EVALUATION OF CLIMATE CHANGE ADAPTATION STRATEGIES: A CASE OF GREENHOUSE TOMATO PRODUCTION AMONG SMALLHOLDER FARMERS, NAKURU COUNTY

BY

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A thesis submitted to the Graduate School in partial fulfilment for the requirements of the award of Master of Science Degree in Agricultural Economics of Egerton University

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DECLARATION AND APPROVAL

1. DECLARATION

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

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Sign-- Date--

2. APPROVAL

This work has been submitted with our approval as University supervisors.

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DEDICATION

My husband Thomas Kirui and my children: Faith, Mercy, Patrick, Benedict and Miriam. Thank you for your; inspiration, encouragement and prayers, and especially, during the period when I was furthering my studies.

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Glory is to God!

ABSTRACT

Agricultural production plays an important role in food security in many African countries. The main challenge of policy makers in these countries is how to attain food self sufficiency, and increased farm productivity and incomes. In Kenya, greenhouse production is among technologies promoted to improve farm output and income among smallholder farmers. Greenhouse production technology in Kenya has, until recently, been the confine of large scale export-oriented flower farmers. The technology is recently picking up among smallholder farmers. This is due to promotional efforts by government and stakeholders through training and loans to buy greenhouse equipment. In Nakuru county greenhouse technology has been adopted by smallholder farmers as one of the emerging climate change adaptation strategies. The major crop grown is tomato. Tomato yields can be increased by up to four times if grown in a controlled greenhouse environment compared to open field production. Despite these promotional efforts, low productivity remains a major challenge. The purpose of the study was to determine levels of technical efficiency and factors influencing technical efficiency of smallholder greenhouse tomato farms in Nakuru County. Three Sub Counties were purposively selected, where all 100 smallholder greenhouse tomato farmers were interviewed. Primary data was collected using observations and interviews using semi-structured questionnaire. Data analysis was done using descriptive statistics, principle component analysis, cluster analysis, stochastic frontier function and two-limit Tobit model. The mean technical efficiency of greenhouse tomato production was 28.71%. Nakuru Sub County had the mean technical efficiency of 29.47%, Rongai 29.1% and Njoro 26.26%. Technical efficiency was positively influenced by cost of greenhouse items and negatively influenced by age, distance to the input dealer and farming experience. The study recommends that farmers should be sensitized on the appropriate input application rates. Also older and experienced farmers need to adopt new and innovative farming technologies to enhance their level of productivity. Incentives should also be provided to private investors to expand their agro-input shops to rural markets for farmers to access farm inputs easily. Finally, the targeted support advocated is that Government puts in measures and processes to ensure that dealers of greenhouse items supply affordable and quality items.

Key words: Greenhouse, Technical Efficiency, Tomato, Smallholder farmers.

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ABREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CAPro	Climate Change Adaptation Project
C-D	Cobb-Douglas
DEA	Data Envelopment Analysis
FAO	Food and Agriculture Organization of United Nations
GHG	Greenhouse Gases
GoK	Government of Kenya
IAD	Institutional Analysis and Development
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
KES	Kenya Shillings
Kgs	Kilograms
KNBS	Kenya National Bureau of Statistics
LH	Lower Highland Zone
LM	Lower Midland Zone
MDGs	Millennium Development Goals
MoA	Ministry of Agriculture
MoAL	Ministry of Agriculture and Lands
NGO	Non-Governmental Organization
NIE	New Institutional Economics
PCA	Principal Component Analysis
SFA	Stochastic Frontier Approach
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
TA	Tropical Alpine Zone
UH	Upper Highland Zone
UM	Upper Midland Zone

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Although human beings have, throughout history, been vulnerable to climate-related hazards, there are concerns that the intensity of such hazards have, in recent years, been on the rise. In turn, this is raising fears that unless farmers adapt appropriately, the contribution of agriculture to food security and economic growth are under increased threat (Ngigi, 2009). The need for appropriate adaptation is underscored by a number of facts: Statistics show that out of the three billion people living in rural areas globally, about 2.5 billion derive their livelihoods from agriculture and 1.5 billion are resource-poor smallholder farmers who farm in less than two hectares of land. Smallholder farmers make up the majority of farmers (85%) in developing countries. A large proportion of these smallholder farmers are in Asia (87%), Africa (8%) and Europe (4%) (FAO, 2012; Oksana, 2005; Subhash et *al*., 2010; World Bank, 2003).Agriculture sustains the livelihoods of 36% of the world's total workforce. In the densely populated countries of Asia and Pacific, this proportion ranges from 40 to 50% and in Sub-Saharan Africa (SSA) two thirds of the working populations still make their living from Agriculture (ILO, 2007).

In Kenya, the agricultural sector is the backbone of the economy contributing about 24% to the Gross Domestic Product directly and 27% indirectly. It provides about 70% of informal employment and 19% of formal employment. In addition, about 80% of the country's population live in the rural areas and an estimated 69% of all households are engaged in farming activities (KIPPRA, 2009). Smallholder farmers dominate the Kenya's agricultural sector accounting for 75% of the total agricultural output and 70% of the marketed agricultural production (MoA, 2008).

According to Ngigi (2009), smallholder farmers are the most vulnerable to climate change, hence the need to adapt their livelihood systems to changing climatic conditions. Given these facts, the major indicators of vulnerability are increased poverty and natural resource dependency at the individual level as well as inequality (Adger, 1999).

It is a known fact that farmers have over the years coped with climate induced changes through the use of indigenous strategies. These include preservation and storage of crop and livestock products, destocking during drought seasons. However, with the increased frequency, intensity, and magnitude of climate change hazards, indigenous strategies have become less effective (Lankao, 2008). As a result, farmers are slowly embracing emerging adaptation strategies for sustained productivity. These Emerging adaptation strategies include: integrating crop and livestock enterprises that are better suited for the changing climatic conditions; conserving soil moisture through mulching and other soil management techniques; altering and staggering the timing for planting; use of relatively higher water-efficient irrigation technologies; processing and conservation of crop residues to be used as livestock feed during the dry season; improved food preservation methods and greenhouse cultivation (Riche *et al*., 2009).

Greenhouse technology was first introduced in production of fruits, flowers, and ornamental crops in Europe in the 17th Century with an aim of optimizing the use of soil and water resources.

In Kenya Greenhouse cultivation has until recently, been the confine of large-scale export-oriented flower farmers. However the technology is fast attracting the attention of smallholder farmers in many parts of the country. This is due to their reaction to climate change coupled with promotional efforts by the government and various development agencies.

Tomato is the most commonly produced greenhouse vegetable crop (Moghaddam *et al.,* 2011). As Munyoki (2011) has noted, growing tomatoes under greenhouses has many advantages, among them the ability to produce high yields on a small piece of land, huge savings in crop protection chemicals, and reduced labour requirement. Furthermore, exposure to chemical toxins associated with application of pesticides is minimised or eliminated altogether. Weeds, insects and other pests known to invade plants are also controlled. In addition, it takes a shorter period (two months) for greenhouse-produced tomatoes to mature, while it takes a minimum of three months with outdoor farming. The tomatoes grown in a greenhouse have a shelf-life of up to 21 days compared with about 14 days for those grown in the open field. In turn, this led to a shift from open pollinated farming to hybrid-high yielding methods, which if adopted in other sectors could lead to massive improvements in crop production, output, incomes and ultimately food self-sufficiency (Hochmuth and Hochmuth, 2012).

