EFFECT OF AGRICULTURAL INTENSIFICATION PRACTICES ON LIVELIHOOD OUTCOMES AMONG SMALLHOLDER FARMERS IN MAKUENI AND NYANDO SUB-COUNTIES, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the award of Master of Science Degree in Agricultural Economics of Egerton University

EGERTON UNIVERSITY

OCTOBER, 2019

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and it has not been submitted in this or any other University for the award of a degree.

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Recommendation

This thesis has been submitted with our approval as University Supervisor.

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DEDICATION

I dedicate this work to my beloved wife Ruth Akinyi Opiyo, my children Malia Sasha and Marshal Slutsky and my parents Mary Adhiambo Ouya and the late Dishon Ouya Bwana.

ACKNOWLEDGEMENT

Almighty God every good things come from you. My sincere gratitude goes to Egerton University for giving me the opportunity to pursue master's degree. I would also like to acknowledge the Department of Agricultural Economics and Agribusiness Management of Egerton University and the Faculty of Agriculture, for the favourable learning environment.

I acknowledge my supervisors Dr. Oscar Ingasia Ayuya and Dr. Isaac Maina Kariuki for the academic guidance during my research process. I also acknowledge Climate Change, Agriculture and Food Security (CCAFS) and International Livestock Research Institution (ILRI) for funding my fieldwork and the technical support from Dr. Nils Teufel and Dr. Mark Van Wijk. Finally, I acknowledge all colleagues and friends who gave me academic challenge to improve this thesis.

ABSTRACT

Developing countries, Kenya included are mostly affected by food problems and poverty as a result of high dependence on agriculture. Agriculture in Kenya is dominated by smallholder farmers, whose production is hampered by climate variability, declining land sizes and low agricultural technologies. Agricultural intensification is aimed at solving the problem of low agricultural productivity and poverty through increasing farm output per unit land area. However it is still not clear the effects of agricultural intensification on smallholder livelihood outcomes. This study therefore analyzed the effect of socioeconomic and institutional characteristics on the level of agricultural intensification, as well as the role of agricultural intensification on smallholders' livelihood outcomes (proxied by progress out of poverty and food security status). The study is based on data collected from a sample of 320 smallholder households from two Sub-counties of Kenya, Makueni and Nyando. Principle Component Analysis (PCA) was first used to group agricultural intensification practices into clusters. The result reveal that all farmers in both sub-counties use agricultural intensification practices and 56% of farmers used 5 level of agricultural intensification practices while 31%, 8%, 3% and 1% of farmers' used 4, 3, 2 and 1 levels of agricultural intensification practices respectively. Poisson regression and Multivariate Tobit Model were used in the subsequent analysis. The Poisson regression results showed that the level of agricultural intensification is significantly influenced by the gender of the household head 28%, land tenure 41%, land slope, 8% off-farm employment 26%, distance to the market, group diversity 6%, and proportion of land cultivated. The Multivariate Tobit results indicated that age of the household head, household size, proportion of land cultivated, number of trainings, group diversity, location and level of agricultural intensification significantly influenced households' food security status during the good and bad months as well as their poverty status. The study recommended on the need for smallholder farmers to form and join many groups which promote social networks thus reduce information asymmetry and improves their bargaining and borrowing power. It also suggested on the need for policy geared towards training and extension which is generation specific that can easily be incorporated by both the old and the young farmers. Through these, there will be increase in the level of agricultural intensification used by smallholder farmers which successfully will lead to improvement of food security and reduction of poverty.

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LIST OF ACRONYMS AND ABBREVIATIONS

CCAFS	Climate Change, Agriculture and Food Security
CFSVA	Comprehensive Food Security and Vulnerability Analysis Guidelines
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GoK	Government of Kenya
HDDS	Household Dietary Diversity Score
HFCS	Household Food Consumption Score
HFIAS	Household Food Insecurity Access Scale
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Council for Research in Agroforestry
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
ILRI	International Livestock Research Institution
KALRO	Kenya Agricultural and Livestock Research Organisation
KES	Kenya Shillings
KNBS	Kenya National Beureu of Statistics
MoALF	Ministry of Agriculture, Livestock and Fisheries
OECD	Organisation for Economic Co-operation and Development
ODK	Open Data Kit
PCA	Principle Component Analysis
RHoMIS	Rural Household Multi-Indicator Survey
SSA	Sub-Sahara Africa
WFP	World Food Program

CHAPTER ONE
INTRODUCTION
1.1 Background of the study

Eradication of poverty and extreme hunger are among the sustainable development goals the world has to overcome (FAO, 2015). Extreme hunger can be solved through increased agricultural production. However, rapid human population increase is a looming challenge to the eradication of global poverty and hunger (Vermeulen *et al*., 2012). It is projected that the world's population will be about 9 billion people by 2050 (Dobermann *et al*., 2013; Tomlinson, 2013). Therefore, there is a need to increase agricultural and food production by between 70 and 100 percent in the next three decades (Godfray *et al*., 2010; Tscharntke *et al*., 2012).

Worldwide, developing countries are the most affected by food problems and poverty as a result of their high dependency on agriculture. Radical change in agricultural and food systems is therefore paramount to enhancing the contribution of the sector to alleviation of poverty and extreme hunger (Dobermann *et al*., 2013). However, agricultural production in developing regions in the world is dominated by smallholder agriculture whose contribution to future food production is hampered by climate variability, declining farm sizes, low use of agricultural technologies and weak policies (Notenbaert *et al*., 2013; Mugi-ngenga *et al.,* 2016; Oluwatayo and Ojo, 2016). Smallholder farmers in developing regions are resource poor thus relatively unable to use the existing technologies and practices to increase agricultural productivity (AGRA, 2014). This limits the contribution of agriculture to the improvement of smallholder farmers' livelihoods, alleviation of poverty and extreme hunger.

Agriculture is one of the most important sectors in Sub-Saharan African (SSA) economies (OECD/FAO, 2016). The sector contributes to an average of 25% Gross Domestic Product (GDP) of the region and it employs 60% of African active working population (Delve *et al*., 2016). About 48 percent of the world's poor people dwell in Africa and close to 80 percent of these people live in rural areas where majority earn their living through agriculture (Oluwatayo and Ojo, 2016; World Bank, 2016). However, agricultural production growth in SSA has been sluggish as compared to other developing regions in the world as it is characterised by open field rain-fed agriculture, which is vulnerable to harsh climatic conditions, a strong evidence for decreasing yield which feeds a population of about 1.138 billion people in Africa (Dobermann *et al*., 2013; United Nations, 2014).

In Kenya, about 80% of the Kenyan populations are rural dwellers and directly or indirectly engaged in agriculture which is the major contributor of the country's economy of about 27.3% GDP (GoK, 2015). The sector also contributes to about 27% of growth in the manufacturing and service sectors (GoK, 2015; MoALF, 2015). About 65% total export earnings come from agriculture. The agricultural sector is also the main source of employment in the Kenyan economy as the sector contributes to rural work force of 80% and formal employment of 18% (MoALF, 2015).

Agricultural production in Kenya is largely practiced by smallholder farmers and is highly dependent on rainfall (Muyanga and Jayne, 2014). Consequently, it is highly vulnerable to climate change and variability. Moreover, Kenya is among the countries in SSA with the highest rural population densities and, therefore, increasing agricultural productivity through expansion of cropland is unsustainable (Ochieng *et al*., 2016). In addition, smallholder farmers in Kenya face a myriad of production related problems as a result of inadequate access to and use of advanced agricultural inputs, poor rural infrastructure, poor market conditions, and high transaction costs (Lemba *et al*., 2012). These challenges result in low agricultural productivity which, in turn, translates into food-related problems and poverty. One way of addressing these challenges of the declining land sizes and climate change requires uptake of agricultural intensification practices by smallholder farmers (Vermeulen *et al*., 2011; Leigh *et al*., 2014).

Agricultural intensification involves increasing capital or labour average inputs on a cultivated land and the grazing land purposely in order to increase output value per acre (Tiffen, 2006; Vermeulen *et al*., 2012) or increasing production per animal and per labour unit. Furthermore, agricultural intensification involves the use of soil and water conservation practices. As farm sizes became smaller and smaller due to population increase and land was continuously being disintegrated among family members, steep plots which were previously left fallow were cultivated. According to Abukari (2014), increasing agricultural production in the face of climate change calls for smallholder farmers intensifying their agricultural production systems. Thus, agricultural intensification has to be pursued as a livelihood strategy for gaining more from agriculture by investing more capital or labour per unit area.

Due to increase in population, urbanization and changing consumer preferences, there is also increasing demand for livestock products such as meat, milk and eggs (Udo *et al*., 2011). Intensification of small animal production has the potential of improving the livelihoods of the very poor households (Lemke *et al*., 2008). The main objective of livestock intensification is to improve farm household incomes which can be attributed to revenues of marketed products, farmers own consumption, manure, livestock draught power among others (Udo *et al*., 2011).

Makueni and Nyando sites were the two project areas chosen by the Climate Change Agriculture and Food Security (CCAFS) because they were regarded as hotspots of climate change. According to CCAFS these two regions were found to be the rapidly developing dry areas in Kenya. National government together with county government of Kisumu and Makueni, non-governmental organizations (ICRISAT, ILRI, CCAFS, ICIPE, KALRO, ICRAF) have been promoting the use of improved seeds, fertilizer, crop rotation, high yielding drought tolerant crop varieties, improved livestock breeds and soil and water conservation practices. This is aimed at increasing output per unit area translating to food security and surplus production which is sold to the market, generating increased income hence alleviate poverty and hunger, leading to improved wellbeing of smallholder farmers in Makueni and Nyando Sub-county.

Majority of smallholder farmers in Makueni and Nyando sub-counties are poor and highly depend on agriculture as their primary source of livelihood. Both sub-counties have an estimated poverty rate of 60% (GoK, 2013a, 2013b). In spite of challenges facing smallholder farmers, the government and private partners promoted and encouraged uptake of agricultural intensification practices in the regions. For instance, these organizations have promoted the uptake of organic and inorganic fertilizers, drought resistant crop varieties, improved indigenous chicken among others. Besides these, there has been promotion of training and capacity building at farm levels. The organizations also encourage formation of local institutions in order to assist in agricultural intensification.

1.2 Statement of the problem

There has been an increasing recognition of the role of agricultural intensification in improving livelihoods of rural smallholder farmers. Agricultural intensification puts less pressure on natural resources, increasing agricultural productivity, building smallholder resilience to climate changes and improvement of their livelihoods. Several interventions such as training of farmers, dissemination of improved agricultural technologies and formation of rural institutions have been implemented in Makueni and Nyando Sub-counties by governmental and non-governmental organizations with the view of encouraging agricultural intensification of smallholder production system. However, there was limited knowledge of the socio-economic and institutional characteristics that influenced the level of agricultural intensification among smallholder farmers. Furthermore, the effect of agricultural intensification on livelihood outcomes is unclear in empirical literature. Therefore, it is against this background that the current study aimed at filling these knowledge gaps.

1.3 Objectives

1.3.1 General objective

To contribute towards improved livelihood through enhanced agricultural intensification of smallholder farmer's production system in Makueni Sub-county and Nyando Sub-county.

1.3.2 Specific objectives

1. To develop the level of usage of agricultural intensification practices by smallholder farmers in Makueni and Nyando Sub-counties.
2. To determine the effect of socioeconomic and institutional characteristics on the level of agricultural intensification among smallholder farmers.
3. To determine the effect of agricultural intensification on smallholder farmers livelihood outcomes.

1.4 Research questions

1. What is the level of usage of agricultural intensification practices by smallholder farmers in Makueni and Nyando Sub-counties?
2. What are the effects of socioeconomic and institutional characteristics on the level of agricultural intensification among smallholder farmers?
3. What is the effect of agricultural intensification on smallholder livelihood outcomes?

1.5 Justification of the study

Agriculture is a key sector in Kenya and across the region. It remains the primary source of livelihood for most of the rural population in Kenya. The Kenyan government and other agricultural stakeholders focus on promoting agricultural intensification as a strategy for making smallholder farming systems more responsive to the changing climatic conditions. However, much focus of agricultural intensification is on ensuring higher yields on the same piece of land, ignoring its links to rural livelihoods.

Understanding the impact of socioeconomic and institutional characteristics of smallholder farmers on agricultural intensification is important to the designing and implementation of poverty reducing policy. This will go a long way in addressing the first and the second Sustainable Development Goals which aims at eliminating both poverty and hunger through achievement of food security and improved nutrition (United Nations, 2017). Furthermore, increased agricultural productivity as a result of agricultural intensification will lead to the realization of the Kenyan food security policy objective of ensuring adequate, safe and nourishing food are accessible to everyone at all times (GoK, 2011). At the same time intensification will be in line with the Kenyan vision 2030 blueprint of promoting sustainable agriculture and enhancing its contribution to wealth creation and rural livelihoods. Therefore, this study informs policy makers and development partners including CCAFS, in the contribution and designing of strategies, when supported enable smallholder farmers' access necessary resources for agricultural intensification, leading to food security, increased output, reduced vulnerability, improved income and their wellbeing.

1.6 Scope and limitation of the study

This study was based on data collected by ILRI/CCAFS in the months of October to December, 2016. The project only considered rural smallholder households in Makueni Sub-county and Nyando Sub-county in Kenya. Most smallholder farmers did not keep records of their farm activities so the study relied on farmers' recall which might not have been exact. This problem was solved by thorough probing. There were incidences of language barriers which was solved by use of translators.

1.7 Definition of terms

Agricultural intensification: This is the process of increasing yield per unit land area through increasing crop intensity (mixed cropping, crop frequency), use of agricultural technologies or techniques and/or changing land use from low value crops/breeds to high value crops/breeds (Pretty *et al*., 2016).

Bad month/Food insecured month: Is the period of the year when smallholder farmers' households experience difficulties in obtaining food.

Food security: Is the condition in which everyone at any given time has adequate, available and accessible, safe and nourishing food that meets their preferred diets.

Good month/Food secured month: The period within the year which normally occurs during main harvesting period when households have adequate and sufficient amount of food.

Household: Are people who live together at least for a period of three months sharing meals and resources and are all accountable to one person who is the head.

Level of agricultural intensification: Is the number of crops and livestock practices applied by smallholder farmer.

Livelihoods: Are activities carried out and resources needed by individual households in order to survive (DFID, 2000).

Livelihood outcomes: These are results of agricultural intensification to smallholder households measured by progress out of poverty and food security status.

Poverty: Is multidimensional and means farmers households having inadequate resources to meet most basic needs and those living below poverty line of US$. 1.25 a day are said to be poor.

Smallholder: Is a farmer who operates in a small piece of land normally less than 20 acres.

Sustainability: Making good use of resources in agricultural production to conserve the environment and to avoid their future depletion.

CHAPTER TWO
LITERATURE REVIEW

This section explores literature of past studies on agricultural intensification, its impact on crops and livestock production, its ability to alleviate poverty status of smallholder farmers as well as reviewing its potential contribution to food security. Several socio-economic, farm and institutional characteristics were investigated to understand their effect on agricultural intensification and how they determine smallholder farmers' livelihood outcomes. These literature reviews helped in identification of knowledge gaps which this study sought to fill.

2.1 The state of smallholder agriculture in Kenya

The contribution of smallholder farmers on agriculture to the economy still remains incomparable as the sector has an estimated GDP share of 27.3% (GoK, 2015; KNBS, 2016), this makes smallholder agriculture a major contributor of food security and income in rural areas. Whereas the Kenyan Smallholder farmers are the major agricultural producers, yet they remain food insecure and economically poor (Muriithi *et al*., 2009). Livelihood of smallholder farmers in rural areas are based majorly on cultivation of crops and livestock keeping (Ulrich *et al*., 2012). Smallholder farmers produce cereals, legumes, horticulture, industrial crops, aquaculture, apiculture, as well as rearing livestock (KNBS, 2016). According to Wang'ombe and Dijk, (2013), the most important food crop grown in Kenya by most smallholder farmers is maize followed by potatoes which contributes 32% overall dietary consumption. Smale and Olwande, (2014) found that most farmers grow hybrid maize varieties as they have long experience with the seed.

The number of livestock, amount and quality of land a smallholder farmer controls in rural area is wealth and major assets they depend on in generating food and cash incomes (Marenya and Barrett, 2005). According to Moebius *et al*. (2014), soil which supports crop growth has been degraded in most rural areas due to intensive use, erosion, low inputs and poor management by the people. Smallholder farmers in Kenya are much vulnerable to climate change as the country highly depends on rain-fed agriculture, technology adoption is very low and infrastructure and markets are poorly developed (Bryan *et al*., 2013). In most part of the country the rainfall pattern is bimodal and there is increasing frequent dry spells leading to crop failures and death of livestock especially in arid and semi-arid areas which on average receives annual rainfall of 400mm (GoK, 2010).

Kenya has high rural population density making agricultural land expansion difficult (Muyanga and Jayne, 2014). Population increase creates high demand for food and smaller fragmentation of arable land which has been degraded hence yielding low agricultural production (Vermeulen *et al*., 2011). Rapid population growth experienced in Kenya tends to increase the demand for agricultural products both in rural and urban areas. This gives better marketing opportunities for smallholder farmers as increasing demand leads to higher prices leading to improved income (Binswanger-mkhize and Savastano, 2016). Rapid population growth in Kenya leads to higher population density also puts more pressure on land in rural areas which shrinks as it is disintegrated among siblings; the farmer has to fend their livelihoods on a reduced area. These forces will lead to higher agricultural intensification (Binswanger-mkhize and Savastano, 2016).

2.2 Agricultural intensification and its implication on livelihood

The success of agricultural intensification has been shown by increasing productivity per unit area hence meeting the increasing global food demand (Bommarco *et al*., 2012). According to Raut *et al*. (2010), in a review study on linkages between agricultural intensification and livelihood improvements in Nepal, they concluded that agricultural intensification positively influences livelihood security economically, socially and institutionally. Uptake and continued use of improved crop varieties, chemical fertilizer and high labour input had significant and positive impact on productivity and farm income. Increase in productivity and income, in turn, had direct and indirect effect on food security status and employment.

Food security is complex as it relates to availability, affordability as well as stability but the study primarily focuses on food availability and accessibility. A food secure household is one with sufficient food, legally obtained, which can satisfy their nutritive needs during the year (Silvia *et al*., 2015). Energy availability for a household is calculated using data on agricultural production and food consumption. Households stated the types of food they consumed on a weekly basis indicating ‘bad season’ and ‘good season’ in a given year (Silvia *et al*., 2015). Indicators of food security are food security ratio (FSR), food self-sufficiency ratio (FSSR), household food insecurity access scale (HFIAS), household food consumption score (HFCS) and household dietary diversity score (HDDS). FSR is the sum of energy required from obtained food which can be through on-farm produce, purchase, gift or gathered divided by the household total energy requirements (Rufino *et al*., 2013). FSSR is quantity of on-farm food production available for consumption over the sum of the household’s energy requirements.

Household Dietary Diversity Score (HDDS) is an indicator used to measure dietary quality. It measures the number of food types consumed by the household during a specified period of time, the last 24 hours or the last 7 days (Hammond *et al*., 2015). It can be used as an indicator of food security from a calorie perspective (Kibrom and Qaim, 2016). Household food consumption score was developed by The World Food Programme (WFP) as a proxy indicator for food accessibility. HFCS is a weighted score for dietary diversity, food frequency and its nutrition. It is calculated by multiplying frequency of foods consumed in the last seven days by weighted score of each food group.

In rural areas where farming is the key economic activity for the households, improving agricultural productivity is the major strategy to alleviate poverty, which can as well address the challenge of food insecurity (Hussain and Hanjra, 2004; Maziya *et al*., 2017). Increasing agricultural productivity is cited by many scholars as an important step in poverty alleviation and improving food security in SSA. It is against this background that Kassie *et al*. (2011) evaluated ex-post effect of improved groundnut variety on poverty and crop income in Uganda. Using cross-sectional data drawn from 927 sampled households. In estimate income and poverty effects of adoption he used propensity score matching methods. Uptake of improved groundnut varieties had a positive and significant effect on farm income and negative effect on poverty.

In a similar study, Shiferaw *et al*. (2014) used a national-representative data of over 2000 farm households to evaluate the implication of improved wheat varieties on food security in Ethiopia. The study used food consumption expenditure as a proxy for household food security. Binary propensity score matching (PSM), endogenous switching regression (ESR) and generalized propensity score (GPS) approaches were used to estimate the treatment effects of adoption and continued use of improved wheat varieties. Results were on average, uptake of improved wheat varieties resulted in a positive effect on food security.

