	.7675413	.8014224	
.8323829	.8506923	.7476118	.478267	.7675413	.6197701	
.8602728	.330129	.8365829	.8771065	.7675413	.7741981	
.659341	.749864	.7975848	.8314983	.7675413	.8014224	
.7780728	.1761695	.7213253	.7402402	.7290791	.8014224	
.2347812	.8027551	.5432021	.4768396	.28962	.8014224	
.8036902	.5278939	.2882613	.449219	.454782	.8014224	
.7761635	.5917197	.3577454	.8536834	.6921414	.8014224	
.6032392	.7929397	.1614845	.8553299	.4679721	.6336153	
.7791787	.1175983	.6880369	.2415841	.1765531	.2601256	