Kenya has witnessed greenhouse tomato production among smallholder farmers since 2007 (Makunike, 2007). Behind its promotion in the country are various stakeholders which includes among others; the Horticultural crops development authority (HCDA), Seminis Seeds, Osho chemical Industries and Amiran Kenya Ltd in collaboration with the ministry of Agriculture. The promotional efforts have included; promotion of greenhouse cultivation practice among smallholder farming communities, enhanced access to loans by smallholder farmers to buy greenhouse equipment and training on the practice; all with an aim of improving productivity and ultimately farm incomes for improved livelihoods.

In the recent past in Nakuru County, greenhouse tomato production has slowly picked up among smallholder farmers across the various sub counties; though the exact number of farmers with greenhouses has not been ascertained. The average yield of greenhouse tomato production in Nakuru County is about 70 tons per hectare against a potential of about 100 tons per hectare (GoK, 2007). Studies in other parts of the world have indicated higher yields of greenhouse tomato production. Results of a research study in Turkey showed yields ranging from 89 to 114 tons per hectare of greenhouse tomato production (Bayramoglu *et al*., 2010). This is above the given potential for Nakuru County.

1.2 Statement of the Problem

Investments have been made by the government and development agencies to promote greenhouse tomato production among smallholder farmers in Nakuru County, in an effort to improve greenhouse tomato productivity in; the light of changing climatic conditions. These efforts have focused on adoption of greenhouse technology and adoption of high yielding varieties of tomato improved farmers' incomes and sustained livelihoods. Despite these efforts, low productivity remains a major challenge to the extent that some farmers have abandoned the practise whereas; greenhouse tomato yields have been proven to be high elsewhere in the world. This is attributed partly to inadequate information on technical knowhow given that the technology is relatively new and more specialised.

On the other hand, very limited information exist on how technically efficient smallholder greenhouse tomato farmers are particularly in Nakuru County. No such study exists that explore whether smallholder greenhouse tomato farmers are maximizing output, through optimal utilization of the scarce farming resources in Nakuru County. At the same time, very limited documentation exists in literature on the levels of technical efficiency in greenhouse tomato production as well as the determinants of technical efficiency among smallholder greenhouse tomato farmers especially in Nakuru County.

Due to inadequate information regarding the technical efficiency of greenhouse tomato production, farmers are unable to make informed choices. This may explain partly why the uptake of the technology is slow. However, this technology may be more beneficial if efficient utilisation of resource inputs and output maximisation are taken into account. The present study will help to fill this knowledge gap in Nakuru County.

1.3 Objectives of the Study

1.3.1 General objective

The purpose of the study was to evaluate the levels of technical efficiency of greenhouse tomato production as a climate change adaptation strategy among smallholder farmers in Nakuru County

1.3.2 Specific Objectives

i. To characterize smallholder greenhouse tomato farmers in Nakuru County.
ii. To evaluate the technical efficiency levels of greenhouse tomato production among smallholder farmers in Nakuru County.
iii. To determine the factors which influence the levels of technical efficiency of smallholder greenhouse tomato production in Nakuru County.

1.4 Research Questions

i. What are the characteristics of smallholder greenhouse tomato farmers in Nakuru County?
ii. What are the technical efficiency levels of greenhouse tomato production among smallholder farmers in Nakuru County?
iii. How do the various factors influence the technical efficiency of smallholder greenhouse tomato production in Nakuru County?

1.5 Justification of the Study

Agricultural production is dominated by smallholder farmers who are more vulnerable to climate change due to their limited resource base. In this regard therefore; farmers will be required to utilise their resources more efficiently in order to maximize productivity.

Farmers in Nakuru County have adapted to climate change through greenhouse technology which is relatively new and specialised. Studies relating to technical efficiency of greenhouse tomato production are inadequate. This study is aimed at providing that information with a likelihood of influencing the future development of greenhouse tomato production for sustainable livelihoods among the farming communities. Farmer characteristics inform the stakeholders on specific needs and endowments of any given cluster of farmers thus providing a base on which to address issues affecting them. Empirical findings on technical efficiency from this study also provide evidence to the various stakeholders on the farmer's ability to optimize in their use of available resources. In addition, the findings will be useful in addressing the factors which hinder the farmers' technical efficiency and promote those that enhance technical efficiency. Therefore these results form the basis for further interventions and research. The study recommendations may be used by both public and private institutions involved in the promotion of greenhouse tomato production in the study area and in the country at large.

1.6 Scope and Limitation of the Study

The study was confined to smallholder greenhouse tomato farmers in Nakuru, Njoro and Rongai Sub Counties in Nakuru County. The findings apply mainly to the study area and may not be generalized for all regions in Kenya since different regions have different farmer and agro-ecological characteristics.

The study relied on the data which was mainly within the period September to November, 2011.

1.7 Definitions of Terms

This study involves a number of key concepts, namely Smallholder farmers, greenhouse, Climate change, adaptation strategies. The way these terms are defined for the purpose of this study is considered as follows:

Smallholder greenhouse tomato farmer: In the context of this research smallholder greenhouse farmer is a farmer with up to 3 greenhouses and a maximum length of the greenhouse of 30 metres

Adaptation Strategies: These are activities carried out by the farmer with an aim of coping up with changes in climate.

Climate change: Is a trend in one or more climatic variables characterized by a fairly smooth continuous increase or decrease of the average value during the period of record.

Greenhouse: It is a special structure made of glass or polythene materials where crops are cultivated under controlled conditions such as temperature, light, humidity and wind among others factors.

Technical Efficiency: Refers to the ability to produce a given level of output with a minimum quantity of inputs under a given technology (Farrell, M.J, 1957).

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter is organized in six sections. The first section provides information about climate change and its effect on agricultural productivity. The second section elaborates on the greenhouse production technology as a climate change adaptation strategy. In the third section, the study presents a brief literature review on the nature of tomato production in Kenya. Selected literature on factors influencing technical efficiency forms the fourth section. Finally, the fifth and sixth sections consist of the theoretical and conceptual frameworks for the study respectively.

2.2 Climate change and agricultural productivity

Climate change is known to potentially have far significant impacts on agricultural productivity. IPCC (2007) has noted that it is difficult to predict climate changes with certainty. What is known is that global warming is likely to have significant impacts on factors affecting agricultural production, which includes temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements (Fraser, 2008). As a result, climate change poses great challenges to the international community with respect to designing strategies for ensuring food security for the growing population, as well as promoting sustainable development. Given that agriculture provides the main source of livelihood for the poor in developing countries, interventions in this sector are essential in coping with these challenges (Bryan *et al.,* 2011). Improving agricultural productivity is critical to achieving food security together with other targets specified under the MDG's such as ensuring environmental sustainability (Rosegrant *et al.,* 2006). Adaptation to climate change is essential to ensure food security and sustained livelihoods of poor farmers (Bryan *et al.,* 2011). Special efforts for adaptation need to be placed on smallholder farmers in SSA. This is because, as Smith et al, (2008) have noted, the SSA countries are relatively more vulnerable to the impacts of climate change due to their limited capacity to adapt. Yet, it is estimated that the African region's economic potential for mitigation through agriculture is about 17% of the total global mitigation potential (Smith *et al.,* 2008).

Kenya's greatest climate change impact on agricultural production has been associated with changes in rainfall variability, including prolonged periods of drought and changes in the seasonal pattern of rainfall (Herrero *et al.,* 2010). Farmers in Kenya are likely to experience many adverse impacts from climate change given that 70% of the rural population depend on agricultural production for its livelihood (FAO, 2010; MoA, 2009). Hence, adaptation strategies (such as the greenhouse production technology) that would reduce yield variability during extreme events can provide the greatest benefit to resource poor farmers. In addition, to increasing the resilience of poor farmers to the threat of climate change, adaptation also offers co-benefits in terms of agricultural mitigation and productivity. That is, many of the same practices that increase resilience to climate change also increase agricultural productivity and profitability and reduce GHG emissions from agriculture (Bryan *et al.,* 2011).