Nata *et al*. (2014) studied the linkage between food security and household adoption of soil conservation practices in Ghana. Using two Logit models to determine how food security influences uptake of soil improving practices and technology adoption. They found that food secure households positively embrace soil-improving practices of minimum tillage or no-till, mulching, cover crops and crop rotation than their food insecure counterparts. This is because they can reinvest some of their production income in soil quality improvements. They also concluded that chemical fertilizer use reduces household chances of being food insecure. A similar study by Abdulai and Huffman (2014) studied uptake and effect of soil bunds and ridges among smallholder farmers in Northern Ghana. The study used cross-sectional data drawn from 342 rice farmers. Endogenous Switching Regression (ESR) was used in estimating the average treatment effect of adoption of the two water and soil conservation practices. The results of the study indicated positive and significant adoption effect on rice yield and returns. Adoption of soil and water conservation practices improved rice productivity and income per unit area.

Samdup *et al*. (2010) assessed the effect of livestock intensification through dairy crossbreeding in Bhutan. They used least square methods in explaining the differences in farm and household characteristics as well as explaining variation of daily milk production due to cattle breeds. The result was crossbred cattle produce 2.4 to 4.6 times more milk than local cattle yielding higher gross margin in intensive and semi-intensive than in extensive areas. Hence crossbreeding reduces pressure on grazing land and improves smallholder livelihoods. Using panel data of 2002 to 2007 growing seasons Smale and Olwande, (2014) applied regression method in assessing the effect of hybrid maize seed adoption of smallholder farmers on their equality status and their income. The result indicated that producing hybrid maize enhances smallholder farmers' gross nominal income by 29% on average. Crop diversity is an important factor in increasing food security as it result in more diversified human diets and it can increase yield stability, it is a smallholder potential strategy for mitigating food security in SSA (Silvia *et al.*, 2015).

The success of development policy is majorly measured by progress on poverty reduction and income inequalities should be considered in making progress on poverty alleviation (Asogwa *et al*., 2012). Poverty still remains a multidimensional problem which traditionally measured with one dimension of income as it captures people's ability to achieve minimum thresholds of basic wants. However people's needs may not be necessarily be satisfied in the market so other poverty measurements have to be considered (Alkire and Santos, 2014; Desiere *et al*., 2015). But state of deprivation according to Alkire and Santos, (2014) can be described widely by social exclusion, poor housing condition, violence, low or lack of education, water scarcity and inadequate sanitation, lack of empowerment, lack of food and unsatisfactory health standards. Alawode *et al*. (2016) examined how agricultural intensification affects poverty status of smallholder farmers in Kogi State, Nigeria. 215 farming households were sampled and using Ruthenberg index, Foster, Greere and Thorbecke (FGT) index and Probit regression model the result shows that land use intensity positively relates to probability that the farmer would be poor.

2.3 The concept of agricultural intensification

Agricultural intensification according to Shriar (2000), is the process of raising the productivity of land through increasing inputs over time per unit land area. This concept is often poorly defined in literature and different approaches for measuring agricultural intensification make it difficult for farming system comparison. Gregory *et al*. (2002) defined agricultural intensification as increasing production per unit of land of farmers' field using either single or a combination of several management options. Agricultural intensification involves increasing capital or labour average inputs on a cultivated land and the grazing land purposely in order to increase output value per unit acre/hectare (Tiffen, 2006; Vermeulen *et al*., 2012) or increasing production per animal and per labour unit.

Agricultural intensification also involves adoption of soil and water conservation technologies. According to Abukari (2014), increasing agricultural production in the event of climate change calls for smallholder farmers intensifying their agricultural production systems. Agricultural intensification when justified on environmental ground can save land through increasing yields, on farm land to reduce expansion of land on agricultural systems. Increased yields lead to improvement in food security and income through sale of surplus which in turn leads to poverty reduction, hence improving the welfare status of smallholder farmers.

2.4 Measurement of agricultural intensification

According to Binswanger-Mkhize *et al*. (1993), one way of realising agricultural intensification is by increasing inputs used per land unit area. It can be measured by frequency of cultivating land per year that is annual cropping seasons. Agricultural intensification occurs when there is an increase of land productivity induced by human activities (Philipp *et al*., 2012). There will never be universal formulae of measuring agricultural intensification; this makes it difficult to compare particular farm structures. According to Shriar (2000), agricultural scientists have developed approaches and methods of measuring agricultural intensification in terms of output, land fallow, farm practices and agro-technologies employed. Shriar suggested that the best method is to develop agricultural intensity index for a given farm unit considering practises and technologies employed in the farm and the extent to which they are used.

2.4.1 Output as a measure of agricultural intensification

The main objective of any farmer is to realise the highest production possible and the ideal measure of agricultural production is output per unit area and time. Output can be considered in terms of mass like tons of cereals harvested, milk production, also caloric value, energy and monetary value of production (Shriar, 2000; Erb *et al*., 2013). The problem with output approach of measurement is the variation of yield influenced by climatic conditions, soil type, and variety or breed types as crops vary from food to fibre and they differ in weights caloric value as well as monetary value (Lobell *et al*., 2009; Neumann *et al*., 2010; Licker *et al*., 2010). A unit mass of potato may fetch a different price compared to a unit mass of maize. To solve the problem scientists developed better methods of assessing yield gaps that cut a cross regional, plot and farm level to give a reference yield under related production conditions (Erb *et al*., 2013). According to Philipp *et al*. (2012), crop yield is a useful yardstick for measuring agricultural land use intensity, so care has to be taken as high yield could be as a result of favourable weather or physical conditions. Erb *et al*, (2013), further escalates that indicators for output can ensure better land-use intensity measurements as they represents agricultural outcome. Output intensification can be viewed in terms of production output increase per unit land area and time. Measuring intensification in terms of output might be biased due to regional climatic and agro-ecological differences which causes variation in yields.

2.4.2 Annual crop frequency as a measure of agricultural intensification

Frequency of cropping staple foods has been used as measure of agricultural intensity since 1965 by Boserup as this specifies the time of the year the land parcel is fallow and the duration it is cropped. According to Erb *et al*. (2013), annual crop yield can be improved by increasing cropping frequency which escalates production. Under the intensive system the same plot bears two or more crops consecutively per year. However, confusion emerges when considering perennial crops or tree crops which take more than a year to produce. The frequency value can be assigned as equivalent yearly production per unit area depending on the nature and objective of the analysis (in terms of mass, calories, and amount) compared with annual crop production (Shriar, 2000).

2.4.3 Agricultural farm practices as a measure of agricultural intensification

Conservation agriculture is important for agricultural production growth especially on rain fed agriculture where soil and water losses are common due to surface runoff and evaporation (Gebreegziabher *et al*., 2009). Through construction of conservation structures such as stone bunds, earth bunds and terraces can prevent soil erosion on steep sloping plot. Other agricultural farm practices like mulching; ploughing across contours can also assist in retaining soil moisture. According to Chhetri (2011), cropping intensity index can be calculated using land use data and it is the fraction of net cropped land area to the total of arable land area. The land which is cropped two times in a season is counted twice.

Farms can be compared on the basis of agro-technologies employed, the types of inputs used and the amount at a particular time. The need for farm inputs will vary depending on the soil type and farming system. Distinction can be made between different farming systems to show the input intensity. Schreinemachers and Tipraqsa, (2012) used FAO data for a period of 1990 to 2009 to study several countries trends and levels in using agricultural pesticide. They used simple regression method and found that a percentage increase in crop production per unit land area is associated with 0.125% increase in pesticide application per hectare. More intensive use of pesticides does not directly lead to increase in production but assist in controlling the potential losses caused by pests and weeds.

Another approach of measuring the level of agricultural intensification is using the level of mechanization of farm operations. This method was applied by Olaoye and Rotimi, (2010) in their measuring agricultural mechanization and productivity in Nigeria. The study constructed mechanization index according to the level of machinery use for pre-planting, planting and post-planting activities. The intensity of machine use was measured as a percentage of work powered by machinery relative to human power. The mechanization index was used as proxy for distinguishing the different levels of machinery intensification.

2.4.4 Extent of agricultural intensification as a measure

Alawode *et al*. (2016) analysed agricultural intensification on land use intensity, labour use intensity and fertilizer use intensity index for each farmer. These were estimated by adopting Ruthenberg index, Foster, Greere and Thorbecke (FGT) index and Probit regression model as land use intensity index (L) is found by dividing length of cropping period by fallow period plus cropping period. According to Ruthenberg (1980), the ratio (R) of cultivation period length to the land utilization cycle length can be useful in indicating whether there is short or long fallow as well as permanent cultivation. Alejandro (2015), argued that information estimating whether the land was semi-permanently or fully cultivated are often rare and difficult to profile. Labour intensity (W) is the ratio of labour used to total area of cultivated land and fertilizer intensity (F) is the ratio of quantity of fertilizer use to cultivated area. High values of W and F means high intensity of their use.

2.5 Determinants of agricultural intensification

Group membership is very important for farmers as they share important information, learn from one another hence increasing the awareness and knowledge of smallholder farmers (Uaiene *et al*., 2009). According to Mignouna *et al*. (2011), household farmers in rural groups are expected to embrace agricultural intensification practices as social capital strengthens trust among group members. Katungi and Akankwasa (2010) studied the impact of community based organization in uptake of corm-paired banana technology in Uganda, and asserted that farmers who mostly participate in community based organizations were most likely to practice the technology as they learn from others. The existence of extension services, agricultural programmes and policies directed in improving crop production are incentives to farmers prompting them to increase production through intensifying frequency of cropping, changing combination of crops they plant in order to maximize land use and reduce risks and uncertainties in production (Udoh *et al*., 2011; Alawode *et al*., 2016).

Population increase has been cited as one of the most critical factors affecting smallholder agriculture in developing countries. As a result, Muyanga and Jayne (2014) conducted a study to establish how smallholder agriculture in Kenya responds to changes in population density over time. Using control function approach in instrumental variable framework, the study found that population density had significant and positive association with farm intensification. The study indicated that land is an important factor affecting agricultural productivity. An increase in population density resulted in reduction in farm sizes which, in turn, influenced farmers' decisions to intensify their production systems. Leigh *et al*. (2014) using household-level panel data drawn from 1293 smallholder farmers in Ethiopia, estimated the impact of rural population density on agricultural intensification and productivity. The results showed that increase in population density on rural households had a positive influence on input demand represented in this case by increased fertilizer use per unit area.

Tesfaye and Seifu (2016) analyzed smallholder farmer's perception on climate change and their adaptation strategies in eastern Ethiopia, and found that majority of farmers are aware of adverse effects of climate change on food security, diversity, income, livestock and crop diseases. Farmers therefore responded to these effects through changing planting timeline, growing various crop varieties, and using conservation agriculture techniques. These were greatly influenced by socioeconomic characteristics such as the gender household head, household size, number of farm plots and farm size. This study suggested a need to support farmers with required resources such as provision of information, credit and extension services among others. Similar findings were found by Ngenga *et al*. (2016). Socio-economic factors of a household such as gender, education level, age, household size and marital status of household head influence the ability of smallholder farmers to adapt to various climate changes. They found that household characteristics influence agricultural operations as well as smallholder farmers' decision making process.

Another way of increasing the productivity agricultural production is using improved agricultural technologies. These will take the form of mechanization, use of improved, productive and early maturity seeds and livestock breeds, disease and drought resistant crop varieties. According to Khonje *et al*. (2015) agricultural intensification through practicing improved maize seed varieties leads to improvement in food security, crop income and consumption expenditure which reduce the of impact of poverty in Eastern Zambia. A similar study on improved legume technology was conducted by Asfaw *et al*. (2012) in Ethiopia and Tanzania and confirmed how technology use improves the welfare of rural household as more consumption expenditure from it leads to lower poverty and high food security and less vulnerability to risks. Soil and water conservation use in the farm is important because it improves the efficiency of water use from rainfall. According to Abdulai and Huffman (2014), adoption of soil and water conservation technology increases rice yield and farmers net returns in Northern Ghana.

Olwande *et al*. (2009) analysed the use of fertilizer intensity among smallholder farmers in Kenya using a double-hurdle model on a panel data of 1275 farmers. The results showed increase in fertilizer application rates countrywide but there is low fertilizer use in drier agro-ecological zones. Their results showed education, age, credit, presence of a cash crop, agro-ecological zones distance from fertiliser market all influence the likelihood of a farmer adopting fertilizer use. They further found that gender, dependency ratio, credit, access to extension services, and presence of cash crops will greatly determine the intensity of fertilizer use.

Yitayih *et al.* (2016) assessed the uptake and use of improved livestock feed technologies among 603 smallholder farmers in Ethiopia. Using Heckman two stage models for analysis, the results indicated that household's adoption success was positively influenced by institutional, individual and farm characteristics. Being a member of cooperative society increases the probability of a farmer to adopt feed technologies. The farmer education level and experience in livestock production was positively associated with adoption. Herd size had positive influence whereas smallholder farmers with less land will shift from open grazing system to more intensive zero grazing units. Distance from urban centres had a negative effect on adoption of feed technologies as it increased transaction costs, limited access to institutions, service providers and market.

Several variables determining agricultural intensification were also cited by scholars. Land tenure positively greatly influence the use of agricultural intensification practices as secure land tenure adopts these technologies than insecure farmers on rented plots (Kassie *et al*., 2010; Teklewold *et al*., 2013). Social capital and networks also positively influence smallholder farmers to embrace agricultural intensification practices. According to Ndiritu *et al*. (2014), gender matters in determining the uptake of agricultural intensification practices as female were less likely to adopt some of these practices like minimum tillage, manure among others compared to male because these practices need more labour and resources.

2.6 Theoretical and conceptual framework

2.6.1 Theoretical framework

This study was informed by the random utility theory as described by Khonje *et al*. (2015). The assumption was that farmers are risk neutral and only choose the agricultural intensification combination which maximizes their benefits subject to other constraints. A rational farmer makes a choice between alternatives and choose the best option which maximizes farmer's utility. Smallholder farmers engage in agricultural intensification which they expect to be advantageous or profitable. The decision to intensify agriculture was modelled in a random utility framework. Let A= 1 for practicing one or combination of agricultural intensification practices, and A = 0 for not engaging in any agricultural intensification practices.

UA_{i1} is utility that individual household i gets if alternative 1 is chosen

UA_{i0} is utility that individual household i gets if otherwise

The utility difference between engaging in agricultural intensification (UA_i) and not practicing any form of agricultural intensification (UA_{i0}) can be denoted as D*, such that utility maximizing farm household (i), only chooses to intensify if the utility derived from agricultural intensification is more than the utility gained from not intensifying:

$$UA_{i1} > UA_{i0} \ (D^* = UA_{i1} - UA_{i0} > 0), \ A_i = 1 \ if \ D_i^* > 0, \ A_i = 0 \ if \ D_i^* \leq 0 \quad \text{......................... (1)}$$

These utilities can be rewritten as follows:

$$D_i^* = \beta X_i + \mu_i \text{ (i = 1,....N) with } D_i = \begin{cases} 1 \, if \; D_i^* > 1 \\ 0 \text{ otherwise} \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where D_i^* is unobserved latent variable, D= 1 for practicing agricultural intensification and D = 0 otherwise. ß is a vector parameter to be estimated; X is a vector of explanatory variables that represents institutional, socioeconomic and farm specific characteristics; and u is the disturbance term; while i = 1 ,……, n is individual smallholder farmers.

2.6.2 Conceptual framework

Conceptual framework simplifies the understanding of relationship between dependent and explanatory variables. Change in the independent variable has an influence on the dependent variable. The framework in figure 1 shows how various variables related and interacted to influence the level of agricultural intensification. Smallholder farmers had different socio-economic characteristics which include age, household size, gender, farm size, livestock ownership, off farm income, farming experience, value of agricultural assets, education level among others which determines whether a farmer was to engage in none, and one or more agricultural intensification practices. Institutional factors (training, land tenure, extension service, membership to a group, infrastructure) also affected the choice of agricultural intensification practiced in the farm. There were also exogenous variables which influenced the level of agricultural intensification practiced and these included climatic variability, government policies, and population growth.

The level of agricultural intensification practices was measured by the number of agricultural intensification practices. It was assumed that use of multiple agricultural intensification practices influenced by the above mentioned variables provided more economic benefits and higher productivity than when employed individually. This helped in identifying the best practices that produced the highest livelihood outcomes. Finally, the choice of agricultural intensification practice a smallholder farmer engaged in was expected to affect the overall farm production which led to a change in livelihood outcomes. A rational farmer only uses the level of agricultural intensification practice which would maximize their farm output increasing their food security status and leads to poverty reduction.

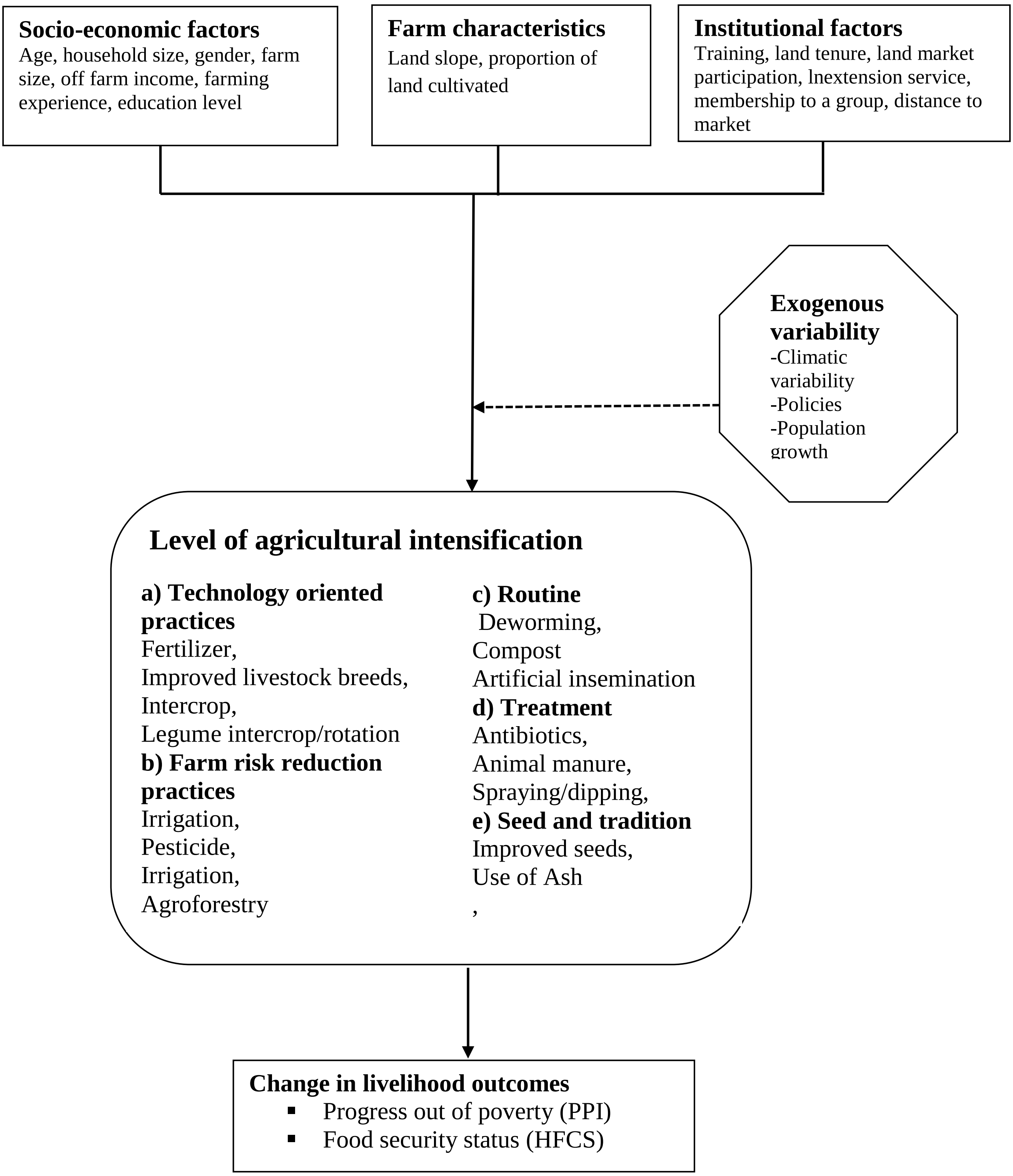

Figure 1. Conceptual framework of the role of agricultural intensification on livelihood outcomes.

CHAPTER THREE
METHODOLOGY

3.1 Study area

This study was based on data collected in September and December, 2016 in Makueni Sub-county in the Eastern Region and in Nyando Sub-county in the Nyanza Region respectively. These sites were selected for research program by Climate Change, Agriculture and Food Security (CCAFS) using poverty levels, agricultural production systems, households susceptibility to climate change, climatic and agro-ecological gradients. These sites were major areas affected by climate change and food security and Makueni (Wote) was the driest site (Silvia *et al*., 2015). Makueni Sub-county has an area of approximately 1547.2 Km^2 with a population of 193,798 persons according to 2009 population census. The area was sparsely populated with high population densities recorded in a major town of Wote. The large part of the sub-county is mostly semi-arid and arid which is prone to frequent droughts. The very dry lower side normally receives little annual rainfall between 300mm to 400mm but some parts can receive annual rainfall as high as 800mm (GoK, 2013a). The rainfall pattern is bimodal with long unpredictable rain season on March and April while short rain season which is their 'main season' occurring on November/December. The Sub-county altitude is generally low-lying at 600m above sea level. The temperature can rise as high as 35.8^{o}C. The Sub-county has experience climate change of unreliable rainfall due to human activities like farming, charcoal burning, and sand harvesting (GoK, 2013a).

Nyando Sub-county covers an area of approximately 249.3 Km^2 with population projected to be 64,511 persons. To the west of Nyando is Kisumu East Sub-county, Muhoroni Sub-County is in the North, Kericho Sub-County in the Eastern side while Nyakach Sub-county is on the Southern border. Nyando Sub-county stretches to the Southwest where its shoreline touches Lake Victoria. Nyando Sub-county is located within the longitudes 34^{o}4$'$ East and the latitudes between 0^{o}23$'$ South and 0^{o}50$'$ South, respectively (GoK, 2013b). The temperatures range between 22^{o}C to over 37^{o}C. The altitude lies from 1100m above the sea level along the Kano plains to 1500m above sea level around the Kericho and Muhoroni border. Nyando also experience bimodal rainfall patterns with the long rain season being between March to June and the short rain season realised between September to November. The annual rainfall has a mean range of 600mm to 1,700mm (GoK, 2013b). The annual rainfall in the Sub-county varies with the Zones. The Upper midland zone UM_3 receives average rainfall of up to 1700mm annually with the lower region LM_4 having as low as 700mm annually (GoK, 2013b).

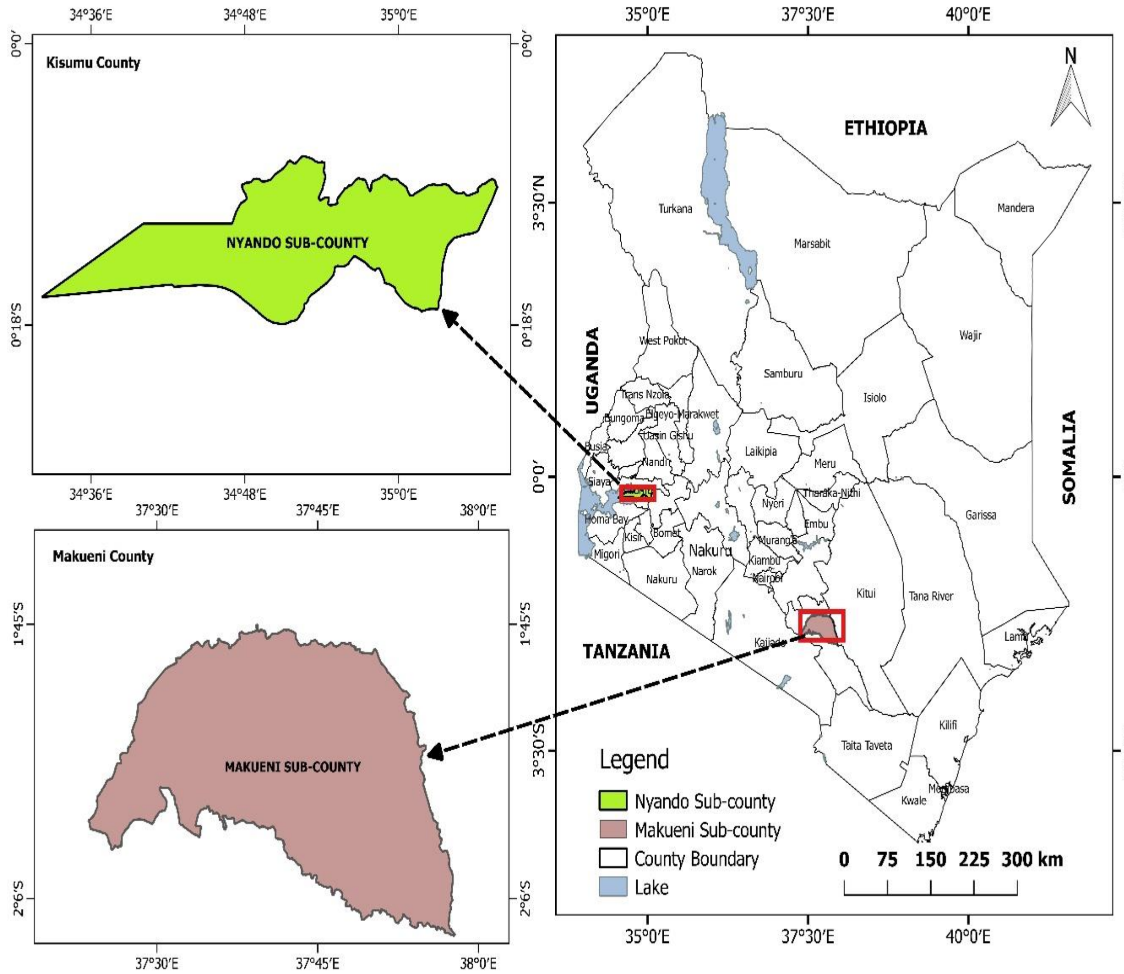

Figure 2. Map of study area

Source: Geography Department, Egerton University. 2017

3.2 Sampling procedure

This study was conducted following a resampling of smallholder farm households previously surveyed by CCAFS research program (https://ccafs.cgiar.org/) in 2012. A 100 Km^2, research grid was picked on each selected site of Nyando and Makueni Sub-counties. Secondary data were gathered by CCAFS research project which acquired high resolution satellite images, generated maps, and geo-referenced lists of all villages within each research grid. On each research grid, the agreed sample of 16 villages was selected. Villages in build-up areas (urban or peri-urban) were excluded from the lists. Household lists were collected from the sampled villages by village elders/managers who knew the boundaries and verification of the lists were conducted by CCAFS officers through door to door confirmation, numbering them and additional households were found in some villages (Rufino *et al*., 2013). This study sampled a total of 320 households that was ten respondents from each of the sampled 16 villages per site.

With household lists from the sampled 16 villages in each grid in place, a systematic random sampling was used in every site and replacements done using the same method.

3.3 Research design

The study used Cross sectional descriptive survey design to determine the effect of agricultural intensification practices on smallholder farmers' food security and poverty status in Nyando and Makueni Sub-Counties in Kenya. These two areas were regarded by CCAFS as the hotspots of climate change because they are rapidly developing dry regions.

3.4 Data and Data collection

This study was based on Rural Household Multi-Indicator Survey (RHoMIS) data which was collected in the months of October, November and December, 2016. RHoMIS is a household survey tool designed to rapidly characterize a series of standardized indicators across the spectrum of agricultural production, poverty and market integration, food security, nutrition, and greenhouse gas emissions. The exercise involved a team of well-trained enumerators with agricultural background and field experience, a team leader and a supervisor, data collection tool which was Open Data Kit (ODK) installed on android Tablets and other incidentals. A semi structured questionnaire was used.

A pretest was conducted in Makueni Sub-county and corrections or adjustments were made to the tool. Data was obtained through interviewing household heads or the spouses. At the beginning of the exercise, a team leader conducted spot checks to identify common problems or poor skills this helped in evaluating and improving interviewer performance. A team leader also conducted back checks by asking few questions to cross check the authenticity of information collected, this was to ensure that the data collected was of high quality. Debriefing was conducted almost on a daily basis where challenges and concerns were raised and field experiences and ideas shared. Enumerators cleaned their data by the end of any data collection exercise, data backed up by the supervisor and sent directly from the tablet to a portal. The data was cleaned, organized and analyzed using STATA and SPSS computer software programs. The data collected included household and farm characteristics, crop productivity, livestock species and products, access to facilities, social capital, food security and progress out of poverty.

3.5 Analytical Framework

Objective One: To develop the level of usage of agricultural intensification practices by smallholder farmers in Makueni and Nyando Sub-counties

Principal Component Analysis (PCA) was used to group the agricultural intensification practices into clusters called principal components. These uncorrelated components accounts for the total original variance. The very first Principal components to be chosen had the greatest variance with the high percentage of explained variance, which is an index of goodness of fit; the remaining components with low percentages of explained variance are dropped. The reduced dataset (groups) was then be used as dependent variable, level of agricultural intensification practices which was analyzed using count models (Cappellari *et al.*, 2003). The grouped model is represented as shown below:

$$Y_1 = \theta_{11}x_{12} + \theta_{12}x_2 + ... + \theta_{1n}x_n$$

$$Y_2 = \theta_{21}x_{21} + \theta_{22}x_2 + ... + \theta_{2n}x_n \quad (3)$$

. . .

$$Y_j = \theta_{j1}x_{j1} + \theta_{j2}x_2 + ... + \theta_{jn}x_n \quad (4)$$

Where Y_1,…………………, Y_j = principal components which are uncorrelated

$\theta_1 - \theta_n$ =Correlation coefficient

x_1,……, x_j, = socioeconomic factors affecting agricultural intensification practices

This objective was then analysed using t-test statistics to compare the similarities and differences on types of agricultural intensification practices applied by smallholder farmers. t-test helped in determining whether there was significant difference in the numbers of smallholder farmers applying agricultural intensification practices between the two sub-counties.

Objective Two: To determine the effect of socioeconomic and institutional characteristics on the level of agricultural intensification among smallholder farmers

This objective was analysed using count models. Some farmers use zero, one or more agricultural intensification practices, so the regressand was of the count type. Poisson Regression model was then used to analyse the dependent variable, which is the level of agricultural intensification practices. The dependent variable now level of agricultural intensification y which takes relatively few nonnegative integer values (0, 1, 2, …) (Wooldridge, 2013). The y_i which is drawn from a Poisson population with the parameter λ_i that is related to independent variables x_i (Greene, 2012). The Poisson regression model is generally defined as follows:

$$prob(y_i = y_i | x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}, \ y_i = 0, 1, 2, \ldots \quad (5)$$

The very common formulation for λ_i is the loglinear model,

$$\ln \lambda_i = x_i^{'}\beta, \quad (6)$$

The expected number of agricultural intensification practiced by a household is given by:

$$E[y_i|x_i] = \mathrm{Var}[y_i|x_i] = \lambda_i = e^{x_i^{'}\beta}, \quad (7)$$

Where e, is the exponential function, β is a 1 by k vector parameters.

$$\frac{\delta E[y_i|x_i]}{\delta x_i} = \lambda_i \beta. \quad (8)$$

It is much easier to estimate the parameters with maximum likelihood techniques as the Poisson model is a nonlinear regression (Greene, 2012). The log likelihood function becomes

$$\ln LL = \sum_{i=1}^{n} \left[-\lambda_i + y_i x_i^{'}\beta - \ln y_i!\right] \quad (9)$$

The likelihood equations are

$$\frac{\delta \ln LL}{\delta \beta} = \sum_{i=1}^{n} (y_i - \lambda_i) x_i = 0. \quad (10)$$

In describing the relationship between the dependent variable (level of agricultural intensification) and independent variables (socioeconomic, farm and institutional characteristics), the magnitude based on estimates parameters from the Poisson regression and their variations, makes it possible to estimate the marginal effect. Change in the number of agricultural intensification following the change of one unit in any exogenous variable x gives the marginal effects.

The variables that were to be used in Poisson were derived given previous studies (Gido *et al*., 2014; Jara-Rojas *et al*., 2012; Mutisya *et al*., 2016). The model and their explanations are shown in Table 1.

Table 1. Variables of the Poisson model

Variable	Description of the variables	Measurement	Expected sign
Dependent variable			
Lvagrintfc	Level of agricultural intensification (0, 1, ..., n)	Discrete	
Independent variables			
Sbcty	Sub-county (1=Makueni 2=Nyando)	Binary	
Age	Age of the household head (years)	Continuous	±
Gend	Gender of the household head (1= male 0= female)	Binary	+
Educlev	Education level of the household head (1= Illiterate 2= literate 3= primary 4= secondary 5= post-secondary)	Categorical	±
Hhsize	The number of dependants in the family	Continuous	±
Landslp	Slope of the land farmed (1 = flat 2 = gentle sloping 3 = sloping 4 = steep slope)	Categorical	+
Lndtnre	Land ownership (1=own land, 2= rent land 3= use common land) with or without title deed	Categorical	+
Proplnd_cult	The size or proportion of land the farmer cultivates to that land owned (acres/hectares/other)	Continuous	+
Grpnos	Number of groups a household belongs to	Continuous	+
Trainum	Access to agricultural training (Number of trainings)	Continuous	+
Lnexten	Log number of contacts with extension officers in a year	Continuous	+
Distmkt	Distance to market centres in (km)	Continuous	+
Off-farminc	The number of non-farming incomes a household is engaged in.	Continuous	+

Objective three: To determine the role of agricultural intensification on smallholder livelihood outcomes

This objective was analyzed using Multivariate Tobit model. Multivariate Tobit model originated from Tobit model which was formulated by James Tobin (1958). Multivariate Tobit model identified dependent variables determining the role of agricultural intensification on livelihood outcomes y: y = (HFCSGM, HFCSBM, PPI). The study was previously designed to use Household food consumption score for the good month (HFCSGM) and Household food consumption score for the bad month (HFCSBM) which were all used as a proxy for food security. Progress out of poverty index (PPI) which is the mostly used standard indicator of poverty, was also used (Hammond *et al.*, 2015).

Household food consumption score (HFCS) Tool is achieved as each food item is grouped and assigned weights as in Appendix 3. Within the 7 days period of the week, if a household ate on a daily basis each food group item, then a maximum score for that household is 112 and if none is eaten then a minimum score is 0. HFCS is important as it is related to health since it captures dietary quality and nutrient adequacy (WFP, 2008). PPI Tool uses 10 questions customized and translated for different countries; each answer is assigned a score. The sum of scores is taken to Lookup table which ranges from 0 (extremely poor) to 100 (not poor). The Lookup table can be used to determine the probability that the household is below the poverty line.

Probit and logit models could be used but they assume a dummy dependent variable taking the value of 0 (no adoption) and 1 (full adoption). This can lead to error of statistical measurements. Estimation of the model using OLS was not appropriate as OLS produce both inconsistent and biased estimates, because OLS reduces the slope by underestimating the true effects of parameters (Gujarati, 2003). Therefore, the maximum likelihood estimation was recommended for Multivariate Tobit analysis. According to Anastasopoulos *et al*. (2016), Ayuya (2018) and Xu *et al*. (2014) the normal Tobit model (Tobin, 1958) is less appropriate approach while analysing two or more dependent variables. Multivariate Tobit model was appropriately applied in this objective because dependent variables were censored. The Multivariate Tobit model accounts for simultaneous equation error correlation among the livelihood outcomes proxies (HFCSGM, HFCSBM and PPI).

The Multivariate Tobit model with three left-censored at zero dependent variables can be expressed as:

$$y_{ij} = x_{ij}\beta_j + \mathrm{u_{ij}} \text{ if } x_{ij}\beta_j + \mathrm{u_{ij}} > 0$$

$$y_{ij} = 0 \quad \text{if } x_{ij}\beta_j + \mathrm{u_{ij}} \le 0 \text{ , } i = 1, 2\ldots, \text{N and } j = 1, 2, 3 \text{.. (11)}$$

Multivariate Tobit model is best stated using latent equation as follows:

$$y^{*}_{ij} = x_{ij}\beta_j + \mu_{\mathrm{ij}} \text{ , ... (12)}$$

$y_{ij} = y^*_{ij}$ if $y^*_{ij} > 0$

$= 0$ if $y^*_{ij} \leq 0$, ... (13)

Where y^*_{ij} is a latent variable for the j^{th} livelihood outcomes intensity (1 through 3 for HFCSGM, HFCSBM, and PPI) for the i^{th} household that is observed only when positive, meaning for values greater than 0 and censored for values less than or equal to 0. The Multivariate Tobit model can be generalized to take account of censoring both from below and from above. x_{ij} is a vector of independent variables which are level of agricultural intensification, socioeconomic and institutional characteristics of smallholder farmers. The β_j is a parameter associated with the independent variables to be estimated. Where the error term μ_{ij} is assumed to be distributed normally with zero mean and a constant variance ∂^2: as μ_{ij} ~ N (0, 1) and μ_{ij} ~N (0, ∂^2), correlation (ρ).

The covariance matrix takes the form (Anastasopoulos *et al.*, 2016):

$$\Sigma_{\mu j} = \begin{pmatrix} \partial^2_{\mu_1} & \rho_{\mu_2\mu_1}\,\partial_{\mu_2}\,\partial_{\mu_1} & \rho_{\mu_3\mu_1}\,\partial_{\mu_3}\,\partial_{\mu_1} \\ \rho_{\mu_1\mu_2}\,\partial_{\mu_1}\,\partial_{\mu_2} & \partial^2_{\mu_2} & \rho_{\mu_3\mu_2}\,\partial_{\mu_3}\,\partial_{\mu_2} \\ \rho_{\mu_1\mu_3}\,\partial_{\mu_1}\,\partial_{\mu_3,} & \rho_{\mu_2\mu_3,}\,\partial_{\mu_2}\,\partial_{\mu_3} & \partial^2_{\mu_3} \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(14)}$$

Where μj represent the error terms of HFCSGM, HFCSBM, and PPI respectively

The density function of y_{ij} given the above error terms can be written as follows (Trivedi and Zimmer, 2005):

$$f_j\left(y_{ij} \middle| \beta^{'}_j x_{ij}\right) = \prod_{y_{ij}=0} \left[1 - \Phi\left(\beta_j x^{'}_{ij} \middle/ \partial_j\right)\right] \prod_{y_{ij}>0} \varphi \left[y_{ij} - \Phi\left(\beta_j x^{'}_{ij} \middle/ \partial_j\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots \text{(15)}$$

Where, Φ is the multivariate normal distribution function, and φ is the multivariate normal density function. The corresponding log-likelihood function for the Multivariate Tobit model is: $L_L\left[\left(y_1 | x_1; \beta_1\right), \left(y_2 | x_2; \beta_2\right), \left(y_3 | x_3; \beta_3\right); \omega\right]$

$$= \sum_{i=1}^{N} \sum_{j=1}^{3} \ln f_{ij}\left(y_{ij} | x_{ij}; \beta_j\right) + \sum_{i=1}^{N} D_{123}\left[F_1\left(y_{i1} | x_{i1}; \beta_1\right), \mathrm{F}_2\left(y_{i2} | x_{i2}; \beta_2\right), \mathrm{F}_3\left(y_{i3} | x_{i3}; \beta_3\right); \omega\right] \ldots\ldots\ldots \text{(16)}$$

Where, D_{123} (.) is the cross partial derivative for the function linking marginal variables into the multivariate distribution (Prokhorov and Schmidt, 2009; Trivedi and Zimmer, 2005), ω is the parameter which measures the dependence between the marginal.

Table 2. Variables to be used in the Multivariate Tobit Model

Variable	Description of the variables	Measurement	Expected sign
Dependent variables			
HFCSGM	Household food consumption score (0 ,......, 80)		
HFCSBM	Household food consumption score (0 ,......, 80)		
PPI	Progress out of poverty index (0,....., 100)		
Independent variables			
Lvagrintfc	Level of agricultural intensification (0, 1, ..., n)	Discrete	
Sbcty	Sub-county (1=Makueni 2=Nyando)	Binary	
Age	Age of the household head (years)	Continuous	±
Gend	Gender of the household head (1= male 0= female)	Binary	+
Educlev	Education level of the household head (1= Illiterate 2= literate 3= primary 4= secondary 5= post-secondary)	Categorical	±
Hhsize	The number of dependants in the family	Continuous	±
Landslp	Slope of the land farmed (1 = flat 2 = gentle sloping 3 = sloping 4 = steep slope)	Categorical	+
Lndmktpt	Land market partn (1= use own land exclusively, 2= use own and rented in or rent out land)	Binary	+
Proplnd_cult	The size or proportion of land the farmer cultivates to that land owned (acres/hectares/other)	Continuous	+
Grpnos	Number of groups a household belongs to	Continuous	+
Trainum	Access to agricultural training (Number of trainings)	Continuous	+
Lnexten	Log number of contacts with extension officers in a year	Continuous	+
Distmkt	Distance to market centres in (km)	Continuous	+
Off-farminc	The number of non-farming incomes a household is engaged in.	Continuous	+

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the results of the analysis of the data obtained. It has been subdivided into sections according to the objectives of the study. The discussion of results is presented while making a comparison of the findings with those of other studies.