2.3 Greenhouse production technology as a climate change adaptation strategy

With respect to adapting to climate change, a greenhouse is suitable in controlling the environment under which the crop is produced. As such, it has a determinant effect on the micro-climate, due to its influence on the quality and quantity of radiation and on the other micro-climate parameters (Ho, 2002).The idea of growing crops in an environmentally controlled area has existed since the Roman times (8^{th} century BC) (Janick *et al.,* 2007) where artificial methods were used to grow cucumbers to ensure their availability every day of the year. At that time, cucumbers were grown in wheeled carts which were put in the sun daily and taken inside to keep them warm at night (Olivier de, 2001).

The precise statistics on the exact area under greenhouse production is not clear but more and more farmers are adopting the technology, with majority of them venturing in tomato production (Cook, 2006). Greenhouses are of different forms based on the construction materials used. According to Cook (2006), greenhouses are either built using glass or plastic material and they may be large tunnels or mini tunnels. In addition, there are two categories of greenhouse agro-systems according to Wittwer and Castilla (1995). The first is the sophisticated and highly controlled type, common in the high latitude areas of Europe and North America, due to the inability to grow crops outdoors in freezing weather. On the other hand, the second type is characterised by minimal climate control enabling the crop to survive and produce an economical yield.

The design of the greenhouse agro-system with respect to the two extreme types greatly depends on whether the region is found in a desert, tropics or temperate environment (Jensen, 2002). Furthermore, economic benefits of greenhouse production, compared to outdoor production, in tropical, subtropical and temperate regions is significantly less than in high latitude areas. As such, investment in the sophisticated structures and environment modification systems may not be economical in these areas unless they are simple and less energy dependent (Albright, 2002).

Green house production has many advantages over the traditional open field cultivation. According to USAID (2012), crops grown in open fields are vulnerable to environmental factors such as drought, excessive rainfall, and pests and diseases. These factors limit yields and affect the quality of produce. Furthermore, a greenhouse is suitable for vegetable and flower production. It enables the farmer to cultivate floricultural crops all year round, even when it is off-season. In addition, crops grown under the greenhouse are superior in utilization of water and chemicals for pest and disease control. Empirical findings from a study by USAID (2012) in Kenya showed that snow peas and sugar snap yields from greenhouse tunnels were 48% higher than in the open fields. The findings also indicated that only 15% of the produce from open fields was marketable, with most of it being affected by pests and diseases; compared to 98% grown in greenhouse tunnels.

The adoption of greenhouse production has further been promoted by the current consumer demand for high quality commodities, produced under environment conscious, labour safety and hygienic condition. These market demands coincide with general image about the greenhouse as a hygienic and environmentally-friendly way of producing crops (Van Uffelen *et al.,* 2000). Despite the above advantages, greenhouse production also has its share of limitations. Albajes *et al.* (2002) indicated that greenhouse structures require a significant investment in construction and installation costs for irrigation systems. In addition, energy is required to heat the greenhouse in the event that sunshine is insufficient.

2.4 Tomato production in Kenya

Within the past century tomato has become one of the most popular and widely consumed crops with an annual world production of about 80 million metric tonnes (FAO, 2001). Tomato has always been a popular vegetable since its introduction to Kenya, both in the fresh market and processing industry. It is the highest vegetable income earner with an annual production of 318,639metric tonnes (Anonymous, 2003).

Its usefulness in fresh or processed form has played a key role in its rapid and widespread adoption as an important food commodity (FAO, 2001). Tomato is an important source of vitamins (A, C and B2) and minerals such as potassium, iron and phosphorus. The vegetable is also gaining importance since it contains lycopene, a food component known to reduce the incidence of prostate cancer, heart, and age related diseases (AVRDC, 2003; Nonnecke, 1989).

Tomato production in Kenya is mainly under open field conditions, where changes in climatic conditions hinder realization of full economic yields. Weather patterns have an influence on spatial spread and yields of field grown tomato. This is mainly due to seasonality and geographic difference in altitudes. For instance, low temperatures have limiting effects on production of tomatoes in high altitudes areas of Kenya. The optimal temperature for tomato production is 21 to 24^{o}C (Kirimi *et al*., 2011). Pests and diseases, as well as poor crop management practices, are other major constraints (Varela *et al*., 2003; KARI, 2005). These result into fluctuations in market supply of tomatoes, with market glut alternating with severe shortages. By modifying the environment to provide plant growth requirements at any time of the year, the use of greenhouses has the promise of a relatively more evened out supply of fresh market tomatoes. It offers warmer conditions that promote faster growth of tomatoes (Kirimi *et al*., 2011). Most commercial tomato cultivars are selected on the basis of their yield potential over a wide range of growing conditions. The majority of greenhouse tomatoes varieties grown in Kenya are hybrids which include; Anna FI, Equador, Cal J, Rio Grande, Rodade, Onyx VF2, Nema 1200, Nema 1400 and Monyala FI (KARI, 2005).

2.5 Technical efficiency and its determinants in agriculture

Tomato production requires a high level of management, high labour and capital inputs as well as close attention to detail. This is manifested in the farmer's level of technical efficiency. Low productivity in smallholder agriculture has been attributed to the inability of farmers to fully exploit the available technologies, such as greenhouse production, resulting in lower production efficiency levels (Murthy *et al.,* 2009). According to a study by Ogunniyi and Oladejo (2011) the mean technical efficiency was 42.3% under constant returns to scale and 54.8% under variable returns to scale among open field tomato farmers in Nigeria.

Another study by Murthy *et al.*(2009) on technical efficiency among field tomato farmers in India indicated that the average technical efficiency level was 28.9% and 51.1% under constant and variable returns to scale respectively.

These levels of technical efficiency are relatively lower compared to those realized among greenhouse farmers. For instance, Hajibagheri *et al.* (2011) studied the economic efficiency of greenhouse tomato farmers in Iran and found that technical efficiency of the farmers under constant and variable returns to scale exceeded 72% and 83% respectively. Similarly, Keikha *et al.* (2012) evaluated technical efficiency of greenhouse cucumber producers in Iran and found that the average level of technical efficiency was 95.4% and that about 53.3% of the farmers had 100% efficiency levels. Croppenstedt (2005) employed Cobb- Douglas stochastic production frontier to measure technical efficiency of wheat production in Egypt. The study found that on average wheat farmers operate at 20% below the potential output.

The farmer's level of technical efficiency is influenced by various socio-economic and institutional factors. The key determinants of technical efficiency are: age, sex, education, experience in farming; credit availability, extension services, off-farm income, tenancy status, labour type, firm size among others(Birungi *et al.,* n.d.). A study by Kibaara (2005) used the Stochastic Frontier to estimate the level of technical efficiency in Kenya's maize production. Results indicated wide variations of technical efficiency within and between maize growing regions and among cropping system.

Efficiency analysis has also been applied in environmental management studies. For instance Illukpitiya (2005) studied technical efficiency in agriculture and dependence on forest resources among rural households in Sri-lanka. The findings of the study showed that the mean technical efficiencies in agriculture in forest peripherals range between 67 and 73%. Factors such as age, education, experience, nutritional status and extension service of the household head were found to determine the level of inefficiency. This was because elderly farmers or those with experience are technically more efficient in allocating resources due to learning by doing. The author also argued that farmers who receive extension assistance tend to have more knowledge on new and improved farming practices hence they become more efficient. Consistent with Kibaara (2005), the author also argued that a good nutritional status (health) of the household head reduced his or her absence from the farm and reduced inefficiency.

The nutritional status of the household head is, however, difficult to determine since it is based on the calories of food intake as is the case in Illukpitiya (2005).

Furthermore, Ogundele and Okoruwa (2006) also using a modified stochastic frontier model studied technical efficiency differentials in rice production technologies in Nigeria. In their approach, inefficiency effects were modelled as an explicit function of certain firm specific factors, and all the parameters were estimated in one step using a maximum likelihood procedure. The study results revealed that the traditional rice variety farmers employed more seeds, labour and herbicides, while they employed less fertilizer than their improved rice technology counterparts. And consistent with the findings by Niringiye *et al.* (2010), the most significant determinant of technical efficiency among both groups of technologies was farm size. Other determinants included hired labour, herbicides and seeds. Education and farming experience were found to influence technical efficiency in traditional technology.

In an analysis of the technical efficiency of rice farms in Ijesha land of Osun state, Nigeria, Tijani (2006) also used a stochastic frontier production function of a Trans log form. The study revealed that technical efficiency ranged from 29.4% to 98.2% with a mean of 86.6%. In addition to the common factors that determine technical efficiency such as off-farm income, education and farm size, the study also found that traditional preparation methods were used to frighten birds off the farms. Hence use of these techniques positively influenced technical efficiency of rice farms.

Another study on rice by Hyuha *et al.* (2007) analysed the profit inefficiency among rice producers in eastern and northern Uganda, using a Stochastic Frontier Model. Similar to the approach by Ogundele and Okoruwa (2006) the study also modelled inefficiency effects as a function of firm specific factors estimated in one step using a maximum likelihood procedure. The findings revealed that rice farmers in Eastern and Northern Uganda do not operate on the profit frontier. The major causes of inefficiency in the focus areas were: level of education, limited access to extension services and credit. It was argued that educated farmers are able to gather, understand and use information from research and extension more easily than their illiterate peers. These results are also consistent with those by Goncalves *et al.* (2008), who found that smallholder milk producers in Brazil had difficulty in obtaining credit. This restricted them from investing in improved techniques and equipment, hence, resulting in inefficiency. However, in estimating profit efficiency, Hyuha *et al.* (2007) only covered selected Sub Counties in which lowland rice is grown; and there was need to replicate this kind of study to other Sub Counties and for other crops in the country.

One major concern for researchers has been to balance between agricultural production and soil conservation. Solis *et al.* (2007) evaluated technical efficiency levels of hillside farmers under different levels of adoption of soil conservation techniques in El Salvador and Honduras. A switching regression model was implemented to examine selectivity bias for high and low level adopters and separate stochastic production frontiers corrected for selectivity bias were estimated for each group. The results revealed that households with above average adoption of soil conservation techniques showed statistically higher technical efficiency than those with lower adoption. Further, households with higher adoption had smaller farms and displaced highest partial output elasticity for land. Intuitively, a farmer with a large farm land will be less pressured to conserve the soil, to guarantee good yields. The findings by Solis *et al.* (2007) also makes sense since a large farm land also serves as security for accessing more credit, which enhances affordability of production inputs that substitute soil conservation.

Bagamba *et al.* (2007) also analysed the technical efficiency of banana production among smallholders in Uganda by using the SFA approach. They examined banana productivity with specific focus on two constraints, soil fertility and labour. Contrary to many studies, the findings revealed that proximity to the market gave mixed results.

Bagamba *et al.* (2007) argued that proximity to the market could either increase farmers' ability to access credit which enables them to buy and apply inputs. Alternatively, it could increase farmers' access to off-farm employment with higher-returns, which implies that they have to reallocate labour from the farm to non-farm activities. In addition, rent and remittances were found to reduce technical efficiencies, which is contrary to Feng (2008) and other authors. It is expected that payment of rent or remittances makes a farmer to be more committed to reducing wastage in resource use, hence such a farm will become more productive compared to one where such remittances are not paid.

Feng (2008) conducted a study to examine the effect of land rental market participation, land tenure contracts and off-farm employment on the technical efficiency in rice production in rural China. The findings were similar to those in Nigeria by Tijani (2006), with the mean technical efficiency of rice production being 82%, ranging from 36 to 97%. Further analysis revealed that households that rented land achieved higher technical efficiency than those with contracted or owned plots unlike what was observed by Bagamba *et al*. (2007). Furthermore, participation in migration did not have an effect on technical efficiency contrary to the expectation. The study presented limitations by relying on various assumptions about the standard errors, such as homoscedasticity and independence of different plots managed by the same household. However, the statistical tests for the validity of these assumptions were not addressed. The study also focused on the plot as the unit of analysis and not the household, thus it ignored implicitly the heteroskedasticity between different households.

Another important factor that influences inefficiency according to Kebede (2001) is gender. The author studied rice producers' technical efficiency in Mardi watershed in Nepal using the SFA approach, and found that female headed households were more efficient. This implies that females carry out most of the farming activities in the study area, with frequent follow-ups and supervision than males. Similarly, a review of studies undertaken in the late 1980s and early 1990s found that when differences in inputs are controlled for, there were no significant differences in technical efficiency between male and female farmers (Quisumbing, 1996). However, it has often been argued that the lower level of physical and human capital among female farmers results in lower measured productivity or inability to respond to economic incentives.

Kebede (2001) also incorporated a land quality variable and found that farmers with poor quality of soil were more technically efficient than their counterparts. This could either imply that higher technical efficiency was achieved through 'mining' the soil, or that these farmers provided extra effort in production activities to make the best of their land. The study however relied on the farmer demonstrations of land quality and failed to explore the history of the plots and the plot-specific physical characteristics which makes this finding partially questionable.

Another study on technical efficiency in rice production was done by Seidu (2008) in Northern Ghana. Like Tijani (2006) and other authors, he adopted the trans-log stochastic frontier function and the results revealed that rice farmers were technically inefficient, while there was no significant difference in technical efficiency between non irrigators (53%) and irrigators (51%). The results further revealed that apart from the earlier identified variables, family size also influenced technical inefficiency. This is not widely reported in literature, however, it is consistent with Bagamba *et al.* (2007) who argued that family size influences technical efficiency through its effect on the labour endowment of an individual household.

Large families were found to be more efficient, since they have the manpower to implement farming activities on time. However, the most unique finding by Seidu (2008) revealed that 14% of the variations in rice output were caused by factors beyond the farmers' control such as erratic rainfall, crop diseases, worms, bush fires, birds and grasshoppers.

According to Tchale (2009) in his analysis of Malawi's smallholder agricultural efficiency, it was observed that smallholder production in developing countries is characterised by many variations and therefore the use of the parametric frontier approach such as stochastic Frontier Approach (SFA) is more appropriate. The non-parametric approaches such as the Data Envelopment Analysis (DEA) are free from mis-specification but do not account for the effect of other factors outside the control of farmers. The findings revealed that fertilizer, land and labour (for labour intensive crops) were key factors in production of major crops grown by smallholder farmers in the maize-based farming system. The average level of technical, allocative and economic efficiencies were 53%, 46% and 38% respectively. The results imply that allocative (cost) inefficiency is worse than technical inefficiency. This echoes the need for more research on allocative efficiency as well.

Additional findings by Tchale (2009) indicated that the size of land holding (farm size) inversely influenced technical efficiency contrary to findings by Croppenstedt (2005) and Fernandez *et al*. (2009). This implies that as the land holding increases it becomes more involving to manage it, thus decreasing the level of technical efficiency.