4.1 Descriptive Statistics

Table 3. Farmers' usage of agricultural intensification practices (Percentage of farmers)

Intensification practice	Site	% of farmers using practice	% of farmers not using practice	Chi Square
Fertilizer	Wote	6	94	80.7768 ***
	Nyando	52	48	
Manure	Wote	78	22	4.1278**
	Nyando	86	14	
Compost	Wote	26	74	40.8631***
	Nyando	2	98	
Pesticides	Wote	61	39	34.1414***
	Nyando	29	71	
Hybrid seeds	Wote	69	31	15.2226***
	Nyando	87	13	
Ash	Wote	1	99	0.3365
	Nyando	2	98	
Irrigation	Wote	13	87	10.2130***
	Nyando	28	72	
Intercrop	Wote	96	4	13.8889***
	Nyando	84	16	
Legume fertilizer	Wote	100	0	8.2051***
	Nyando	95	5	
Vaccination	Wote	46	54	7.8644***
	Nyando	54	46	
Deworming	Wote	89	11	0.0321
	Nyando	89	11	
Antibiotics	Wote	67	33	0.4945
	Nyando	63	37	
Traditional	Wote	21	79	0.8696
	Nyando	25	75	
Spray/dip	Wote	53	47	1.5341
	Nyando	59	41	
Improved breed	Wote	7	93	53.1638***
	Nyando	40	60	
Agroforestry	Wote	47	53	25.9611***
	Nyando	20	80	

Table 3 presents the results of the relationship between farmers' usage of different agricultural intensification practices and study site. Results revealed a significant relationship between the study site and the level of usage of agricultural intensification practices. Regarding fertilizer application, the study revealed a significant difference in usage of this agricultural intensification practice between Nyando Sub-County and Wote Sub-County at a 1% significance level. The majority of surveyed households (52%) in Nyando Sub-County were using fertilizer as compared to their counterparts in Wote Sub-County (6%). The proportions of households not applying fertilizer in Nyando and Wote Sub-Counties were 48% and 94%, respectively. A high level of fertilizer usage in Nyando Sub-County may be due to low soil fertility levels in the area as compared to Wote Sub-County.

There was a significant difference in manure application between Nyando Sub-County and Wote Sub-County at a 5% level. Most of the farmers in Nyando Sub-County (86%) use manure compared to farmers in Wote Sub-County (76%). High level of manure usage in both study sites may be due to the fact that most farmers own livestock which is a source of manure. Generally, the results revealed low usage of compost manure in Nyando and Wote Sub-Counties. However, the proportion of farmers using compost manure was significantly (Chi-square= 40.8631, p>0.0000) higher in Wote Sub-County (26%) than Nyando Sub-County (2%). Farmers in Nyando Sub-County may be lacking the necessary skills and resources to make and store compost.

Pesticide usage was significantly higher in Wote Sub-County compared to Nyando Sub-County at a 1% level. The proportions of farmers applying pesticides in Wote and Nyando were 61% and 29%. The low level of pesticide usage in Nyando may be attributed to increased farmers' concern on health and environmental risk from chemical pesticides. These descriptive results also revealed that most of the farmers in Nyando (87%) and Wote (69%) use hybrid seeds. However, chi-square results show that the proportion of farmers using hybrid seeds in Nyando Sub-County was significantly higher than the proportion in Wote at a 1% level. A high level of hybrid seed usage in both sites may be due to increased farmers' awareness and exposure levels facilitated by disseminators of agricultural innovations.

The study results show a low application of ash in both areas. The proportions of farmers using ash as an agricultural intensification practice in Nyando and Wote were 2% and 1%, respectively, however, these results were insignificant between the two study sites. Irrigation helps in improving agricultural productivity thus ensuring sustainable food security and income generation among smallholder households. In this regard, only a few farmers were using irrigation in Nyando (28%) and Wote (13%). Chi-square results reveal a significant difference in the proportion of farmers using irrigation in Nyando and Wote at a 1% level. Nyando and Wote are dry areas with low annual rainfall which hinders irrigation production.

The study results revealed a significantly higher level of intercropping in Wote (96%) than in Wote (84%) at a 1% level. All sampled farmers in Wote were applying legume fertilizer as compared to 95% in Nyando. This shows that the majority of farmers in Wote significantly (Chi-square= 8.2051, $p>0.0000$) use legume fertilizer as compared to those in Nyando. A high level of application of legume fertilizer is attributed to increased dissemination efforts by different agencies to raise farmers' awareness of the agricultural intensification components. Livestock vaccination helps in protecting animals from diseases and pests attack, thus helps in ensuring good animal and human health and income generation. The results revealed a significant relationship between vaccination and study site at a 1% level. In other words, a higher proportion of farmers in Nyando (54%) were practicing vaccination as compared to the proportion in Wote (46%). There is a need to strengthen awareness campaigns and farmer extension on the role of animal vaccination. Results in Table 3 revealed that an equal number of farmers in Nyando and Wote were using deworming, antibiotics, traditional methods and spraying /dipping, thus there were insignificant results in their level of use.

The enlisted descriptive analysis revealed that a higher proportion of farmers were significantly keeping the improved breed in Nyando Sub-County (40%) as compared to their counterparts in Wote Sub-County (7%). Generally, few farmers keep improved breeds in Nyando and Wote Sub-Counties. The proportion of farmers not keeping improved breeds in Nyando and Wote was 60% and 93%, respectively. There is a need to train farmers on the role of breeding and genetics in livestock production.

The study revealed a significant relation between agroforestry and the study site at a 1% level of significance. Results showed that a higher proportion of farmers in Wote (47%) were practicing agroforestry as compared to those farmers in Nyando (20%). The proportions of farmers’ not practicing agroforestry in both Nyando and Wote were relatively higher at 53% and 80%, respectively.

Table 4. Mean and t-values of farm and farmer characteristics for continuous variables.

Variables	Wote		Nyando		Combined		
	Mean	**Sd**	**Mean**	**Sd**	**Mean**	**Sd**	**t-value**
Age of the household head	56.05	16.086	54.696	14.820	55.371	15.455	0.7846
Education of the household head	2.063	1.068	1.842	1.044	1.953	1.060	1.8636*
Household size	5.687	3.151	5.919	2.487	5.804	2.835	-0.7317
Land size	8.700	9.044	6.221	8.579	7.457	8.887	2.5193**
Distance to extension services	4.846	2.333	7.419	4.200	6.136	3.631	-6.7804***
Number of extension services	.794	1.166	.373	1.089	.583	1.146	3.3443***
Distance to the market	2.732	2.470	3.648	3.268	3.191	2.929	-2.8315***
Number of trainings	.875	1.263	.475	1.369	.675	1.330	2.7170***
Group participation	6.325	2.598	5.181	2.740	5.753	2.727	3.8316***
Group trust	7.356	2.506	6.425	2.962	6.891	2.779	3.0359***

Notes: ***, **, *, indicates significance level at 1%, 5% and 10% respectively

Table 4 presents the results of the mean age of household head, education years, household size, land size, distance to nearest extension services, number of extension services, distance to the nearest market, number of training, group participation and group trust. Overall, the average age of the household head was 55 years. The average age of farmers in Wote was 56 years while that of farmers in Nyando was 55 years. The t-test results indicate that there was an insignificant difference in the mean age of farmers in Nyando and Wote. Consequently, the results in Table 4 revealed that farmers in Wote had on average, significantly more years of formal education (2 years) compared to farmers in Wote (1 year) at a 10% level. This is an indication that farmers in Wote had higher levels of education thus much more informed to effectively search and interpret information related to the importance of modern agricultural production and marketing technologies.

The results also show that farmers in Wote and Nyando had an average number of 6 household members. However, the t-test results revealed that there was no statistically significant difference in the average number of household members in Nyando and Wote. Overall, the mean land size for sampled households was 7.45 acres. The average land size for farmers in Wote was 8.7 acres with a standard deviation of 9.044 while the average land size for farmers in Nyando was 6.22 acres with a standard deviation of 8.579 as shown in Table 4. Statistically, there was a statistically significant difference related to an average land size between farmers in Wote and Nyando at a 1% level of significance. This is an indication that farmers in Wote significantly have bigger farms size as compared to their counterparts in Nyando.

The average distance to the nearest market center was 3 kilometers. The results in Table 4 show that there was a significant difference in the mean distances to the nearest market center between the two groups (t-value= -2.8315, p>0.0000). The distance to the nearest market center is used as a proxy for access to market information as well as access to possible output markets. On average, farmers in Wote live closer to the market centers (3 kilometers) compared to those farmers in Nyando (4 kilometers).

The average distance to the nearest source of extension service was 6 kilometers for the whole sample. The results also showed that there was a statistically significant difference in the mean distance to the nearest source of extension services between Nyando and Wote (p =0 .0000). Averagely, farmers in Nyando had to travel approximately 7.4 Kilometres to the nearest source of extension service compared to 4.8 kilometers traveled by farmers in Nyando. Farmers in Wote live closer to the source of extension services compared to those in Nyando. Distance to the nearest extension center is used as a proxy for access to extension information. The study also revealed a significant difference in the mean number of extension visits between farmers in Nyando and Wote at a 1% level. Farmers in Wote significantly had a higher number of extension visits (0.794) as compared to their counterparts in Nyando (0.373).

Farmers in Wote significantly had higher cases of training (0.875) as compared to their counterparts in Nyando (0.475) at a 1% level. Better access to extension service and training serves as a source of agricultural production and marketing information which enables farmers to search and uptake new improved agricultural intensification practices. The t-test results also showed that there was a statistically significant difference in the mean number of group memberships between the two groups of farmers at a 1% level, as shown in Table 4. On average, farmers in Wote recorded the highest number of group memberships (6 groups) as compared to their counterparts in Nyando (5 groups). Similarly, groups' trust was significantly higher among farmers in Wote (7.35 units) compared to farmers in Nyando (6.42). Overall, the average group membership and trust for the whole sample was 6 groups and 7 units, respectively. A high level of group participation increases information sharing on agricultural intensification practices. It also increases bargaining power as well as reducing transaction costs by engaging in many social networks.

Table 5. Description of dependent and independent Variables to be used in the analysis

Variables	**Variable Description**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
(a) Dependent variables					
FCSGM	FCS for good month measured from 0, a food insecure HH to 80, absolutely food secure HH.	62.49	11.33	17.5	80
FCSBM	FCS for bad month measured from 0, a food insecure HH to 80, absolutely food secure HH.	49.54	14.45	9.5	80
PPI	Continuous from 0=low to 100=high probability of living below poverty line	51.14	14.66	18	93
(b) Independent variables					
Socio-economic characteristics					
Age of the household head	Age of household head (years)	55.28	15.40	22	103
Gender of the household head	Dummy = 1 if household head is male, 0 otherwise	0.75	0.43	0	1
Education level of the head	Categorical from 1=low to 5=high	1.96	1.05	0	4
Household size	Number of people in the household	5.82	2.83	1	23
Off-farm income	Household engaged in off-farm activity 1, 0 otherwise	0.92	0.27	0	1
Farm characteristics					
Land market participation	Whether household participate 1, 0 otherwise	0.57	0.21	0	1
Land slope	Categorical from 1=flat to 4=steep slope	2.00	1.08	1	7
Proportion of Land cultivated	Proportion cultivated to total land accessed	0.66	0.82	0.03	11
Institutional characteristics					
Distance to the market	Distance to agricultural product market (km)	3.20	2.93	1	20
Number of trainings	Number of agricultural trainings attended by hhh	0.68	1.33	0	11
Group diversity	Number of groups mature household members belong	2.17	1.98	0	18
Log extension number	Logarithm of extension services accessed per year	0.14	0.36	0	2.4
Site/Location	Dummy, 0=Wote or 1=Nyando	0.50	0.50	0	1

Table 5 presents the description of the dependent and independent variables used in the analysis. The average household food consumption score for a good month was 62.49 with a standard deviation of 11.33, and a minimum and maximum value of 17.5 and 80, respectively. Averagely, household food consumption score was relatively lower for bad months at 49.54 of 14.45 standard deviation, and minimum and maximum value of 9.5 and 80, respectively. Progress out of poverty index ranges from a minimum value of 18 to a maximum value of 93 with an average value of 51.14. The average age and education level of the household heads were 55.28 and 2 years, respectively. The majority of the sampled farmer were male farmers and largely engaged in off-farm income activities. More than half of the sampled farmers participated in land markets. The average land slope was recorded at 2 with a minimum and maximum value of 1 and 7, respectively. The mean proportion of cultivated land was 0.66 acres with a standard deviation of 0.82 while minimum and maximum value were 0.03 and 11 respectively. The average distance to the nearest market was reported to be 3.2 kilometres. The mean number of groups' mature household members (group diversity) was 2. The mean number of agricultural training attended by household heads was 1. The study sample was equally divided between the two study sites. Finally, the mean natural logarithm of extension services accessed by household head per year was 0.14 with a minimum and maximum value of 0 and 2.4, respectively.

4.1.2 Level of usage of agricultural intensification practiced by smallholder farmers

This objective is aimed at establishing the level of agricultural intensification practices used by smallholder farmers in the two sites. Agricultural intensification practices are grouped using the Principle Component Analysis which only select datasets explaining higher percentage of total variability. The last section of this objective clearly indicates similarities and differences in the level of usage of agricultural intensification practices among smallholder farmers in Nyando Sub-County and Makueni Sub-County.

From the result smallholder farmers in Makueni and Nyando Sub-Counties used 16 agricultural intensification practices in their farming systems. Some of these intensification practices were correlated with one another and Principal Component Analysis (PCA) was used to reduce these intensification practices into smaller number of principle components. Principal Component Analysis helps in reducing data dimensionality without loss of much information. This study has used Scree Plot test in choosing number of principle components, the aim of using PCA is to reduce the dataset and just using eigenvalues greater than or equal to one might give more components which are unreasonable. Table 6 shows principal components (PCs) and proportion of eigenvalues for each component.

Table 6. Eigenvalue proportion for each principal component

Component	Eigenvalue	Proportion (%)	Cumulative (%)
Comp1	2.90673	18.17	18.17
Comp2	2.09806	13.11	31.28
Comp3	1.54692	9.67	40.95
Comp4	1.24544	7.78	48.73
Comp5	1.10187	6.89	55.62
Comp6	1.03169	6.45	62.07
Comp7	0.91215	5.7	67.77
Comp8	0.83408	5.21	72.98
Comp9	0.81903	5.12	78.1
Comp10	0.69210	4.33	82.43
Comp11	0.65755	4.11	86.54
Comp12	0.60313	3.77	90.3
Comp13	0.45671	2.85	93.16
Comp14	0.43654	2.73	95.89
Comp15	0.35042	2.19	98.08
Comp16	0.30758	1.92	100

In Figure 3 below, a Scree Plot showing number of principal components on the x-axis and the eigenvalues on the y-axis. The point at which the slope turns from a steep slope to a gentle slope gives the number of principal components to be generated by the analysis. The components on the steep slope were extracted, it converted the original set of 16 practices into a smaller set of 5 linear combinations called principal components. The remaining components were dropped because they explained very little variation of the original variables.

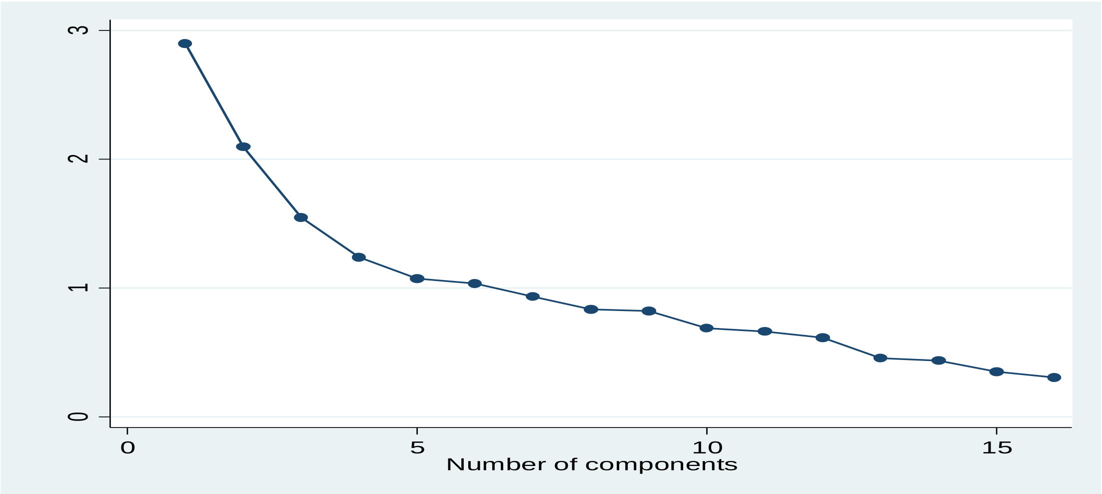

Figure 3. Scree plot of Eigenvalues

The reduced dataset of 5 principal components explains 56% of the total variability meaning the PCA results explain the data well. The very first component explains 18% variance. The second principal component explains 13% of the variation. Principal component 3 explains 10% variation, while principal components 4 and 5 explain 8% and 7% of the total variations respectively as shown in Table 6. The remaining components continue to explain less and less variation in the data hence dropped.

Table 7 shows loading of the five principal components given the level of agricultural intensification practices and their coefficients of linear combinations called loadings. The components where each practices falls are in bold.

Table 7. Loadings of the five components for agricultural intensification practices

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Fertilisers	0.1791	**-0.4600**	0.0497	0.1676	0.0089	0.4238
Manure	**0.4030**	0.0455	-0.2424	0.1008	-0.2430	0.3550
Compost	-0.2178	0.1294	0.4145	**-0.4574**	0.1863	0.2624
Pesticides	0.2620	0.2335	**0.2746**	-0.0875	0.1755	0.5260
Hybrid_Seeds	0.1309	-0.2488	0.3844	0.1280	**-0.3989**	0.3960
Ash	-0.0146	-0.0032	0.0680	0.4004	**0.5495**	0.4598
irrigation	0.1522	0.0222	**0.3340**	0.2337	0.2178	0.6387
intercrop	-0.0149	**0.4950**	0.0268	0.3032	-0.2609	0.2947
agroforestry	0.0772	0.1988	**0.4652**	-0.0595	0.0080	0.5606
legume_fert	-0.0065	**0.3743**	0.0738	0.3210	-0.3174	0.4581
impr_breed	0.2468	**-0.4044**	0.1714	0.1438	-0.0091	0.4086
Vaccinations	0.2752	-0.0402	**0.2818**	-0.0919	-0.2268	0.5863
Deworming	0.2947	0.0183	-0.0080	**-0.4386**	-0.1053	0.4950
Antibiotics	**0.4506**	0.1728	-0.1417	-0.1886	0.1222	0.2555
Traditional	0.2592	0.1288	0.0784	0.2218	**0.2786**	0.6137
Spraydip	**0.3860**	0.1269	-0.2646	-0.0935	0.2070	0.3668

Table 8 shows the composition of each component from the greatest weight to the lowest. The first principal component was livestock treatments and its product for soil nutrient improvement used by 86% of farmers and was related to use of manure, antibiotics and spraying/dipping. The second principal component was technology oriented practices applied by 99% of all smallholder farmers and was associated with fertilizer application, intercropping, improved breeds and use of legume as an intercrop or rotation. The third principal component which was farm risk reduction practices comprised of pesticides application, irrigation, agroforestry and vaccination and practiced by 79% of farmers, while principal component four was routine farm practices applied by 90% of farmers and comprised of compost and deworming. Finally, the fifth principal component included improved seed varieties and traditional farm techniques practiced by 83% of farmers who used hybrid seeds, ash in farms and traditional methods of livestock treatment.

Table 8. Combinations of agricultural intensification practices

Group	Percentage of users	Components
Livestock treatments and its product for soil nutrients improvement	86	Manure Antibiotics Spraying/dipping
Technology oriented practices	99	Fertilizer Intercrop Legume (intercrop/rotation) Improved breeds
Farm risk reduction practices	79	Pesticides Irrigation Agroforestry Vaccination
Routine farm practices	90	Compost Deworming
Improved seed varieties and traditional farm techniques	83	Hybrid seeds Ash Traditional

The results in Table 9 below further shows that there was a significant difference of farmers who applied component 1 (group 1) practices at 1% level of significant as more farmers in Nyando practiced component 1 than those in Wote. This was attributed by the fact that farmers in Nyando owned more livestock hence more manure and likelihood of Acaricide (spraying and dipping) use. Manure was highly used by farmers in both Wote and Nyando Sub-Counties. In Table 1, there was 10% level of significant difference in manure usage in both Wote and Nyando Sub-Counties at 78% and 86% respectively. For component 2 there was no significant difference on farmers who used these practices as almost all farmers from Wote and Nyando used it. There was also no significant difference on smallholder farmers in Wote and Nyando who used component 3 and 4.

The use of component 5 has 1% level of significant difference between smallholder farmers in the two Sub-Counties. Farmers using component 5 in Wote Sub-County and Nyando Sub-

County were 75% and 91% respectively. This difference might have been caused by use of hybrid seeds which was significant at 1% significant level in Table 3 between the two sub-counties where 69% of farmers in Wote adopted the use of hybrid seeds while 87% of smallholder farmers in Nyando used hybrid seeds. Table 9 below shows farmers' usage of group of agricultural intensification practices.