Tchale (2009) also found that the use of purchased seed improved the degree of technical efficiency, such that farmers who planted purchased seeds showed an average of 9% higher level of efficiency than those who did not. Similar to Idiong (2007), the author also found that farmers who were members in extension-related, market-related or credit-related organisations exhibited higher levels of efficiency than non-members. It was also revealed that informal sources of learning and information sharing helped farmers in updating their farming methods; hence this positively influenced their efficiency levels. Tchale (2009) also found that assets owned by the farmers improved their liquidity position thereby ensuring that they were able to respond rapidly to demand for cash to buy inputs and other factors. Furthermore, in reality individuals also invest in assets that generate more income to supplement their farm income or facilitate their movement and the ease of information sharing. Therefore, asset ownership is a positive determinant of technical efficiency.

While the stochastic frontier approach has been widely used in the efficiency literature, the Data Envelopment Analysis (DEA) approach has also been used in some studies especially where scale efficiency is measured. According to Binam *et al.* (2003) the average level of technical efficiency among coffee farmers in Cote d'Ivoire was 36%. In addition, farm size, ethnic cohesion and membership to farmer groups and associations were the most significant factors that were found to influence technical efficiency. These findings were similar to those by Tchale (2009). The study employed the DEA technique to compute farm- level technical efficiency measures of peasant farmers in Cote d'Ivoire; while the two limit Tobit regression technique was used to examine the relationship between technical efficiency and various farm or farmer characteristics. The approach is acceptable and has been applied by many other others using the DEA technique.

Another study is by Tahir *et al.* (2009) who used a non-parametric DEA approach to estimate technical and scale efficiency of Malaysian commercial banks. The results indicated that the degree of scale efficiency was lower than the degree of overall or technical efficiency. Impliedly, the portion of overall inefficiency was due to producing at inefficient scale rather than producing below the production frontier. This study thus brought out a new realization that the whole portion of inefficiency in smallholder agriculture is not often as a result of technical inefficiency; hence there is need for more scale efficiency studies to be done.

Niringiye *et al.* (2010) also did a study to establish the relationship between farm-size and technical efficiency in East African manufacturing firms. The study adopted a two stage methodology to examine the relationships. In the first step, technical efficiency measures were calculated using DEA approach while in the second step the GLS technique was used where a technical efficiency equation was estimated to investigate whether technical efficiency is increasing with firm size. The findings were consistent with those by Edeh and Awoke (2009) and Tchale (2009), revealing a negative association between firm size and technical efficiency in manufacturing firms.

However, Fernandez *et al*. (2009) used the same approach to analyse the level of technical efficiency in sugarcane production in Philippines and found contradicting results. In addition, labour, land, seeds, NPK fertilizer and power inputs were found to be the most binding constraints. In addition, farmers' age, farming experience, access to credit, nitrogen fertilizer application, soil type and farm size influenced technical efficiency positively. The results by

Fernandez *et al*. (2009) regarding the influence of farm size are contrary to most studies reviewed, though it implied that larger farms would have a beneficial impact on the efficiency of the Philippines' sugar industry.

The production function approach has also been used in efficiency analysis, although there are few such cases. Goni *et al.* (2007) analysed resource use efficiency in rice production in Nigeria. In their analysis, a conventional neoclassical test of economic efficiency was derived where; the ratio of the marginal value productivity and marginal factor cost was used to determine the economic efficiency of resource use. In addition, the elasticity of production was used to compute the rate of return to scale for determining the technical efficiency levels of firms, as proposed by Farell (1957). The findings from the study revealed that rice farmers were technically inefficient in the use of farm resources. Specifically, fertilizer, seeds and farmland were underutilised, while labour was over utilized. The inefficiency was attributed either directly or indirectly to the high cost of fertilizer, rent and seed inputs. The findings in this study are still relevant though they left out some farm inputs, like herbicides and pesticides, given that one of the greatest challenges facing small-holder agriculture has been found to be pests and diseases.

2.6 Theoretical and conceptual framework

2.6.1 Theoretical framework for measuring efficiency

The theoretical formulation for this study is based on the theory of the firm and has been borrowed and modified from Hyuha *et al.* (2007). The theory of the firm states that firms exist and make decisions in order to maximize profits. They interact with the market to determine pricing and demand and then allocate resources according to models that ensure they maximize net profits. In measuring economic efficiency of a firm we require an understanding of the decision making behaviour of the producer. A rational producer, producing a single output from a number of inputs, $x = x_1 \ldots\ldots x_n$, that are purchased at given input prices, $w = w_1 \ldots\ldots w_n$ is thought to be efficient if operating on a production frontier. But if the producer is using a combination of inputs in such a way that it fails to maximize output or can use less inputs to attain the same output, then the producer is not economically efficient. A given combination of input and output is therefore economically efficient if it is both technically and allocatively efficient; that is, when the related input ratio is on both the isoquant and the isocost curve.

The figure below (Figure 1) is a diagrammatic exposition with a simple example of firms using two inputs land and labour to produce greenhouse tomatoes. Firms producing along AB are said to be technically efficient because they are operating on the “efficiency frontier” or the isoquant, although they represent different combinations of land and labour inputs, used in producing output Q. This is the least cost combination of inputs. In addition, DD' is an isocost line, which represents all combinations of inputs, land and labour, such that input costs sum to the same total cost of production, given the firm’s budget. However, any firm intending to maximize profits has to produce at X, which is a point of tangency and representing the least cost combination of land and labour in production of Q metric tonnes of tomatoes. Therefore, at point X the producer is economically efficient.

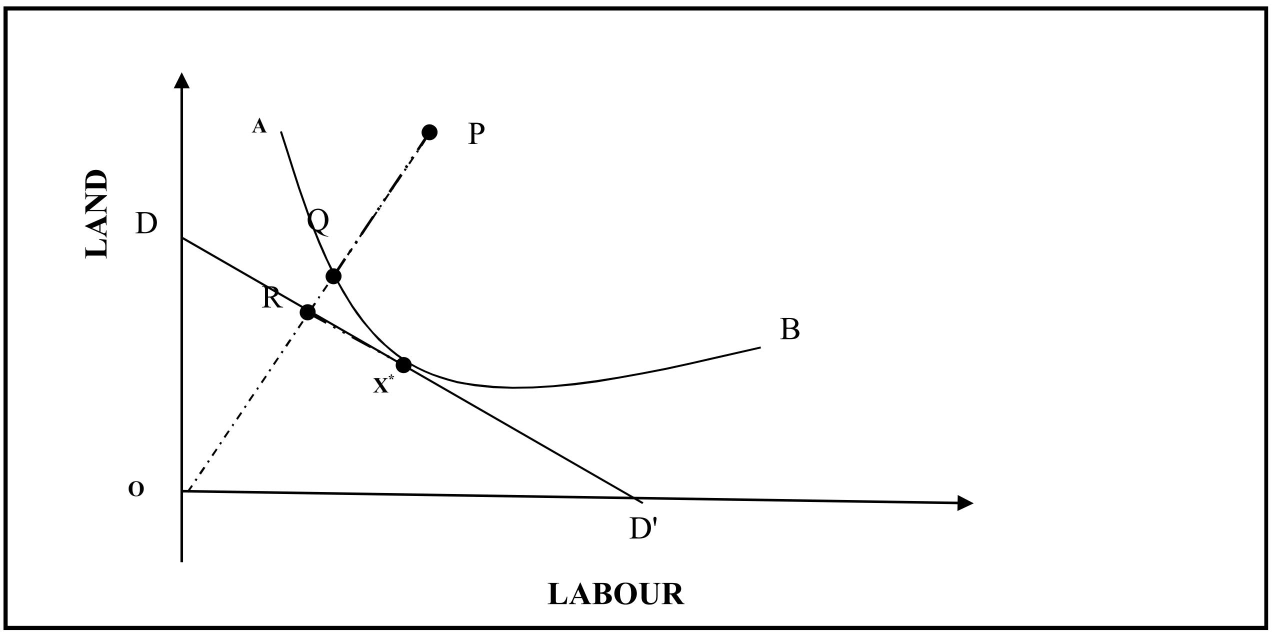

Figure 1: Technical, allocative and economic efficiency
(Source: Hyuha *et al.,* 2007)

To illustrate the measurement of technical efficiency, we suppose a greenhouse tomato producing firm whose output is depicted by isoquant AB, with input (land and labour) combination levels as shown in Figure 1. At point P of input combination, the production is not technically efficient because the farmer can instead produce at Q (or any point on AB) with fewer inputs. The degree of technical efficiency of such a firm is given as TE= OQ/OP. For a fully efficient firm, TE = 1 but for all inefficient firms a degree of TE < 1 is achieved. The difference between the estimated TE and 1 (or TE_i-1) depicts the proportion by which the firm should reduce the ratios of both inputs used to efficiently produce a metric ton of tomatoes (Gelan and Muriithi, 2010).However, TE does not take into account relative costs of inputs which are captured in the discussion of allocative and economic efficiency measures.

The slope of the isocost line DD^1 represents the input price ratio. Point R is the point of Allocative efficiency (AE) and can be calculated by the ratio OR/OQ. The decrease in production costs with the distance from Q to R would happen if production is performed at point X which is allocatively and technically efficient instead of producing at point Q which is technically efficient but allocatively inefficient.

The total economic efficiency (EE) is defined as the ratio OR/OP which combines technical efficiency and allocative efficiency. The distance from P to R represents the costs cut if the firm produces at point R with technical efficiency and allocative efficiency instead of at point P with technical inefficiency and allocative inefficiency.

2.6.2 Conceptual framework

The conceptual framework for this study is operationalized as shown in Figure 2, which represents how various factors inter-relate to influence greenhouse tomato productivity and hence the welfare of tomato producers. The policy environment is characterized by the existing political and economic trends in the country which have an influence on the farming system and indirectly determine the tomato output. However, within the farming system various sets of factors inter-relate to determine tomato productivity.

Production factors such as labour, seeds, fertilizers, crop land, manure, insecticides and fungicides are used as inputs into the production process. The availability and distribution of these inputs may be influenced by the policy framework in place, which in-turn determines the extent of tomato productivity. It is expected that the more inputs used by the farmer, the higher the tomato yields per hectare of land. Although for chemical inputs, increased usage may produce negative effects on output if the farm has reached diminishing returns with respect to that input.

Tomato productivity is also affected by the farm's level of technical efficiency. This is supported by the notion that for a production process to be effective, the manner in which available farm resources are utilized is crucial. But the farm's technical efficiency is also influenced by institutional and socio-economic characteristics of the farmer. Institutional factors such as group membership, credit-access and extension contacts are hypothesised to have a positive influence while distance to the nearest input dealer has a negative effect on technical efficiency.

Socio-economic characteristics of the farmer such as education level, farming experience, off-farm income, household size, cost of greenhouse items and land tenure are hypothesized to influence technical efficiency positively. On the other hand, age of the household head has a negative influence on technical efficiency.

A farm that is technically efficient is therefore expected to realize higher tomato output per hectare compared to one that is less technically efficient in production. Furthermore, such a firm is hypothesised to incur less production costs leading to higher returns from the enterprise. This has a positive spill over effect on the welfare of the tomato producing household. Improved welfare of the household then provides a feedback effect in form of increased access to production inputs and relevant lessons to policy makers.

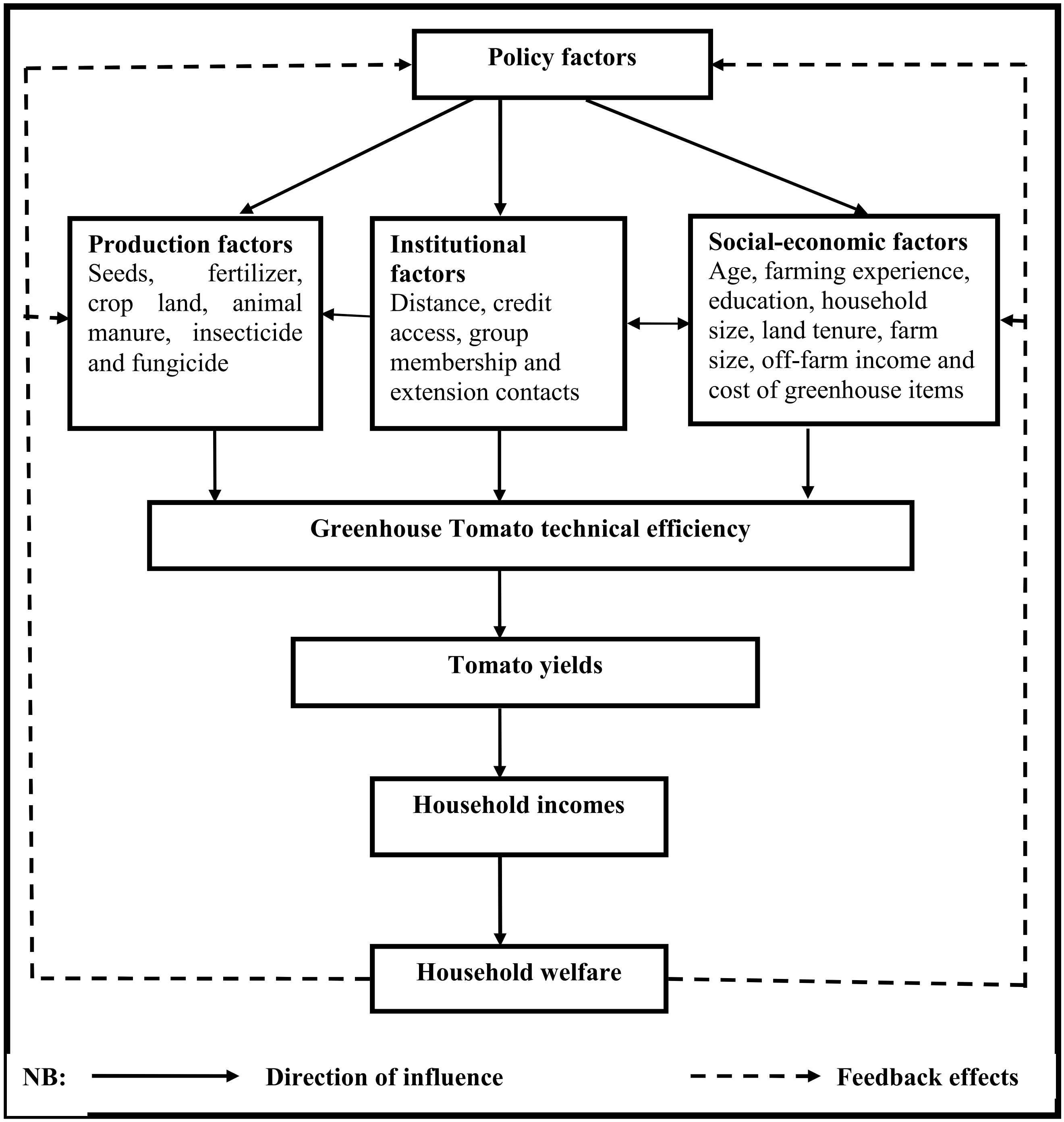

Figure 2: The conceptual framework of factors influencing technical efficiency

(Adapted from New Institutional Economics theory)

CHAPTER THREE
METHODOLOGY

3.1 Study area

The study was conducted in three sub counties (Nakuru, Njoro and Rongai) of Nakuru County. Nakuru Sub County covers an area of 297.2 Km^2. The Sub County has approximately 27,920 farm families with a population of about 309,783 persons. It has three divisions (Municipality, Barut and Lanet), seven locations and 22 sub-locations. Njoro Sub County covers an area of 702 Km^2. The Sub County has approximately 28,791farm families with a population of about 178,180 persons. It has four divisions (Njoro, Lare, Mau-Narok and Mauche), 23 locations and 44 sub-locations. Finally, Rongai Sub County covers an area of 993.1 Km^2. The Sub County has approximately 19,739 farm families with a population of about 142,123 persons. It has four divisions (Kampi ya Moto, Ngata, Rongai and Solai), 18 locations and 38 sub-locations.