Table 9. Farmers' usage of group of agricultural intensification practices (%)

Variables	Site	Using practice	Not using practice	Chi Square
Treatment	Wote	82	18	6.7457***
	Nyando	92	8	
Technology	Wote	100	0	2.0126
	Nyando	99	1	
Risk	Wote	83	17	2.6891
	Nyando	75	25	
Routine	Wote	92	8	0.5556
	Nyando	89	11	
Seed and Traditional	Wote	75	25	13.7221***
	Nyando	91	9	

***Represent 1% level of significance

In general all farmers in Makueni and Nyando Sub-counties embraced at least one level of agricultural intensification practice.

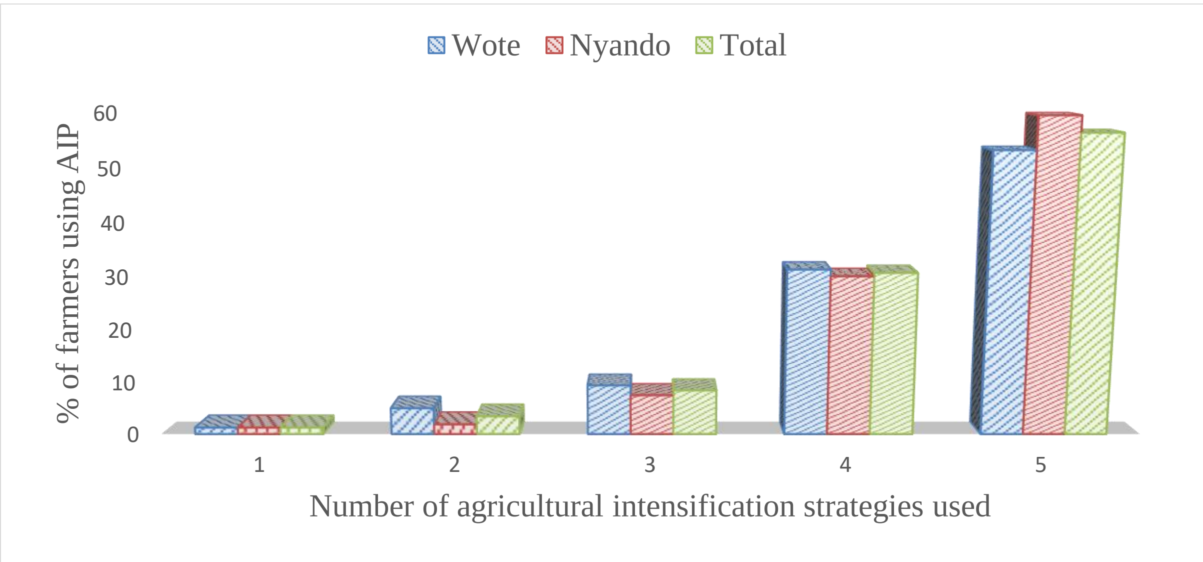

Figure 4. Farmers level of agricultural intensification practices (AIP) used

The result in Figure 4 shows that 56% of farmers used 5 level of agricultural intensification practices while 31%, 8%, 4% and 1% of farmers' used 4, 3, 2 and 1 levels of agricultural intensification practices respectively. Level of agricultural intensification practices used by smallholder farmers is compared between the two sites. The t-test and chi square were statistically tested to determine if there was any significant difference between the study sites as presented in Table 9.

The results in Figure 4 further revealed that 53% of farmers in Wote Sub-County used all 5 groups of intensification practices compared to 59% of farmers in Nyando Sub-County. In each of these counties 1% of farmers used only 1 component of intensification practices this was due to the fact that group 2 level of intensification was almost practiced by every farmer who might have adopted zero level of intensification. For farmers who practiced two groups of intensification, Wote farmers had the highest level of 5% than their Nyando counterparts with the level of 2%. Three levels of agricultural intensification practices were practiced by 9% of farmers in Wote Sub-County and 8% of farmers in Nyando respectively. 31% and 30% of rural smallholder farmers in Wote and Nyando Sub-Counties used 4 levels of agricultural intensification practices.

4.2 Effect of socioeconomic and institutional characteristics on the level of agricultural intensification among smallholder farmers

In this objective, socioeconomic, farm and institutional characteristics which considerably affect smallholder farmers' level of usage of agricultural intensification practices are estimated using Poisson regression model. Poisson model allows for modelling of count data and the intensity can be assessed by using less or more techniques/practices as farmers may decide to use more, less or none of the intensification practices. In the first section, the regressors were tested for the multicollinearity and heteroscedasticity. Negative Binomial Regression was also used to confirm whether there was over-dispersion but alpha test was not significant. Factors which were significantly affecting farmers' level of agricultural intensification practices were discussed from the Poisson regression model results.

4.2.1 Preliminary diagnostics of the predictor variables to be used in the econometric analysis

In this section, the problem of multicollinearity and heteroscedasticity were tested on the socio-economic, farm and institutional variables. According to Wooldridge. (2013), multicollinearity is a state of high correlation between two or more explanatory variables. Multicollinearity test was conducted for continuous independent variables using variance inflation factor (VIF) and for categorical independent variables using pair-wise correlation. The variance inflation factors result values were tabulated in Table 10 below. From the results VIF values were less than 10 this confirms that regression coefficients were properly estimated as VIF values between 5 and

10 indicates high correlation and above 10 confirms a very high multicollinearity among independent variables and as a rule of thumb this occurs when R^2 exceeds 0.90 (Gujarati, 2003). Results of pair-wise correlation presented in Table 11 equally presented that no high linear relationship exist among categorical explanatory variables as indicated by coefficients of less than 0.5.

The results of Table 10 and 11 clearly shows that there was no high correlation or strong relationship among all independent variables. In this regard, all the proposed potential independent variables were used in regression analysis. Both Breusch-Pagan and White test for Heteroskedasticity were used to look for the evidence of association between the variance of the disturbance term and the explanatory variables without assuming any specific relationship.

Table 10. Variance inflation factor test results for continuous independent variables

Variable	VIF	1/VIF
Log value of extension number	1.79	0.5581
Number of training attended	1.77	0.5640
Group diversity	1.06	0.9463
Household size	1.05	0.953
Proportion of land cultivated	1.04	0.9619
Age of the household head	1.03	0.9681
Distance to the market	1.02	0.9802
Mean VIF	1.25	

Table 11. Pair-wise correlation test results for categorical independent variables

	site	gender	educ	land_tenure	land_slope	Offincome
Sub-county (site)	1.0000					
Gender of the household head	-0.0289	1.0000				
Education level of the head	-0.0951	0.5149	1.0000			
Land tenure	0.2189	0.0044	-0.0336	1.0000		
Land slope	-0.0756	0.0067	0.0252	-0.0421	1.0000	
Off-farm income	0.0116	0.1008	0.0330	0.0690	-0.0433	1.0000

Table 12. Test for Heteroskedasticity

Type	chi2	df	P
White test	78.06	101	0.9562
Breusch-Pagan test	28.51***	1	0.0000

***Represent 1% level of significance

The results presented in Table 12 above present result for heteroskedasticity test. White test results indicated that the model was homoscedastic implying that the variance of the error term was constant hence we failed to reject the null hypothesis of homoscedasticity. In contrast, the Breusch-Pagan test result for homoscedasticity as indicated by a chi2 value of 28.51 and a p-value of 0 suggested presence of heteroskedasticity an indication that heteroskedasticity might be linear. Based on Breusch-Pagan result, the null hypothesis of homoskedasticity was rejected a conclusion that the model was heteroskedastic. This problem was solved in the subsequent analysis by using robust standard errors.

4.2.2 Intensity of agricultural intensification practices among smallholder farmers in Makueni and Nyando Sub-counties

The intensity of agricultural intensification practice was measured using the number of agricultural intensification practices (components) generated by the Principal Component Analysis. The results in objective one indicated that the number of components of users was ranging between 1 and 5. That is from low users of strategy 1, partial users of 2, 3 and 4 to full users of 5.

Agricultural technologies have diverse components which farmers could fail to practice, partially practice or fully embrace. This situation can be best handled by the Poisson regression or Negative binomial regression model. These count models have the capacity to estimate the effect of socioeconomic and institutional characteristics on the level of agricultural intensification among smallholder farmers whether on the probability of one or multiple events as well as no events (Agula *et al*., 2018). For the purpose of this study, each component of agricultural intensification practices was assessed as a discrete technique.

Factors influencing the level of agricultural intensification among smallholder farmers was determined using Poisson model given the dependent variable was a count data. The intensity was modelled as the number of techniques/strategies practiced out of a maximum of five. Table 13 present the results for the Poisson regression model. The results of the Poisson regression indicated that Pseudo R2 was high, the data fitted the model well because chi-square was highly statistically significant at 1 percent. This implied that smallholder farmers in these two sub-counties intensifying agricultural practices were determined by the set of explanatory variables in the model. The rate ratios were represented by the coefficients while marginal effects captures the intensity impact of each explanatory variables (Pedzisa *et al*., 2016). A further confirmation with The Negative Binomial Regression showed in Appendix 7 helped in determining whether there was over-dispersion problem. The results revealed that the likelihood ratio test for alpha equals to zero and the test for alpha (Prob >= chibar2 = 1.000) was not significant. This indicated that there was no over-dispersion an evidence that the conditional mean was equal to the conditional variance hence Standard Poisson model was appropriate.

Table 13. Standard Poisson regression model results

Variables	Coefficients	Robust Standard Errors	Marginal Effect (dy/dx)
Socio-economic characteristics			
Age of the household head	0.0012	0.0008	0.0053
Gender of the household head	0.0647**	0.0328	0.2821
Education level of the head	0.0197	0.0133	0.0859
Household size	0.0046	0.0044	0.0202
Off-farm income	-0.0607*	0.0316	-0.2645
Farm characteristics			
Land tenure	0.0958***	0.0161	0.4175
Land slope	0.0190**	0.0077	0.083
Proportion of Land cultivated	-0.0166***	0.0051	-0.0723
Institutional characteristics			
Distance to the market	-0.0085**	0.0041	-0.037
Number of trainings	0.0045	0.0128	0.0195
Group diversity	0.0148***	0.0056	0.0645
Log extension number	-0.0049	0.0343	-0.0213
Sub-county (Site)	0.0500**	0.023	0.218
Constant	1.1244***	0.0873	
Number of obs = 320			
Wald chi2(13) = 72.69			
Prob > chi2 = 0.0000			
Pseudo R2 = 0.6572			
Log pseudolikelihood = -560.31775			

*, **, ***Represent 10, 5 and 1% levels of significance respectively

The results in Table 13 indicates that the socioeconomic and institutional characteristics that significantly affected the level of agricultural intensification among smallholder farmers included gender of the household head, land tenure, slope of the land, participation in off-farm employment, distance to the market, group diversity, Log number of extension visits, and proportion of land cultivated. The sub-county where farmers resided also significantly affected the level of agricultural intensification practices.

Gender of the household head was positive and statistically significant at 5 percent revealing that it is associated with higher level of agricultural intensification practices. The results indicated that male headed households were more likely to intensify than their female headed household counterparts. This can explained from the cultural and social settings of African people where land resources and large livestock are controlled and owned by men. Male headed households are regarded as dominant inherited most land from their forefathers giving them exclusive rights to make major agricultural decisions. This concurs to Mugi-Ngenga *et al*. (2016) finding that men are more likely to access and control resources which are fundamental in agriculture due to socio-cultural and customs. According to Odendo *et al*. (2009), male headed households have a higher probability of fertilizer use and other intensification combinations than female headed ones because they are more likely to access resources and information regarding technology. According to Ndiritu *et al*. (2014) adoption of certain intensification practices require some resources like more labour, knowledge, livestock, credit among others of which female households may lack them in adequate amounts.

Land tenure was positively associated with the level of agricultural intensification practice at 1% level of significance. The marginal estimate of land tenure indicated that a unit increase in land tenure index will increase the level of agricultural intensification by 42%. The finding is so because those who own the land will take care of the land protecting it from any form of degradation as they are assured of using it for lifetime and for the generation to come. Land owners will invest on their land to make it more productive even for future use. Those who rent in land do not normally invest in land as they are aware that future returns might be beneficial to someone else. A previous study by Baba *et al*. (2017), reported farmers positive impact on adoption of mulching and mixed agroforestry measures on their own farms. This confirms the Marshallian inefficiency hypothesis where tenants on borrowed and rented land use inputs less efficiently than land owners.

Level of agricultural intensification was further influenced by the slope of land cultivated or used by the farmer. Land slope was significant at 5 percent. Steeper land can be easily eroded so farmers will increase the intensity to protect soil erosion by using agroforestry among other agricultural intensification practices. Farmers will also reclaim the already depleted soil by adding more nutrients to the soil for crops grown in these regions, this may be in the form of manure, compost or fertilizer application. This finding is consistent with Clay *et al*. (2016) who argued that steeper slopes encourage farmers to invest in practices helping in protecting the land from erosion.

Participation in off-farm employment was negatively associated with level of agricultural intensification and significant at 10 percent. The marginal estimate for off-farm income indicated that one additional off-farm employment leads to 26% decrease in the level of agricultural intensification. This implied that farmers who engage in off-farm income generating activities were more likely to use less intensification practices or low level of agricultural intensification practices. This finding is consistent with (Manda *et al*., 2016) who found that access to off-farm income leads to decrease of some sustainable agricultural practices packages. This finding is also in line with Mathenge *et al*. (2014), who argued that farmers who are occupied in off-farm income generating activities will spend less of their time and effort on farm activities. Farmers who engage in off-farm generating activities will divert most of their time and effort away from agricultural activities leading to relatively low investment in intensification practices and less labour allocation on farm. Amare *et al*. (2012), also found that household head whose primary occupation is farming have better access to improved maize seed than their counterparts.

Distance to the market was negative and significant at 5 percent. The marginal effects shows a 3.7% decrease in level of agricultural intensification for a one kilometre increase from the market. Farmers who were closer to the market were likely to invest in most of the farm technologies because farmers closer to input traders incur less transportation cost as in the case of fertilizer and improved seeds. This result is in line with Shiferaw *et al*. (2014), who found that adoption is negatively associated with the distance to seed dealers. Teklewold *et al*. (2013), also found that input market distance has a significant negative effect on farmers improved seed adoption due to high transaction costs. Market centres are also associated to information sources as most NGO, government offices, community based organization as well as faith based offices are often situated in the market. This helps in reducing information asymmetry to farmers closer to the market and in case of new technology or new method of input application they will be the first to get the information. Closer to the market also allows for access to varieties of input products as promoters of certain inputs may give free trials or sell their products at a lower cost to farmers who might find the product to be very effective and use it consecutively. According to Yitayih *et al*. (2016), households near district centres are more successful adopters than those who live far. The infrastructure is poorly developed and those who live far from the market incur high transaction costs to acquire inputs and access output markets which decrease profitability of intensification leading to its lower uptake.

Group diversity was positively associated with level of agricultural intensification practices at 1 percent significant level. Marginal effects revealed that one additional group membership by a household leads to 6.7% increase in the level of agricultural intensification. This can be attributed to the fact that in groups, apart from their main activities farmers always share their challenges and opportunities in farming and through this they learn, advice one another as well as sharing important ideas which leads into members engaging in agricultural intensification. Participating in farmers' groups helps in sharing experiences and exchange of information about new agricultural technologies (Kassie *et al*., 2011). According to Cunguara and Darnhofer, (2011), a household whose members belong to farmers association were more likely to use improved farm technologies. The reason being discussion among farmers reduce information asymmetry. The more the number of groups a household is in, the more the sharing of information, gaining knowledge which leads to increase in the level of agricultural intensification practices. Groups promote social networks which can also contribute to other benefits leading to access of finance and inputs to its members as well as serving as informal insurance in time of emergency (Kassie *et al*., 2015). Social capital according to Khonje *et al*. (2015), is helpful to farmers in accessing inputs, input credit, savings and credit, soil and water conservation among others. All these are easily accessible if farmers belong to groups or cooperatives.

Proportion of land cultivated was found to be significant at 1 percent. The marginal estimate for land cultivated indicated that one acre increase of cultivated land by a smallholder farmer leads to 7% decrease in the level of agricultural intensification. A negative relationship observed between proportion of land cultivated and level of agricultural intensification practices supports the hypothesis that farmers with less cultivated land, dedicate their time and effort to maximize any form of intensification practice to get more produce from the small cultivated land. Small plot is easy to manage by a smallholder farmer than a large plot or many plots. This could be due to resource constraints which can be human resource in form of family labour or financial resource to aid in other input investments. Farmers who kept livestock in these areas had on average small herds of ruminants or even poultry, which might not produce enough manure to apply in large cultivated plots. In both sub-counties manure is not sold but can be given freely by a neighbour who might not also have adequate amount. This result is in contrast with (Manda *et al*., 2016) who found that households with large tracks of land are likely to adopt sustainable agricultural practices than those with less land or small tracks of land. Most smallholder farmers who used inorganic fertilizers and hybrid seeds did not have the capacity to apply these inputs in every plot or in all cultivated plots, they normally applied them in one plot or in a proportion of the farm. This finding is in line with (Leigh *et al*., 2014) who stated that farmers with greater landholdings use less fertilizer per hectare, as they are likely to farm less intensively than their counterparts with less land. Farmers who keep few livestock are likely to manage pests and diseases more easily and efficiently than those with many. This finding differs with Shiferaw *et al*. 2014 and Wu *et al*. (2010), who argued that farmers with more land are likely to cultivate a larger proportion of land and are more likely to adopt new technology. On the other hand, Idrisa *et al*. (2012), further argued that adopters being successful might have increased their scale of operation by cultivating a higher proportion of their land.

Furthermore, level of agricultural intensification practices was found to vary across different (agro-ecological zones) sites. Sub-county dummies in the model were found to be statistically significant at 5 percent. The marginal effect show that the level of agricultural intensification in Nyando Sub-county was 22% higher than that in Makueni/Wote Sub-county. Taking Makueni Sub-county as a reference, smallholder farmers in Nyando Sub-county had relatively higher probability of using higher level of agricultural intensification practices than their Makueni counterparts. Smallholder farmers in different agro-ecological zones use different intensification techniques because they are in different climatic conditions, soil type, and land slope among other factors. Those in highlands are likely to use more of soil and water conservation measures than those in lowlands. Same results were found by (Seifu, 2016).

4.3 The effect of agricultural intensification on smallholder livelihood outcomes

Livelihood outcomes in this study were poverty and food security and these were measured using two indicators, Progress out of Poverty Index/Poverty Probability Index (PPI), and Household Food Consumption Score (HFCS). This objective looked at the smallholder farmers' poverty status and food security situation both in the food secured months and the food insecured months of the year which differs between the two sites. Food secured month is a period just after harvest where most foods are available to respondents in adequate quantity while insecured month is a period of the year before harvesting and food is scarce to respondents. This objective therefore used Multivariate Tobit Model in determining the effect of agricultural intensification on smallholder farmers' poverty status and food security both in the good month and the bad month of the year.

4.3.1 The Food secured months and Food Insecured months of the Year

The two sites of the study differs in seasonality even though they both have two rainy seasons in a year, but harvesting in both sub-counties is normally experienced once in one major season of the year. In Nyando Sub-County the best month is August when most crop harvesting take place and its worst month is April, while in Makueni/Wote Sub-County the best month is February and its worst months are November and December respectively. These are shown in figure 5 to 8 below.