The main agro-ecological zones and major agricultural activities in Nakuru County are as given in Appendix 2. There are 14 agro ecological zones ranging from Tropical Alpine (TA) to Lower Midlands (LM). The altitude ranges from 1480-3050 meters above sea level and the rainfall from 550-1900 mm per annum (Appendix 2). In addition, the average temperatures vary from 20-35^{0}C.

The study specifically targeted greenhouse tomato production among smallholder farmers in Nakuru County. Promotions of greenhouse tomato production by various stakeholders have in the recent past, targeted mainly smallholder farmers in a bid to adapt to climate induces effects across Nakuru County. The Technology is picking up across the county.

The three Sub Counties were purposively selected for the study because they are relatively vulnerable to climate change hazards especially drought and that most smallholder farmers in these Sub Counties have adopted greenhouse tomato production technology (GoK, 2008).

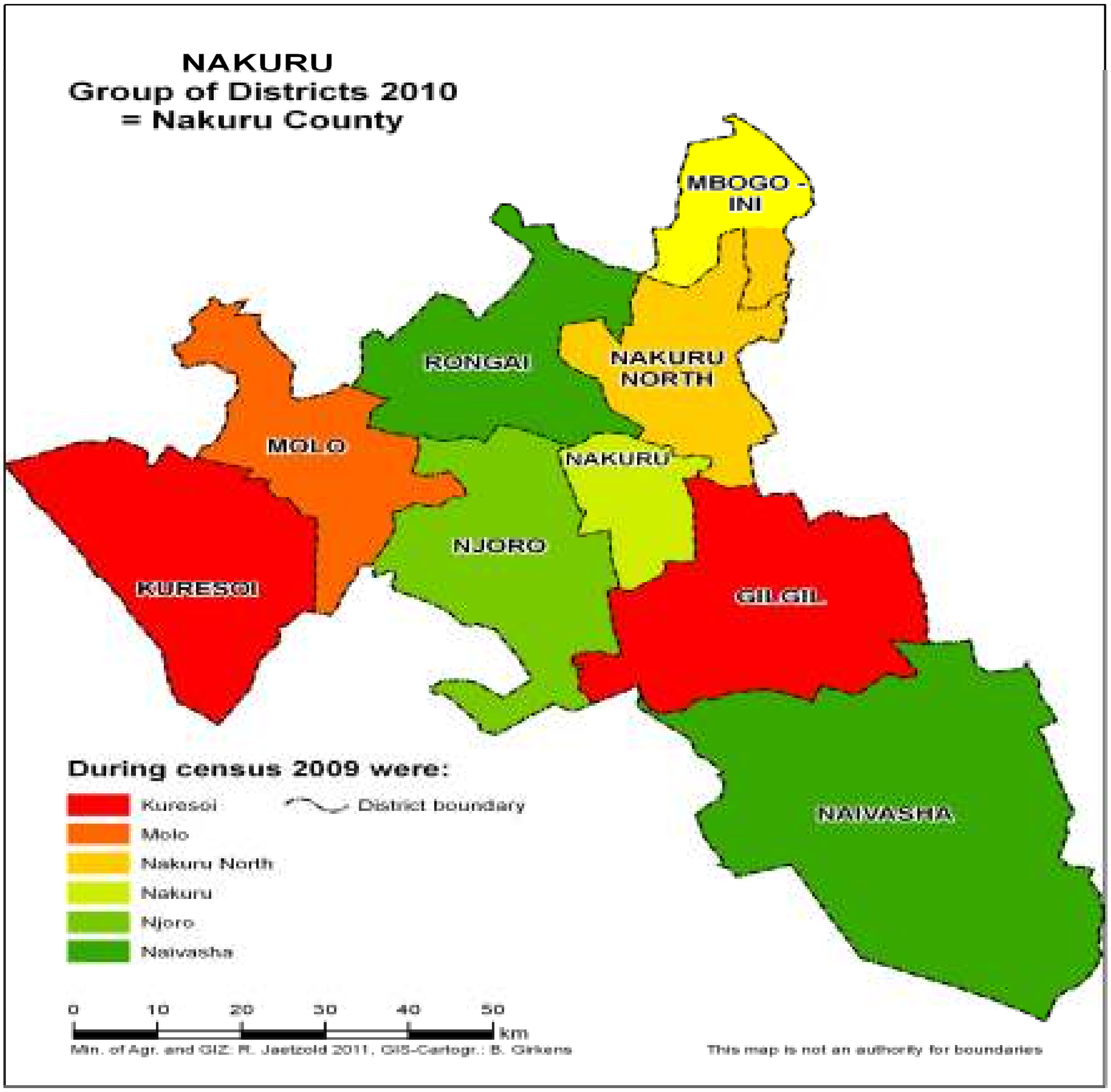

Figure 3: Map of Nakuru County showing the nine Sub Counties (Source: Ralph *et al.,* 2009)

3.2 Sample size and sampling procedure

The study adopted a purposive sampling technique in the selection of three out of the nine Sub Counties in Nakuru County. In each Sub County, all the smallholder greenhouse tomato farmers were selected for the study. This was occasioned by the limited number of greenhouse tomato farmers in the study area; hence, this approach was essential for attaining the desired sample size. The lists of greenhouse farmers were obtained from the respective Sub County agricultural officers

3.3 Methods of data collection and data sources

Both primary and secondary data were collected. Primary data was collected through observations and interviews using a semi-structured questionnaire which was administered to smallholder greenhouse tomato farmers. The data included information on greenhouse tomato farming operations such as: quantities of seeds, planting and topdressing fertilizer, pesticides, herbicides, fungicides, manure, crop land, irrigation water and labour man-days. Corresponding information on average input prices was also collected from the respondents. The land area under greenhouse tomato (hectares) was then used to standardize the rest of the inputs, so that each input was considered in terms of the quantity per hectare.

Additional data focused on household socio-economic and institutional characteristics such as the farmer's age, gender, years of schooling, farming experience, primary and secondary occupation, household size, the income profile, and distance to the input dealer, extension contacts, group membership and credit. In addition, secondary data was sourced from; Ministry of Agriculture (MoA). The secondary data collected comprised of climatic data and County profile.

3.4 Data analysis

Descriptive statistics, Principal Component Analysis (PCA) and K-means cluster analysis were used to achieve the first objective; to characterize smallholder greenhouse tomato farmers. Descriptive statistics results were presented in tables and charts from which inferences were drawn. Comparison of variances across the three Sub Counties was done using ANOVA and chi-square tests at 5% significance level.

The PCA is a data reduction technique used to reduce the number of dimensions in a large number of variables to just few dimensions called principal components.Principle components are a set of linearly uncorrelated values generated through an orthogonal transformation to represent a set of observations of possibly correlated variables (Ilin and Raiko, 2010). The PCA is widely adopted as an effective dimension reduction method since it uses singular value decomposition which gives the best low rank approximation to original data. Through the extraction process nine socio-economic and seven production variables were identified which satisfied the minimum requirements for PCA and were able to explain a sufficient portion of the variance of all the original farmer and farm factors.