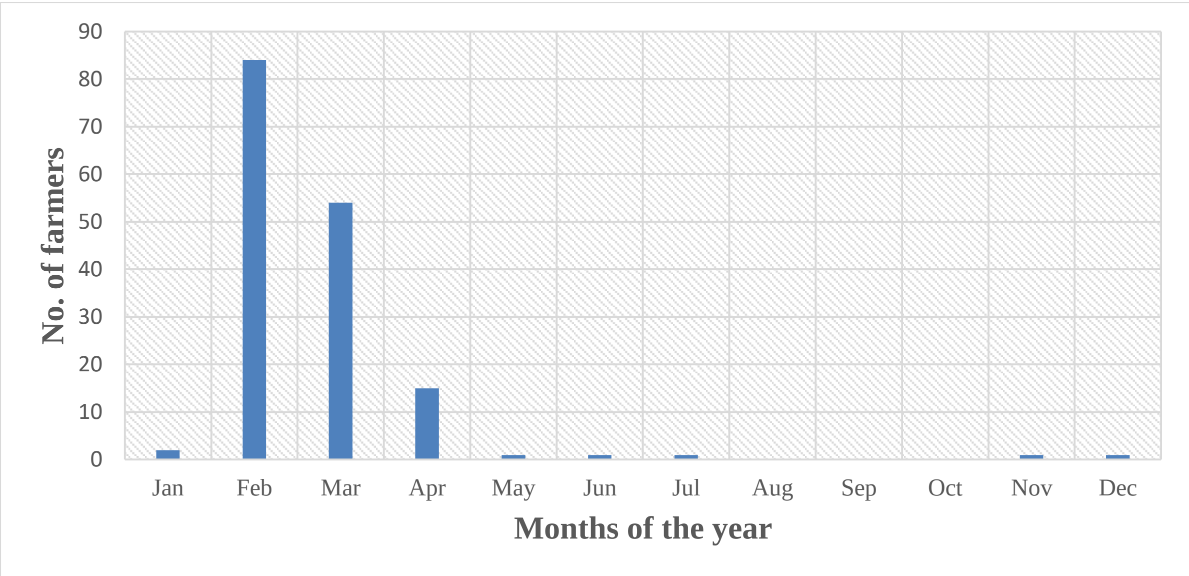

Figure 5. Makueni/Wote Sub-County food secured month

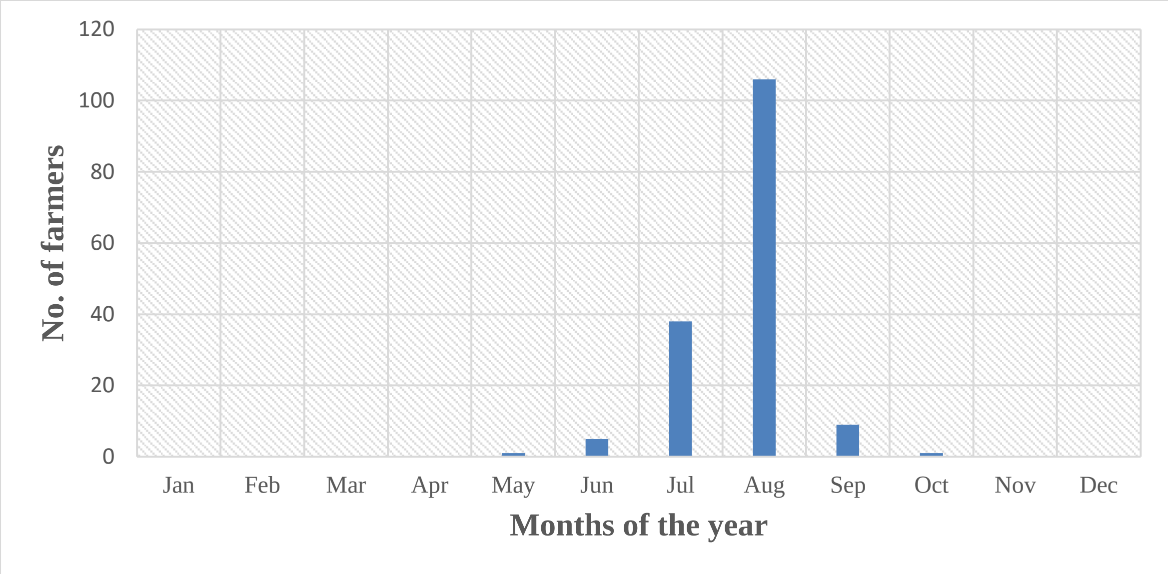

Figure 6. Nyando Sub-County food secured month

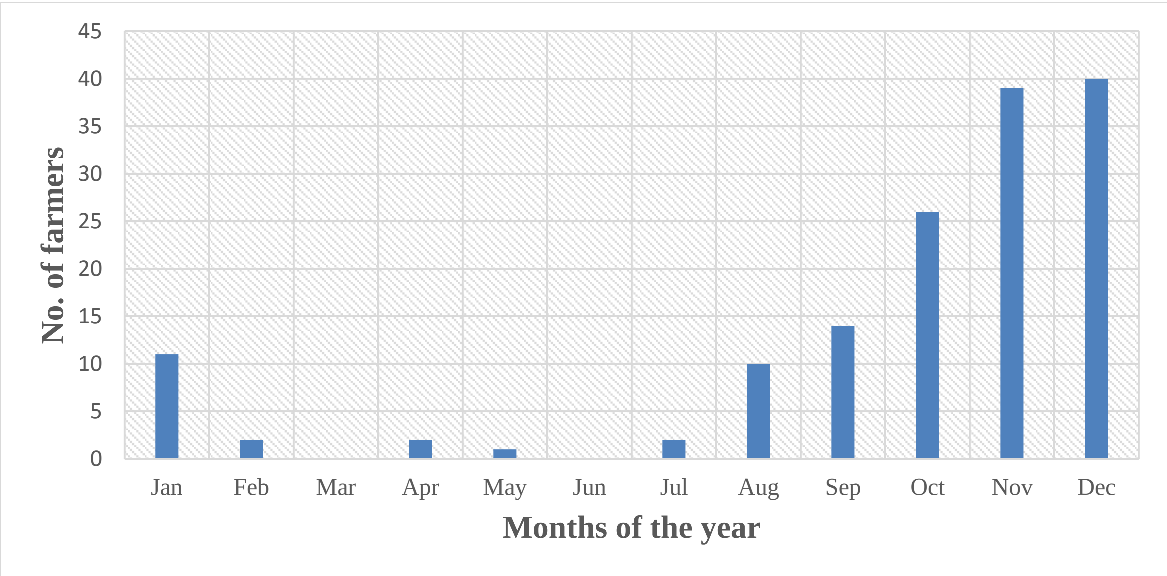

Figure 7. Makueni/Wote Sub-County food insecured month

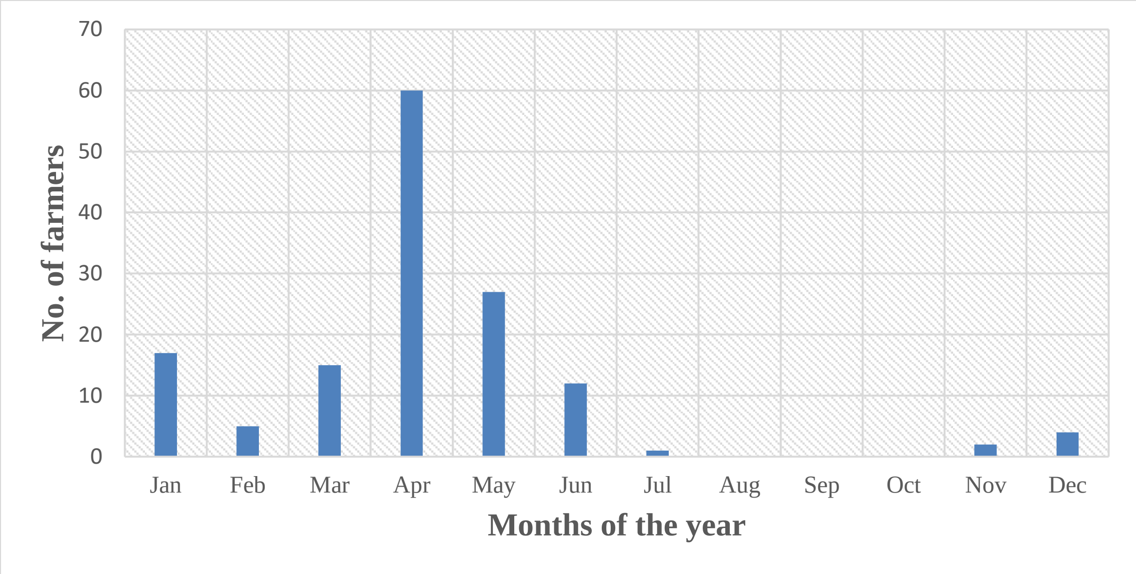

Figure 8. Nyando Sub-County food insecured month

4.3.2 Progress Out of Poverty Index/Poverty Probability Index (PPI)

The study used PPI to measure the extent of poverty in the two selected sites of Wote/Makueni and Nyando Sub-counties. This study used the international US$ 1.25 per day poverty line (Ravallion, 2013). The US$ 1.25 which is the global common poverty measure which considers exchange rates and currency differences and is measured in economic unit called Purchasing Power Parity not in dollars (Grameen Foundation, 2018). It is used by international agencies, donors, many Non-governmental organizations as well as microfinance institutions. PPI scores in Appendix 6 were added and the scores were from 0 to 100. Zero (0) meant the household was most likely to be below the poverty line while 100 meant least likely below a poverty line/unlikely to be poor. Poverty likelihood score card in this study was used to estimate the probability that a particular farm household had a per-capita income below poverty line and it can also be adopted in estimating the poverty rate of a group of farm households at a point in time.

PPI scores were converted using look-up table in Table 14 below to poverty likelihoods which is the probability that a household is below the poverty line. This was due to the fact that poverty is multidimensional. A household with a PPI score of 82, according to the look-up table for the PPI for Kenya, that household had a 0.1% likelihood or probability of living below the $1.25 per day, meaning this household was well off and was probably living above the poverty line. A household with a PPI score of 20 according to look-up table had 81.9 % probability of living below the $1.25 per day implying that the per capita income is far below the poverty line and are not in a position to afford the basic necessities of life.

Table 14. Look-up tables, Progress out of Poverty Index (PPI) for Kenya

PPI Score	$ 1.25 per day
0-4	100.0
5-9	97.5
10-14	86.2
15-19	86.0
20-24	81.9
25-29	70.1
30-34	63.1
35-39	49.0
40-44	35.1
45-49	24.9
50-54	9.6
55-59	6.8
60-64	1.4
65-69	0.8
70-74	0.1
75-79	0.1
80-84	0.1
85-89	0.0
90-94	0.0
95-100	0.0

Source: *Kenya's 2005/06 Integrated Household Budget Survey by Mark Schreiner of Microfinance Risk Management, L.L.C. Retrieved from* www.progressoutofpoverty.org.

4.3.3 Household Food Consumption Score as a proxy for measuring Food Security

The study used the adjusted Household Food Consumption Score (HFCS). The seven days recall of the World Food Program (WFP) was used for standardization and for comparison. The Food Consumption Score of the WFP applies dietary diversity of the food groups and the food frequency for number of days each food group was consumed within a week, this is according to Comprehensive Food Security and Vulnerability Analysis Guidelines (CFSVA). It is a fact that HFCS does not necessarily reflect the food security situation of the household as the CFSVA base its data collection on the current food security which is a short term classification, relying on the past seven days food consumption which might be influenced by seasonal factors, food aid among other factors (Headey and Ecker, 2013).

This study used different data collection method and analytical strategy which deviates from world food program (Kennedy *et al*., 2010; Headey and Ecker, 2013). RHOMIS used dietary diversity of food groups and the same weighting system as used in WFP was maintained except asking how frequent these foodstuffs were consumed within a month or four weeks period in good season and in bad season (Hammond *et al*., 2015). The response are in 'daily', 'weekly', 'monthly', or 'never'. This approach might give a lower accuracy than a seven day recall but it takes consideration of seasonality of some food items to avoid biasness as well as to capture household food security at all times of the year allowing for seasonal variation. Appropriate locally consumed foodstuffs were chosen in each location (Silvia *et al*., 2015: Rufino *et al*., 2013). The calculations of HFCS in this study were made using a modification of World Food Program (WFP) table in Appendix 3.

The frequency scores for ‘daily’ was 5, ‘weekly’ was 1.5, ‘monthly’ was 0.25 while ‘never’ was 0. Using these frequencies, the maximum HFCS for the good month had a total of 80 and the maximum for the bad month also had a total value of 80 which could only be realised if a particular household ate each food group on daily basis for the last one month. Lower score means food insecure household while higher score means food secure household.

HFCS calculations in this study followed the WFP instructions in most aspects but departed from the standard advice in terms of reference time period. The seven days recall period which can be very helpful in conducting Emergency Food Security Assessment. It can also be useful when the sites considered have the same characteristics like seasonality, and having the same harvesting period. But in a case where data is to be collected in a particular period for various sites at almost the same time like my study Sites Makueni and Nyando Sub-Counties, generalization and restriction of HFCS to seven days recall is biased, this is what most researchers do (Kennedy *et al*., 2010).

The use of good and bad season or month is appropriate because households normally know their food consumption patterns (Hammond *et al*., 2015). HFCS is a qualitative measure of dietary and nutrient intake by the household which is less costly and less time consuming to collect (Kennedy *et al*., 2010).

4.3.4 Determining the effect of agricultural intensification on smallholder livelihood outcomes

Diagnostics Statistics

To determine the effect of agricultural intensification practices on smallholder livelihood outcomes, Multivariate Tobit model was used for analysis. Table 15 below shows the results of Multivariate Tobit Model. The dependent variables are PPI, Household Food Consumption Score (HFCS) for the Good month and for the Bad month. Tests for the goodness of fit indicated that the data fits the model reasonably well. The Wald test (Wald chi-square (40) = 208.13; Prob = 0.0000) that all regression coefficients are jointly equal to zero is rejected. Meaning all independent variables are statistically significant. The Likelihood Ratio Test (LR

Test: chi-square (3) = 103.479, Prob > chi-square = 0) compares this model to other alternative models which is the individual Tobit models for three regressions. The LR Test is highly significant at 1% level, meaning the data fits Multivariate Tobit Model well.

This study estimated both the food secured months and the food insecured months household food security using HFCS as a function of household socio-economic, farm and institutional characteristics as well as level of agricultural intensification. The results from Table 15 indicated those factors which significantly influenced household food security both for good and bad months/seasons include location site, household size, number of trainings, group diversity, proportion of land cultivated while intensification level and distance to the market only affected food security during bad seasons whereas age of the household head only affected food security during good seasons. Estimate of factors influencing poverty status of smallholder households was not as robust as those affecting food security of the same households. This was because in poverty regression some variables were dropped because they were used to generate poverty scores. These variables were education level of the household head and household size which could have caused reverse causality where the dependent variable could be a function of independent variable. Not excluding such variables would lead to endogeneity problem meaning the estimates can be biased causing underestimation or overestimation.

Table 15. Results of the Multivariate Tobit Regression for Household Food Consumption Score and Progress out of Poverty Index

Variables	HFCS (Good Month)		HFCS (Bad Month)		Poverty Likelihoods	
	Coefficients	**Robust Std. Err.**	**Coefficients**	**Robust Std. Err.**	**Coefficients**	**Robust Std. Err.**
Socio-economic characteristics						
Age of the household head	-0.0862*	0.0467	-0.0491	0.0558	0.1565***	0.0758
Gender of the household head	-1.4947	1.4321	-0.5686	2.0724	-2.2632	3.0323
Education level of the head	-0.4449	0.7266	0.4966	0.9009	–	–
Household size	0.7238***	0.1857	0.5684*	0.3126	–	–
Off-farm income	0.0755	2.2835	0.0435	2.8368	4.2645	3.8346
Farm characteristics						
Land market participation	-4.2764**	1.7500	-2.5607	1.8609	-2.2675	2.9261
Land slope	-0.6352	0.5858	-0.8535	0.6398	1.4949	1.0560
Proportion of Land cultivated	1.6992***	0.4832	2.1389**	0.8468	-2.7583*	1.5255
Institutional characteristics						
Distance to the market	0.2072	0.1881	1.0056***	0.2484	-0.3572	0.4409
Number of trainings	-0.8749*	0.4942	-1.4865**	0.7599	1.4765	1.1426
Group diversity	1.0104***	0.2849	1.2824***	0.3550	-1.7200**	0.5137
Sub-county (site)	3.4004***	1.3273	9.1319***	1.7094	3.8703	2.8155
Log of extension number	0.9018	1.8615	3.2853	2.6410	-6.1201	4.1374
Level of Intensification	-1.0039	0.7695	1.5970*	0.9117	-2.9829*	1.5587
Constants	67.0631	5.9931	25.5541	7.5472	24.7930	10.1283

Number of obs = 320
Iteration log pseudolikelihood = -3803.578
Wald chi2(40) = 208.13, Prob > chi2 = 0
LR Test: chi2(3) = 103.479, Prob > chi2 = 0

*, **, ***Represent 10, 5 and 1% levels of significance respectively

Result in Table 15 shows that Age of the household head had a negative and significant influence on food security status for the good month at 10% level of significance, as well as a positive and significant effect on poverty status of the household at 5% level of significance. These results could imply that older farmers tend to have a low receptivity towards newly introduced agricultural technologies since they are more likely to be conservative with their traditional ways of farming which results in low agricultural output and income hence they become less food secure. Furthermore, older farmers might lack incentive to attend agricultural training that would enable them learn how to engage in and the importance of agricultural intensification practices thus making them less food secure compared to younger farmers. Similar finding was found by Onasanya and Obayelu (2016) and Yahaya *et al*. (2017) who argued that younger farmers were likely to be more innovative and were more interested in learning activities thereby increasing their awareness to participate in the trainings and uptake of agricultural intensification practices for improved agricultural production and incomes compared to their elderly counterparts. A positive and significant effect of household age on poverty status could also be attributed to the fact that older farmers are less energetic, less mobile and lacks flexibility, and thus negatively influence their awareness of the new agricultural technologies than younger household heads. This negatively affect their productivity, output, income and consumption expenditure thus leading to higher level of poverty among them than younger household head. This is similar to the findings of Abebe (2017) who asserted that increase in age of the household head increases the vulnerability of these households to poverty due to lack of mobility.

Household size is found to be positively and significantly influencing food security. For the good month it is highly significant at 1% while for the bad month, it is significant at 10%. This is because more household members means more labour leading to more output hence more food production. Large family size also gives more family labour to the farm which reduces labour cost and the saved money can be spent in purchasing food thereby improving household food security status. Family labour is also of high quality compared to hired one as members are tender, thorough and takes sufficient care because the farm, products and all benefits belong to them these leads to higher food production hence improved food security, this is in line with (Obayelu, 2012). This finding is in contrast with Asghar and Muhammad, (2013), Silvia *et al*. (2015) and Bashir *et al*. (2013) finding that the size of the household is positively associated with food insecurity of the household as food secure households are fewer in size compared to their counterparts because resources to be shared are limited.

Some smallholder farmers households interviewed operated on their own land exclusively, while others operated on owned land as well as rented in or rented out land. Those who own land as well as renting in or out part of the land were classified as farmers participating in land markets while those who operated strictly on own land were none participants of land market. From the results it was found that land market participation has a negative significant influence on food security during the good season at 5% level. This implies that farmers who participated in land market either by renting in or renting out their plot were less food secure compared to those who operated on their own land exclusively. This was attributable to the fact that land rented in these study sites are degraded leading to lower production. The other reason is likely to be the effects of information asymmetry which is present in land market. For instance due to information asymmetry, a farmer might find himself buying a less productive land or a farmer might end up renting out his productive land thus resulting to low crop production. This finding is in contrast with O'Neill and Hanrahan, (2012) who found that good soil quality leads to increased land renting.

Proportion of land allocated for crop cultivation had a positive significant effect on food security and a negative significant effect on poverty status of the household. This implied that households who allocated a greater proportion of their land for crop cultivation were more food secure than those who allocated small proportions of their land for crop cultivation. This was because households with large land sizes had the capacity to produce more crops thus increasing their food production hence were more food secure. This finding is in line with Shiferaw *et al*. (2014) who reported that the likelihood of food security increases in proportion to increase in the area dedicated to improved wheat varieties. On the other hand, households with more land under cultivation were more likely to live above the poverty line. Large cultivated land enables farmers to produce more crops which can be sold hence generate income for the household leading to a reduction in poverty status. More land cultivated means several crops can be allocated portions in the farm and the farmers can easily diversify, a strategy to reduce the vulnerability of harsh climatic conditions in order to increase yield hence alleviating poverty. According to Abebe (2017), households with large tracks of land have enhanced welfare than those with smaller land sizes because they can produce more crops. In contrary, Kassie *et al*. (2011) argued that households with small farm sizes had a tremendous reduction in poverty than households with large land sizes.

Distance to the market had a positive and high significant effect on food security at 1% significant level only during the bad month. Meaning those who are far from the market are comparatively food secure during bad season than those closer to the market. This finding is in contrast to the normal economic belief that market access is the place where households can purchase any food item throughout the year. A positive association between market distance and food security during bad month can be explained by the fact that households who are far from the market are less likely to sell their farm produce during harvesting time or good months. They store much of their produce which they consume at difficult time of the year. Smallholder farmers who reside far from the market realize increase in transaction cost which discourage them from market participation during harvesting period when prices are low. This makes households far from the market more food secure than their counterparts who are closer to the market who are normally encouraged or attracted to sell their produce to the market during harvesting time, because they need cash then rely on market supply later when food prices are at the peak. This finding is in line with Zakari *et al*. (2014), that most farm households even though are closer to the market where food is available, lack purchasing power during difficult times of the year as they sell most of their produce at lower prices during harvesting period and demand these food again from the markets when prices are high.

Number of trainings attended by household members for both good months and bad months were found to be negatively influencing food security and significant at 10% and 5% respectively. Training should upgrade the skills of farmers in order to effectively implement agricultural intensification practices to increase food production. This is only possible depending on how efficiently and effectively training was delivered to farmers. Training in this study negatively affected food security, this is an indication that there is high likelihood that farmers do not apply what they learnt from training. Training should be farmers demand driven, that is farmers are craving for it but it seems that those who attended training were inclined to either allowances or other benefits best known to them. The other reason for this might be that training was too general and not farmers or farm specific in nature. It might also be that the mode of delivery was not adequate to lead to a substantial impact on food production. This finding is in contrast to Yahaya *et al*. (2018) result that households who participated in sustainable agricultural intensification practices training were more likely to have improved access to food. Training was expected to transfer important agricultural knowledge and skills which is beneficial to farmers improving food production (Stewart *et al*., 2016).

Group diversity was significant and found to be positively and negatively influencing food security and poverty status at 1% and 5% level, respectively. A household whose members belong to several groups were more food secure. This is because group membership promotes social capital as a platform where they share knowledge, experiences and even can give, lend and borrow food items when in need thus enabling smallholder farmers to overcome credits and resource constraints which reduce food insecurity. This finding is in line with Kassie *et al*. (2014), who stated that membership of households to farmer groups decreases their likelihood of severe food insecurity because social networks are important resource that households can use to help in alleviating the effect of adverse shocks. On the other hand, households who belonged to many groups were less likely to be poor than those belonging to few groups. Having members of different groups with different background brings in variety of information, experience as well as knowledge to be exchanged. Household members in groups can easily access credit than those who do not belong to any group this is because group members act as collateral. Borrowed funds can also be put into development use which improves the welfare of these households hence alleviate their poverty status. Teklewold *et al*. (2013), found that social capital and networks are crucial in influencing diffusion of most sustainable agricultural practices in Ethiopia leading to poverty alleviation

Location/Site matters in explaining food security status of smallholder farmers' household in the two regions. With site dummies, Wote/Makueni Sub-County was used as a base category and assumes 0 and 1 for households from Nyando Sub-County. Nyando had a positive coefficient and was statistically significant at 1% level of significant. Both Sub-Counties are subject to low and unevenly distributed rainfall and agricultural intensification is vital in reducing farm households' vulnerability to effect of climate change on food security. Smallholder farmers do not necessarily get their food sources from own farm production but can also obtain food from other sources like purchasing, food aid and gifts, hunting and gathering from forest and lakes among other sources. The significant difference might be because Nyando Sub-County was surrounded by agriculturally high productive areas which supply their markets with foodstuffs at reasonable prices. It might also be as a result of good road network which makes transportation cost of goods and other foodstuffs from neighbouring sub-counties comparatively cheaper. This finding is supported by Kristjanson *et al*. 2012 who found that locations/sites differ respectively with the total number of changes in farming systems over the years. Similarly, Workneh (2017), also affirmed that Locations which has less economic opportunities with weak social networks and protection have higher incidence of food insecurity.

The results also indicates that level of agricultural intensification significantly influenced food security for the bad month and poverty level of smallholder farmers' households. The influence of agricultural intensification on food security for the bad month was positively significant at 10% level. On the other hand, the influence of agricultural intensification on poverty was negative and significant at 10%. This implies that the higher level of agricultural intensification the higher the likelihoods of being food secure as well as leaving above the poverty line due to increased agricultural productivity, output, income, and consumption expenditure. Another likely reason for this result is that the adoption of more agricultural intensification practices might help in improving soil conditions as well as alleviating the adverse effect of climate change thus leading to improved agricultural productivity, increase in surplus yield and incomes which translate to food security and poverty alleviation among smallholder households. This finding is also in agreement with Kassie *et al*. (2011) who stated that the adoption of agricultural intensification practices such as improved groundnut seed variety increases crop income thus leading to poverty reduction. Khonje *et al*. (2015), also found that technology adoption increases agricultural production and farm productivity hence reduces poverty and improves food security.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

i. This study identified and grouped related farm practices using Principal Component Analysis. Farmers in both sub-counties use at least one level of agricultural intensification practice.

ii. From the results, socioeconomic, farm and institutional characteristics were found to be significant in influencing the level of agricultural intensification practices. Gender of the household head, land tenure, slope of the land, site and group diversity were found to be positively influencing the level of agricultural intensification among rural smallholder farmers. This observation plays a very vital role for relevant interventions to promote the use of agricultural intensification practices among smallholder farmers.

iii. The results indicated that level of agricultural intensification has the potential of contributing to the improvement of food security and a high probability of poverty reduction for rural smallholder farmers' households. Thus intensive use of agricultural practices in the semi-arid rural areas will lead to increased food security and reduced household probability of being poor.

5.2 Recommendations

a) Since farmers from these sub-counties are poor and majorly rely on rain-fed agriculture yet they face adverse climatic conditions, they should be empowered to adopt multiple agricultural intensification practices. One way of achieving this is through the government together with other development agencies creating irrigation infrastructure in these regions which will lead to constant water supply hence increased agricultural productivity.

b) Smallholder farmers should be encouraged to form groups and join as many beneficial groups as possible as these groups promote social networks as they share ideas, advice, experiences helping in reducing information asymmetry. Being in agricultural production or marketing groups can improve their borrowing and bargaining power and can easily advance their access to extension services, which will create demand for agricultural intensification practices.

c) There is need for the government and CCAFS to develop and disseminate incorporation of both traditional and new agricultural practices which are production context specific and also come up with interventions which are generation specific, easily incorporated by both the young and the old. This can be achieved by reaching them through their social network platforms. Finally, farmers should be encouraged to carry out multiple agricultural intensification practices through multi-stakeholder training and education in order to boost their food security status and reduce their vulnerability to poverty.

5.3 Areas of further research

The study based its finding on cross-sectional data, however, future research should consider using time series data to produce robust results in analysing dynamics in factors influencing the level of agricultural intensification practices overtime. This research should also be extended to other sub-counties in the country with similar agro ecological and climatic conditions.

To get a deeper understanding of farmers perceived use of certain agricultural intensification practices, further research should be conducted to get their opinion based on their past experiences or encounters why they use or not using some of the agricultural intensification practices.

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APPENDIX 1: CONSENT FORM

Hello, my name is ___________________________________ and I am a researcher working with International Livestock Research Institute (ILRI) which is in collaboration with Climate Change, Agriculture and Food Security (CCAFS). The study is a revisit survey targeting households surveyed in 2012 with the CCAFS Impact Lite tool. Data collected in this study will help the study team to assess changes in poverty, food security, nutrition and livelihood strategies in the last four years since the implementation of the initial study. I will take time to explain more about the research, please stop me whenever you need clarifications or to clarify meanings of words that you don't understand. I therefore request you to kindly respond to the questions in this survey to help us understand your livelihood strategies, food security and agricultural productivity. The information that I will collect from this study will be managed carefully. Any information about you will have a number instead of your name if it is accessed by persons other than the researchers collecting the data. Only these researchers will know what your number is and we will protect that information securely. It will not be shared or given to anyone except the researchers in this project. Some of the collected information, which cannot be linked to you, will be made publicly available for further research after a certain time period, as demanded by the project donor.

Respondent's Name.. Signature........................... Date..................

APPENDIX 2: QUESTIONNAIRE

Rural Household Multiple Indicator survey (RHoMIS)

1.0 Household identification

	General information	
Country		
Site name		
Village		
Name of Interviewer		
Household ID		
	Latitude decimal degrees	Longitude degrees
Household GPS code		
Name of the respondent		
Gender		
Age		
Position in household		
Household type		

Position in household	**Household type**
1= Married to Head 2= Child of head 3= Parent of head 4= Other family member 5= Not a family member	1= Has partner (married or non-married) 2= Single woman 3= Single man 4=Woman at home, man works away 5= Man at home, woman works away 6= Both work away

2.0 Household Roster

2.1 How old is the head man of the household? ________

2.2 How old is the head woman of the household? ________

2.3 What is the highest level of education the head man or woman has completed? ________

1= illiterate 2= literate 3= primary 4= secondary 5= post-secondary

3.0 Members of the household

Include only members who live there at least 3 months per year.

3.1 How many people in your household? ________

ID	Age	Number of male	Number of female
1	Aged 3 or under		
2	4-10		
3	Aged 11-24		
4	Aged 25-50		
5	Over 50		

4.0 Farm land sizes

4.1 Does your household own land, rent land or use common land? _______

1= Own land with title 2= Own land without title 3= Rent in land 4= Rent out land 5= Use common land

Land size	How much land does your household own?	Who owns your household's land?	About how much land does your household rent for use?	About how much land does your household rent out for other people to use?	In total, how much land do you use for growing crops?
Area					
Unit					

Unit: 1= Acre 2= Hectare 3= Other

Ownership: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

4.2 Is your land flat, sloping or steep slopes?

1= Flat 2= Gentle Sloping 3= Sloping 4= Steep slope

4.3 Do you have a home garden? Yes/ No _______

4.4 Do you use any grazing land for your animals? Yes/ No

4.5 Do you own any of the grazing land? _______

1= Own it 2= Do not own it 3= Own some of it

4.6 Who works on your land- household members or other people too? _______

1= Household members 2= Reciprocal arrangements with family, friends or neighbours 3= Hired labour

5.0 Crop productivity

5.1 Do you grow any crops? Yes/ No _______

List the 8 most important crops grown by the household in past year in the table below

ID	CROP	About how much of your land did you use for this crop during the last year?	About how much did you harvest in the last year	Weight unit	Was the harvest good or bad in the last year?	Did you grow this crop alone, or did you grow it mixed with other crops? 1= Alone 2= Mixed with other crops	What do you do with the main harvest of this crop?	About how much of the crop was consumed by the household in the last year?
1								
2								
3								
4								
5								
6								
7								
8								

Proportions

1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

Weight Unit: 1= kg 2= Gorogoro 3= Debe 4= Tons

Harvest: 1= Good harvest 2= Normal harvest 3= Bad harvest

Crop use: 1= Eat it/ use at home 2= Sell it 3= Feed to livestock 4=Give away/exchange

ID	Crop	About how much of the crop was sold by the household in the last year?	About how much of the crop was fed to livestock in the last year?	How much did you make from selling the crop during the last year?	Sale price unit	What do you do with the crop residues?	Who usually sells or trades the harvest?	Who usually decides when to eat the crop?
1								
2								
3								
4								
5								
6								
7								
8								

Sale price unit: 1= Price per kg 2= Price per Gorogoro 3= Price per Debe 4= Other

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Crop residues:

1= Leave it in the soil 2= Burn it in the fields 3= Use it as fuel 4= Feed it to animals 5= Make compost 6= Use as construction materials 7= Sell it

5.2 What other crops were grown or harvested by your household during the past year?

____

5.3 Who decided which crops to plant? _______

1=Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

5.4 Did you harvest any of your crops early in the last year? Yes/ No _______

5.5 Which crops did you harvest early?

____

5.6 Why did you harvest the crops early? _______

1= Fear of theft 2= Hunger 3= Needed Income 4= Erratic rainfall or poor weather 5= Other

5.7 Do you make any of your crops into products you can store or sell? Yes/ No _______

If yes,

	Product	Do you eat this product at home?	Do you sell product ?	How much money did you make from selling the products in the last year?	Who usually sells the products?	Who decides when to eat the products?
1	Flour or Meal					
2	Foods for sale (breads, snacks, meals)					
3	Food ingredients (e.g. spices, coffee, tea)					
4	Dried fruits, nuts or similar					
5	Sweet preserves (jams, syrups etc)					
6	Pickled foods (preserved in vinegar)					
7	Drinks (alcoholic or non-alcoholic)					
8	Medicines					
9	Baskets, carvings, etc					
10	Fuel wood, charcoal, etc					

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

6.0 Agricultural inputs

6.1 Do you use any inputs on your farm? Yes/ No ________

6.2 What do you use? ________

1= Urea 2= NPK 3= CAN 4= DAP 5= SSP 6= TSP 7= Other

6.3 On which crops did you use fertilizers during the last year?

____

6.4 How much fertilizer in total was used on your farm in the last year? ________

Fertilizer amount units: 1=kg 0= other

6.5 What types of fertilizer do you normally use?

____

6.6 On which crops did you use manures or compost during the last year?

____

6.7 On which crops did you use pesticides during the last year?

____

6.8 For which crops did you use improved seed varieties during the last year?________________

7.0 Storage

7.1 How do you store your crops after harvest? _______

1= Traditional granary 2= Sacks 3= Metal silos 4= Hermetic bags 5= Other

7.2 Do you add anything to help preserve the crops in the storage? Yes/ No _______

7.3 What do you add to help preserve the crops? _______

1= Pesticide or insecticide 2= Traditional ash 3= Other

8.0 Irrigation

8.1 Do you grow any crops under irrigation? Yes/ No _______

8.2 Which crops did you irrigate during the last year?

____

8.3 Which months of the year do you irrigate?

____

8.4 Where do you get the water for irrigation from? _______

1= Communal pond 2= Household pond 3= Household pond with fish 4= River 5= Well 6= Rainwater harvesting 7= Other

8.5 What type of irrigation method do you use? _______

1= Basin dug around plant 2= Gravity- fed (river diversion) 3= Sprinkler 4= Drip 5= Other

8.6 Do you use an electric or diesel powered water pump? Yes/ No _______

9.0 Innovative technologies

Current use of innovative technologies

		Current use
Cropping	Mechanised land preparation (tractor ploughing) [% of cult. Land]	
	Use of purchased seed (any crop, produced as seed) [% of cult. Land]	
	Use of pesticide [% of cult. Land]	
	Use of manure as fertilizer [% of cult. Land]	
	Use of chemical fertilizer [% of cult. Land]	
	Mechanised harvest [% of cult. land]	
livestock	Improved breed [% of total herd]	
	Artificial insemination (AI) [% of total herd, females]	
	Vaccination [% of total herd]	
	Deworming [% of total herd]	

10.0 Integrated farming

10.1 Do you make use of any trees on your land? Yes/No _______

10.2 What do you use the trees for? _______

1= Food or fruits 2= Fuel wood 3= Timber 4= Animal food 5= Good for land (soil, water, shelter etc) 6= Only cut trees to clear land 7= Other

10.3 Do you till or plough your land? Yes/ No _______

10.4 If yes, how do the tillage? _______

1= By hand 2= Use animal power 3= Use a machine

10.5 Do you grow legumes (peas, beans) in combination with other crops? Yes/ No _______

10.6 Do you grow legumes (peas, beans) in rotation with other crops? Yes/ No _______

10.7Do you grow trees and crops mixed together? Yes/ No _______

11.0 Key livestock species

11.1 Does your household own any livestock or animals? Yes/No________

	How many owned	Breed	How many used for draught power	No. bought the last year	No. sold in the last year	Total amount earned from selling	Who owns the animals?	Who sold the animals?	Amount of time spent in stable or pen?
Cattle									
Goats									
Sheep									
Pigs									
Chicken									
Other birds									
Horses, donkeys, or similar									
Rabbits									
Fish									
Bee hives									
Other 1									
Other 2									
Other 3									

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Amount of time in pen: 1= All or nearly all (90- 100%) 2= More than half of it (60- 90%) 3= About half of it (40-60%) 4= Less than half of it (10- 40%) 5= A small amount (1-10%) 6= None (0%)

Breed: 1= Local 2= Improved or hybrid 3= Both

12.0 Animal products:

12.1 Animal products: Meat

	No. slaughtered in the last year	About how much do you eat	About how much do you sell	How much money did you make from selling the meat in the last year?	Who usually sells the meat?	Who usually decides when to eat the meat?
Cattle						
Goats						
Sheep						
Pigs						
Chicken						
Other birds						
Fish						

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

12.2 Animal products: Milk

	How much milk produced in the good season	Unit of milk production	Bad season milk produced?	About how much milk do you consume?	About how much milk do you use for making dairy products?	About how much milk do you sell?	How much money do you make from selling the milk?	Sales Unit	Who usually sells the milk?	Who usually decides when to eat the milk?
Cows										
Goats										
Sheep										

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

Sales unit: 1= Total 2= Per liter product

Milk unit: 1= Liters per animal per day 2= Total liters per day

12.3 Animal products: Eggs

	How many eggs produced during the good season?	How many eggs produced during the bad season?	Egg unit	About how many eggs do you keep for eating?	About how many eggs do you sell?	How much money do you make from selling the eggs	Unit sales	Who usually sells the eggs?	Who usually decides when to eat the eggs?
Chicken									
Other birds									

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

Egg unit: 1= Eggs per animal per day 2= Eggs per day 3= Eggs per week 4= Eggs per month 5= Other

12.4 Animal products: Honey

	How much honey do you collect in the year?	Honey Unit	About how much honey do you eat?	About how much honey do you sell?	How much money do you make from selling the honey?	Unit sales	Who usually sells the honey?	Who usually decides when to eat the honey?
Honey								

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

Honey Unit: 1= Kg 2= Gorogoro 3= Debe 4= Liters 5= Other

Unit Sales: 1= Total 2= Per unit product

12.5 Processed animal products and other products

	How much do you usually produce?	Units of production	About how much do you eat/ use at home?	About how much do you sell?	How much money do you make from selling?	Unit sales	Who usually sells the produce	Who usually decides when to eat the produce
Cheese								
Butter								
Wool								
Other 1								
Other 2								

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6=None (0%)

Units of production: 1= Kg 2= Gorogoro 3= Debe 4= Liters 5= Other

Unit Sales: 1= Total 2= Per unit product

13.0 Livestock input use

13.1 Do you buy or use any medicines for your livestock? Yes/ No If yes:

	Use: Yes/ No?	Which animals do you give the medicines to?
Vaccinations		
De-worming		
Antibiotics		
Traditional medicines		
Other		

Which animals: 1= Cattle 2= Goats 3= Sheep 4= Pigs 5= Chicken 6= Other birds 7= Horses 8= Fish 9= Bees 10= Other

14.0 Animals: Manure

14.1 What do you do with the manure from the animal pens? _______

1= Put on crops 2= Put in a pile for more than a month before use 3= Store inside a closed space for more than a month before use 4= Put in a digester 5= Use as fuel 6= Sell it 7= Dispose it

	Proportion put on crops	Proportion put in a pile for more than a month before use	Proportion stored inside an enclosed space for more than a month before use	Proportion put in a digester	Proportion used as fuel	Proportion sold	Proportion disposed
All animals							

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

15.0 Wild foods

15.1 Do you or your family gather any wild foods? Yes/ No _______

15.2 If yes, which months of the year do you collect wild foods?

____

15.3 What types of foods did you gather in the last year? __________________

1= Meat 2= Fish 3= Insects 4= Plants 5= Fruits 6= Nuts 7= Honey 8= Mushrooms

15.4 How important is it for you to collect wild foods? _______

1= Very important food source 2= Very important for selling 3= Common part of the diet 4= Not important

15.5 Approximately, which proportion of your household's food comes from wild foods? _______

Proportions: 1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%) 6= None (0%)

16.0 Food security

Food security	
Is there a time of the year when there is less food available compared to other times?	1=Yes 0= No
If so, which months?	
Which is the worst month of the year for food?	
Which is the best month of the year for food?	
During the worst month	
How often did somebody have to go a whole day and night without eating anything?	
How often did somebody have to go to sleep hungry at night?	
How often was there no food to eat of any kind in your household?	
If the answer to **all three** above questions was "never", proceed and ask the following 6 questions. Otherwise, move on to the next section.	
How often did somebody have to eat fewer meals than they wanted?	
How often did somebody have to eat smaller meals than they wanted	
How often did somebody have to eat some foods that you really did not want to eat?	
How often did someone have to eat a less variety of foods?	
How often was someone in the house not able to eat the kinds of foods they wanted to?	
How often do you ever worry that there will not be enough food for your household?	

Options: 1= A lot (daily or more than three times per week 2= Sometimes (Once or twice a week) 3= A little (Once or twice a month) 4= Rarely or never (less than once a month)

17.0 Nutrition Knowledge

Main source of nutrition knowledge (tick all that apply**)**

Farmer-to-farmer	Government extension	Non-gov extension	Print and visual media	Others (specify)

18.0 Dietary diversity

Dietary Diversity	How often?	Where does this food come from?
Think of: grains, rice, flour, or starchy white vegetables. How often were these eaten in your house? (e.g. rice, maize, ugali, muthokoi, nshima, porridge, bread, plantain, yam, cassava, potato, kohlrabi, white or pale sweet potato)		
Worst month?		
Good month?		
Think of: beans, peas, lentils. How often were these eaten in your house? (e.g. gram, cow pea, beans, peas, lentils)		
Worst month?		
Good month?		
Think of: nuts or seeds. How often were these eaten in your house? (e.g. peanut, groundnut, cashew, pumpkin seeds, sunflower seeds, nuts, seeds)		
Worst month?		
Good month?		
Think of: leafy green vegetables. How often were these eaten in your house? (e.g. amaranth, mustard leaves, pea shoots, Chinese cabbage, spinach, kale, sweet potato leaves, broccoli)		
Worst month?		
Good month?		
Think of: orange coloured vegetables or fruits. How often were these eaten in your house? (e.g. pumpkin, squash, carrot, orange sweet potato, red pepper, red palm oil, palm nuts, mango, ripe papaya, peach, mandarin, orange, avocado, persimmon, cantaloupe, apricots)		
Worst month?		
Good month?		
Think of: other vegetables. How often were these eaten in your house? (e.g. tomato, cabbage, onions, gourd, cauliflower, lettuce, chayoute fruit, cucumber, eggplant)		
Worst month?		
Good month?		
Think of: other fruits. How often were these eaten in your house? (e.g. durian, green papaya, guava, lemon, white sappote, banana,		

watermelon, longan, pomelo, apple, pineapple, Hanoi plum, strawberry, mulberry)		
Worst month?		
Good month?		
Think of: meat, poultry or fish. How often were these eaten in your house? (e.g. chicken, beef, pork, goat, duck, buffalo, meat, liver, heart, frog, river fish, sea fish, crab etc.)		
Worst month?		
Good month?		
Think of: eggs. How often were these eaten in your house? (e.g. chicken eggs, duck eggs, any other eggs)		
Worst month?		
Good month?		
Think of: sugar. How often were these eaten in your house? (e.g. sugar, honey)		
Worst month?		
Good month?		
Think of: fats and oil. How often were these eaten in your house? (e.g. cooking fats, cooking oil, ghee)		
Worst month?		
Good month?		
Think of: milk or dairy foods. How often were these eaten in your house? (e.g. cow milk, goat milk, cheese, butter, yoghurt)		
Worst month?		
Good month?		

How often:1= A lot (daily, or more than 3 times per week) 2= Sometimes (1 or 2 times per week) 3= A little (1 or 2 times per month) 4= Rarely or never (less than once a month)

Where does the food come from: 1= Self-produced 2= Purchased 3= Both 4= Gathered, gifted or traded

19.0 Household Dietary Diversity

19.1 Please describe the foods (meals and snacks) that you or any member of your household ate or drank yesterday during the day and night. Include only foods consumed at home, not those purchased and consumed outside of the home. Start with the first food eaten in the morning.

Write down in the spaces below all foods and drinks mentioned. When composite dishes are mentioned ask for the list of ingredients. Probe for any meals/snacks not mentioned. When the recall is complete, fill in the food groups based on the foods mentioned during the recall. For any food groups not mentioned, ask the respondent if a food item from this group was consumed.

Breakfast	Snack	Lunch	Snack	Dinner	Snack

Question No.	Food group	Examples	Yes=1 No=0
1	CEREALS	Bread, noodles, biscuits, cookies or any other foods made from millet, sorghum, maize, rice, wheat, ugali, muthokoi, nshima, porridge or pastes or other locally available cereal foods	
2	VITAMIN A RICH VEGETABLES AND TUBERS	Pumpkin, carrots, squash, or sweet potatoes that are **orange** inside and other locally available vitamin-A rich vegetables (e.g. sweet pepper)	
3	WHITE TUBERS AND ROOTS	White potatoes, white yams, cassava, or foods made from roots	
4	DARK GREEN LEAFY VEGETABLES	Dark green/ leafy vegetables, including wild ones + *locally available vitamin A-rich leaves such as cassava leaves etc.*	
5	OTHER VEGETABLES	Other vegetables (e.g. tomato, onion), including wild vegetables	
6	VITAMIN A RICH FRUITS	Ripe mangoes, cantaloupe, dried apricots, dried peaches + other locally available vitamin A-rich fruits	
7	OTHER FRUITS	Other fruits, including wild fruits	
8	ORGAN MEAT (IRON-RICH)	Liver, kidney, heart or other organ meats or blood-based foods	
9	FLESH MEATS	Beef, pork, lamb, goat, rabbit, wild game, chicken, duck, or other birds	
10	EGGS	Any eggs	
11	FISH	Fresh or dried fish or shellfish	
12	LEGUMES, NUTS AND SEEDS	Beans, peas, lentils, nuts, seeds or foods made from these	
13	MILK AND MILK PRODUCTS	Milk, cheese, yoghurt or other milk products	
14	OILS AND FATS	Oils, fats or butter added to food or used for cooking	
15	SWEETS	Sugar, honey, sweetened soda or sugary foods such as chocolates, sweets or candies	
16	SPICES, CONDIMENTS, BEVERAGES	Spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages OR local examples	
17	INSECTS	Termites, grass-hoppers	

Other characteristics of yesterday's food

	Yes= 1 No=0
Did you or anyone in your household eat anything (meal or snack) OUTSIDE of home yesterday?	
Was yesterday a celebration or feast day where you or anyone in your household ate special foods or was it a day where you or any	

member of your household ate more or less than usual?	

Comments ____

20.0Access to facilities

Please indicate the distance to the following facilities

a) What is the distance from your homestead to the nearest **extension advice?**	**dextn**	_______ km
b) What is the distance to the nearest **A.I** service provider	**Aikm**	_______ km
c) What is the distance from your homestead to the nearest **market place** for f**arm produce**	**mktkm**	_______ km

Extension service providers and training

20.1 Did the household receive agricultural extension contacts in the last year?

1= Yes, 0=No **Exten_______** If yes, specify the number of times: **Extennum _______**

20.2 Has anyone in the household attended a farmer training last year?

1= Yes, 0= No **Train _______** If yes, how many times: **Trainnum_______**

21.0 Social capital

21.1 Is anybody in the household a member of a group? 1= Yes 0= No

21.2 How many household members belong to groups **Hhgroupmem_______**?

21.3 How many groups do household members belong to **Groupnum_______?**

21.4 Fill details of the group, which is most important to the household for agricultural production;

Group type	No. of female members	No. of male members	Group activities	Rank your participation in decision making in group [scale of 1-10; 10= most]	Rank level of trust to group members [scale of 1-10, 10= most]

Group types: 1= Self-help group 2= Welfare group 3= Cooperative society 4= Other (specify)

Group activities: 1= Crop production 2= Livestock production 3= Marketing 4= Other (specify)

22.0AID

22.1 Have you received aid from the government, NGOs or other organizations in the last year? Yes/ No _______

22.2 If yes, which type?

1= Food 2= Agricultural inputs (fertilizers, seeds, crops etc.) 3= Animals 4= Cash 5= Other

22.3 During the last year, about how much of the food eaten by your household was from aid sources? _______

1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%)

22.4 Have you received any significant gifts from family, friends, neighbours in the past year? Yes/No _______

22.5 If yes, which type _______

1= Food 2= Agricultural inputs (fertilizers, seeds, crops etc.) 3= Animals 4= Cash 5= Other

22.6 During the last year, about how much of the food eaten by your household was from gift sources? _______

1= All or nearly all (90-100%) 2= More than half of it (60-90%) 3= About half of it (40-60%) 4= Less than half of it (10-40%) 5= A small amount (1-10%)

23.0 Debt

23.1 Do you have any debts or loan, or did you have any in the last year? Yes/ No _______

23.2 In the last year, did you ever find it difficult to pay the debts? Yes/ No _______

24.0 Off farm income

24.1 Do you have any sources of income apart from selling what you produce on the farm? Yes/ No _______

24.2 If yes,

Type of income	Does your household earn money from this source? 1= yes 0= no	Which months does your household earn money from this source?	Who decides how to spend the money from this source?
Labour on other farms			
Labour, not on a farm			
Work in local business			
Have own business			
Remittances			
Work for government or public institution			
Rent out land to others			
Rent out equipment or animals to others			
Other			

Who: 1= Husband or other male 2= Wife or other female 3= Male youth or child 4= Female youth or child

24.3 Think of all the money earned in your household during the last year from selling crops and livestock, and from off farm work. Did more come from off farm work or more from sales of crops and livestock? _______

1= All or almost all from off-farm- almost none from farm 2= Most from off-farm- some from farm 3= Half from off-farm- most from farm 4= Some from off-farm- most from farm

24.4 What sort of things do you spend the money on that is earned from off-farm sources?

1= Buying food 2= Buying possessions e.g. clothes, household items 3= Improve the farm e.g. machinery, fertilizers 4= Spend on people e.g. education, health care, travel to city

24.5 What sort of things do you spend the money that is earned from your farm, by selling crops and livestock?

1= Food 2= Possessions 3= Invest on the farm 4= Invest on people (education etc)

25.0 Influence of ideas on one's life

Idea	**What influence has it had on your life?**
Living in a peaceful community and a peaceful country	
Being curious and learning about new things	
Having authority, leading and commanding other people?	
Self-discipline, self-restraint, and resistance to temptation	
Taking care of the natural environment, such as trees, soil, water, animals	
Obtaining wealth, possessions, money	
Honouring parents and elders, and showing respect	
Leading an exciting life	
Fairness, justice, and care for the weak	
Being influential, having an impact on people and events	
Family security and safety for loved ones	
Having new experiences and testing out new ways of doing things	

Influence: 1= Big influence 2= Small influence 3= No influence

26.0Farm changes

26.1 Compared to four years ago, do you own more, or less or about the same?

Item	More	Less	About the same
Land			
Harvest			
Changes in crops grown			

Inputs for crop production			
Livestock			
Changes in livestock type kept			
Inputs for livestock production			
Produce sold			
Earnings from off-farm activities			

Item	(a)If more or less, did you want to or forced to by circumstances	(b) If wanted to , where did you get the idea from?	(c)If forced to, why?
Land			
Harvest			
Changes in crops grown			
Inputs for crop production			
Livestock			
Changes in livestock type kept			
Inputs for livestock production			
Produce sold			
Earnings from off-farm activities			

a) 1=Wanted to 2= Forced to
b) 1= Was my own idea 2= Extension workers or other organizations 3= Neighbours, friends or family 4= Others (specify)
c) 1=Climate or weather-related 2= Market related 3= Labour/ time shortage 4= Could not afford to continue 5= Other

26.2 What are your main plans for your farm in the next 5 years?

____

26.3 When a new thing comes along for example a new crop or a new fertilizer, are you the first to try it out, or do you wait and see how it works out for other people?

1=First 2= Wait to see if it works for others 3= One of the last 4= I don't try new things

26.4 If you had a good harvest and earned more cash than usual, what would you spend the money on?

1= Buying food 2= Buying possessions 3= Improving the farm 4= Spend on people 5= Save the money

26.5 Would you like your children to be farmers?

1= Yes 2=No 3= Some of them 4= Don't have any

26.6 Do your children want to be farmers? ________

1= Yes 2=No 3= Some of them 4= Too young to decide 5=Don't have any

26.7 Overall, how satisfied are you with your situation in life? *Includes health, family, happiness, community, food, income, opportunities.* ___________

1= Very satisfied 2= Satisfied 3= Unsatisfied 4= Very unsatisfied

27.0 Progress out of poverty indicator

	Response
How many members does your household have?	1= Nine or more 2= Seven or eight 3= Six 4= Five 5=Four 6= Three 7= One or two
What is the highest school grade that the female head or spouse has completed?	1= None or pre-school, 2= Primary standards 1 to 6, 3= Primary standard 7, 4= Primary standard 8 or secondary forms 1 to 3, 5= No female head/spouse, 6= Secondary form 4 or higher
What kind of work is the main occupation of the male head/ spouse?	1= Does not work 2= No male head/spouse 3= Agriculture, hunting, forestry, fishing, mining, or quarrying 4=Any other
How many habitable rooms does this household occupy?	1= One 2= Two 3= Three 4= Four or more
What material is the floor of the house made of?	1= Wood, earth or other 2= Cement or tiles
What is the main fuel used for lighting?	1= Collected firewood, purchased firewood, grass, or dry cell (torch) 2= paraffin, candles, biogas, or other 3= Electricity, solar, or gas
Does your household own any electric or charcoal irons?	Yes/No
How many mosquito nets does your household own?	1= None 2=One 3= Two or more
How many towels does your household	1= None 2= One 3= Two or more
How many frying pans does your household own?	1= None 2=One 3= Two or more

28.0Closing the survey

Before we finish, do you have any question or comments?

____

Thank you for your time and for sharing the information!

Time interview **ended** :	HH:		MM:		

To be answered privately by the enumerator immediately following the interview

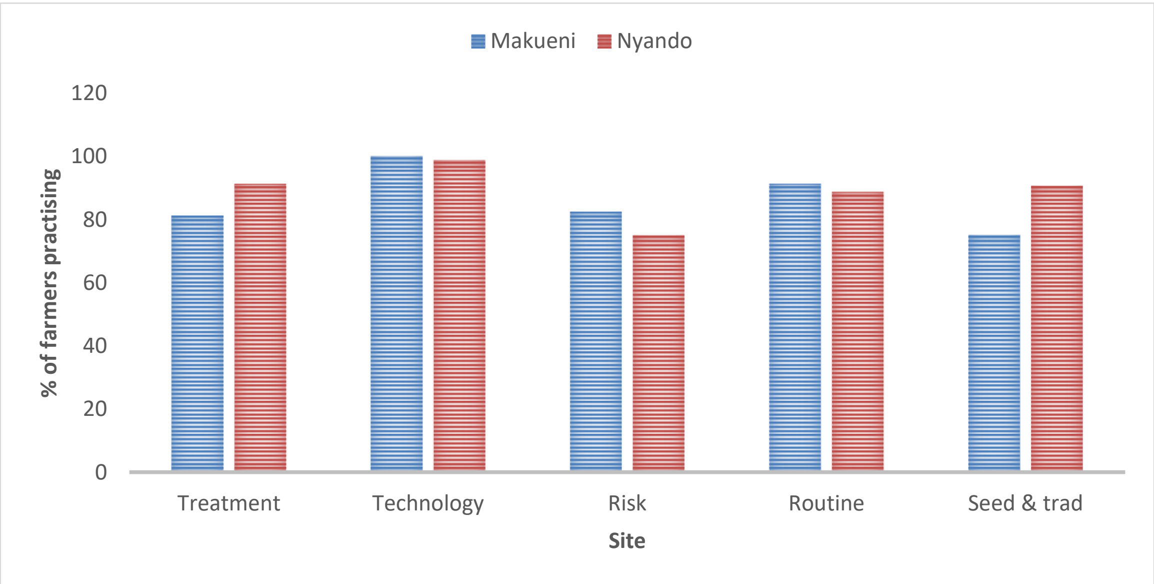
How many people contributed to answering the survey? ______

APPENDIX 3: FOOD GROUPS FOR HFCS BY WFP

Food Item	Food Group	Weight
Rice Wheat/other cereals Potato (including sweet potatoes)	Cereals and tubers	2
Pulses/beans/nuts	Pulses	3
Milk/Milk products	Milk	4
Meat and fish Poultry Eggs Fish and sea food(fresh/dried)	Meat and fish	4
Dark green vegetables-leafy Other vegetables		1
Sugar/honey		0.5
Fruits		1
Oil		0.5
Spices, tea, coffee, salt, fish powder, small amounts of milk for tea	Condiments	0

The maximum FCS has a value of 112 which would be achieved if a household ate each food group every day during the last 7 days. The total scores are then compared to pre-established thresholds. Poor food consumption: 0 to 28, borderline food consumption: 28.5 to 42 and acceptable food consumption: > 42.

APPENDIX 4: PERCENTAGE OF FARMERS PRACTICING AGRICULTURAL INTENSIFICATION PRACTICES



APPENDIX 5: LOOK-UP TABLES, PROGRESS OUT OF POVERTY INDEX (PPI) FOR KENYA.

The following look-up tables are used to convert PPI scores to poverty likelihoods: international 2005 PPP Lines.

PPI Score	$ 1.25 per day	National	USAID "Extreme"
0-4	100.0	95.4	91.5
5-9	97.5	95.0	73.9
10-14	86.2	85.8	57.9
15-19	86.0	82.5	46.9
20-24	81.9	77.3	46.3
25-29	70.1	67.9	36.5
30-34	63.1	63.7	27.6
35-39	49.0	46.4	16.8
40-44	35.1	36.9	15.4
45-49	24.9	30.0	7.4
50-54	9.6	17.8	2.5
55-59	6.8	13.9	2.3
60-64	1.4	6.1	0.3
65-69	0.8	4.6	1.2
70-74	0.1	3.8	0.2
75-79	0.1	0.0	0.0
80-84	0.1	0.4	0.4
85-89	0.0	0.0	0.0
90-94	0.0	0.0	0.0
95-100	0.0	0.0	0.0

This PPI was created in March 2011 using data from Kenya's 2005/06 Integrated Household Budget Survey by Mark Schreiner of Microfinance Risk Management, L.L.C. Retrieved from www.progressoutofpoverty.org.

APPENDIX 6: PROGRESS OUT OF POVERTY INDEX SCORE FOR KENYA

A PPI score **must** be converted into a poverty likelihood using the PPI Look-up Table.

Indicators	Responses	Scores
1. How many members does the household have?	A. Nine or more B. Seven or eight C. Six D. Five E. Four F. Three G. One or two	0 5 8 12 18 22 32
2. What is the highest school grade that the female head/spouse has completed?	A. None, or pre-school B. Primary standards 1 to 6 C. Primary standard 7 D. Primary standard 8, or secondary forms 1 to 3 E. No female head/spouse 6 F. Secondary form 4 or higher	0 1 2 6 6 11
3. What kind of business (type of industry) is the main occupation of the male head/spouse connected with?	A. Does not work B. No male head/spouse C. Agriculture, hunting, forestry, fishing, mining, or quarrying D. Any other	0 3 7 9
4. How many habitable rooms does this household occupy in its main dwelling (do not count bathrooms, toilets, store rooms, or garage)?	A. One B. Two C. Three D. Four or more	0 2 5 8
5. The floor of the main dwelling is predominantly made of what material?	A. Wood, earth, or other B. Cement or tiles	0 3
6. What is the main source of lighting fuel for the household?	A. Collected firewood, purchased firewood, grass, or dry cell (torch) B. Paraffin, candles, biogas, or other C. Electricity, solar, or gas	0 6 12
7. Does your household own any irons (charcoal or electric)?	A. No B. Yes	0 4
8. How many mosquito nets does your household own?	A. None B. One C. Two or more	0 2 4
9. How many towels does your household own?	A. None B. One C. Two or more	0 6 10
10. How many frying pans does your household own?	A. None B. One C. Two or more	0 3 7
Total Score:		

This PPI was created in March 2011 using data from Kenya's 2005/06 Integrated Household Budget Survey by **Mark Schreiner** of Microfinance Risk Management, L.L.C. For more information, please visit **www.progressoutofpoverty.org**.

APPENDIX 7: NEGATIVE BINOMIAL MODEL RESULTS

```
  ___  ____  ____  ____  ____ (R)
 /__    /   ____/   /   ____/
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Notes:
      1.  Unicode is supported; see help unicode_advice.

. use "C:\Users\Fredrick\Desktop\FredOuya\MainData_05032018.dta"

. nbreg Intensification_level site age_hhh gender educ hhsize land_tenure land_slope offincome
distmkt traingno group_nos PropLand_cult lnextno, dispersion(mean) vce(robust)

Fitting Poisson model:

Iteration 0:   log pseudolikelihood = -560.31775
Iteration 1:   log pseudolikelihood = -560.31775

Fitting constant-only model:

Iteration 0:   log pseudolikelihood =  -826.1497
Iteration 1:   log pseudolikelihood = -564.40634
Iteration 2:   log pseudolikelihood = -564.40634
```

```
Fitting full model:

Iteration 0:   log pseudolikelihood = -560.32363

Iteration 1:   log pseudolikelihood = -560.31775

Iteration 2:   log pseudolikelihood = -560.31775


Negative binomial regression                      Number of obs     =        320

                                                  Wald chi2(13)     =      72.69

Dispersion           = mean                       Prob > chi2       =     0.0000

Log pseudolikelihood = -560.31775                 Pseudo R2         =     0.6072


-------------------------------------------------------------------------------------

                      |               Robust

Intensification_level |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]

----------------------+--------------------------------------------------------------

                 site |   .0500134   .0230328     2.17   0.030       .00487    .0951567

              age_hhh |   .0012179   .0007945     1.53   0.125    -.0003392    .0027751

               gender |   .0647161   .0328217     1.97   0.049     .0003868    .1290454

                 educ |   .0197012   .0133412     1.48   0.140     -.006447    .0458495

               hhsize |   .0046302   .0043689     1.06   0.289    -.0039326    .0131931

          land_tenure |   .0957663   .0161452     5.93   0.000     .0641222    .1274104

           land_slope |   .0190393    .007687     2.48   0.013      .003973    .0341055

            offincome |  -.0606628   .0316032    -1.92   0.055    -.1226039    .0012783

              distmkt |  -.0084995   .0040608    -2.09   0.036    -.0164586   -.0005404

             traingno |   .0044788   .0128373     0.35   0.727    -.0206817    .0296394

            group_nos |   .0147937   .0056472     2.62   0.009     .0037255    .0258619

        PropLand_cult |  -.0165748   .0050959    -3.25   0.001    -.0265627    -.006587

              lnextno |   -.004883   .0342971    -0.14   0.887    -.0721041    .0623381

                _cons |   1.124447   .0873481    12.87   0.000     .9532479    1.295646

----------------------+--------------------------------------------------------------

             /lnalpha |  -49.83273          .                             .           .

----------------------+--------------------------------------------------------------

                alpha |   2.28e-22          .                             .           .
```

APPENDIX 8: RESEARCH PERMIT FROM NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **206034**

Date of Issue: **19/September/2019**

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