Thereafter, cluster analysis procedure was used to identify relatively homogeneous groups of farmers based on sets of characteristics selected through PCA. There are three different procedures that can be used to cluster data in SPSS computer software. These are hierarchical, k-means and two-step cluster analysis. This study opted for the k-means clustering since it is applicable to a moderately sized data set. In addition, it does not require computation of all possible distances or similarity between the pairs of cases.

A stochastic frontier production function was used to analyse the second objective; to evaluate the levels of technical efficiency of greenhouse tomato farms, from which the technical efficiency scores for each farm were obtained. Finally a two limit Tobit regression model was estimated to determine factors influencing the levels of technical efficiency among greenhouse tomato farms (objective three). The descriptive statistics and principal component analysis were run in SPSS (version 17) while the empirical models (stochastic frontier and two limit Tobit regression model) were run in STATA (version 9) computer soft-wares.

3.5 Stochastic Frontier Model specification:

There have been a series of studies in the analysis of efficiencies in all fields following Farrell's (1957) contribution. Specifically in the field of agriculture, the modeling and estimation of the stochastic function by Aigneir *et al.* (1977) and Meeusen and van den Broeck (1977), has proven to be instrumental. There are two approaches that have been used in measuring efficiency namely: the parametric and non-parametric models, which differ in two ways. Firstly, they differ on assumptions of the distribution of the error term that represents inefficiency. Secondly, they differ in the way in which the functional form is imposed on the data. Parametric models use econometric approaches to impose functional and distributional forms on the error term whereas the non-parametric models do not (Hyuha *et al.,* 2007). However, parametric models have been criticized, in the sense that they do not take into account the possible influence of measurement errors and other noises in the data. This is the main strength of the stochastic frontier models (Thiam *et al.,* 2001). The results from parametric models can also be misleading because they do not allow for a random error as is the case with stochastic frontier models. Besides, non-parametric models lack statistical tests that would tell us about the confidence of the results. For this reason, this study adopted the stochastic frontier model to evaluate the levels of technical efficiency among greenhouse tomato farms.

3.5.1 Stochastic frontier model

The basic structure of the deterministic production frontier model proposed by Afriat (1972) is as shown in Equation 1.

$$Y = f(x, \beta) e^{-\mu}$$ …………………………………………………………………………. *Equation 1*

Where *f* (x, ß) is the frontier production function and µ is a one-sided non-negative distribution term. This model imposes a constraint of $\mu \geq 0$, which implies output is less than or equal to the potential, within the given input and output prices. The model is in full agreement with production theory, but the main criticism against it is that all the observed variations are accounted for by the management practices as pointed out in section 3.5. However, no account is taken of statistical noise such as random errors, omitted variables and shocks.

As a result of this weakness in the deterministic production frontier model, Aigneir and Chu (1968) made the first contribution in developing stochastic frontier models by suggesting a composite error term. Since their work, much effort has been exerted to finding an appropriate model to measure efficiency. This resulted in the development of a stochastic frontier model. The model improved the deterministic model by introducing 'ν' into the deterministic model to form a composite error term model or a stochastic frontier model. The composite error term is assumed to have two additive components. The first is a symmetric component which represents the effect of statistical noise (e.g. weather, topography, distribution of supplies and measurement error among others). The second is a random error component that captures systematic influences that are unexplained by the production function and are attributed to the effect of technical inefficiency (Tijani, 2006). The model is as specified in Equation 2.

$$Y = f(x, \beta) e^{(\nu - \mu)}$$ ………………………………………………………………………………. *Equation 2*

Where *f* (x, ß) is the frontier production function and ν-µ is the error term. The V_i's are random variables which are assumed to be independent and identically distributed as N $(0, \delta V^2)$ and independent of the μ_i's which are distributed as $N(0, \delta u^2)$.The μ_i's are the non-negative random variables assumed to account for technical inefficiency in production.

From Equation 2, it is possible to derive the technically efficient input quantities (X_{it}) for a given level of output Y^*. Assuming that Equation 2 is a self-dual production frontier function such as the Cobb-Douglas functions, and then the dual cost frontier function can be expressed as shown in Equation 3.

$$C_i = g(P_{i;}\alpha)e^{(v+\mu)} \quad \text{…………………………………………………………………………. Equation 3}$$

where C_i is the minimum cost incurred by the greenhouse tomato farm to produce output Y; P_i represents a vector of input prices employed by the greenhouse tomato farm in tomato production; α is the parameter to be estimated; while $V_i's$ and μ_i's are as specified in Equation 3. Then apply Shepherd's Lemma in partially differentiating Equation 3 with respect to each input price to obtain the system of minimum cost input demand equations as given in Equation 4.

$$\frac{\partial C}{\partial P_i} = X_{di} = f(P_i Y_i; \varphi) \quad \text{…………………………………………………………………………Equation 4}$$

In equation 4, φ is a vector of parameters to be estimated. Further, it is now possible to calculate the cost of the actual or observed input bundle as $\sum_i X_i * P_i$ while the costs of the technically efficient input combinations, given the farms' observed level of output Y_i, are given by $\sum_i X_{it} * P_i$. Hence we calculate technical efficiency estimates based on these cost measures as follows given in Equation 5.

$$TE_i = \Sigma_i X_{it} * P_i \Big/ \Sigma_i X_i * P_i = \frac{\cos t \ of \ TE \ input \ bundle}{\cos t \ of \ observed \ input \ bundle} \quad \text{………………Equation 5}$$

It is further assumed that the average level of technical efficiency, measured by the mode of the non-negative half-normal distribution (i.e. U_i), is a function of exogenous factors believed to affect inefficiency as shown in Equation 6.

$$U_i = \delta_0 + \delta_i Z_i \quad \text{……………………………………………………………………………… Equation 6}$$

Where Z_i is a column vector of hypothesized technical inefficiency determinants and δ_o and δ_i are unknown parameters to be estimated. It is however important to mention that in this study, the factors influencing efficiency were determined using the Tobit model as is explained in section 3.5.3, instead of incorporating them in the stochastic frontier model as shown in Equation 6 above.

3.5.2 Empirical stochastic frontier model

The Cobb-Douglas (C-D) functional form of the stochastic frontier production function was employed for this study because it is self-dual and therefore it allows for the estimation of both the production and cost functions in logarithm form. Therefore the estimated coefficients reflect the output elasticities (Kumbhakar and Lovell, 2000). However, the C-D is usually fitted and highly restrictive with respect to returns to scale and elasticities than the transcendental logarithmic form employed in many studies (Bagamba *et al.,* 2007; Tijani, 2006). In any case, the impact of functional form on estimated efficiency levels has been reported to be very limited (Kopp and Smith, 1980). Thus the stochastic frontier production function is reduced as given in Equation 7:

$$\ln Y_i = \beta_0 + \sum_{i=1}^{8} \beta_i \ln X_i + (V_i - U_i) \qquad \text{……………………………………………………. } \textit{Equation 7}$$

Where Y_i is the greenhouse tomato yield (Kgs); X_1 is the area under greenhouse (ha); X_2 is labour (man-days); X_3 is fertilizer (Kgs); X_4 is foliar (litres); X_5 is Insecticide (Kgs); X_6 is fungicide (Kgs), X_7 is animal manure (Kgs) and X_8 is seeds. U_i captures the level of farm-specific technical inefficiency; and V_i is the statistical disturbance term.

Table 1: Variables used in the stochastic frontier production function

Variable	Description	Expected sign
Dependent(y)	Total greenhouse tomato yield in Kgs	
Cropland	Area of land under greenhouse tomato production in ha	+
Labour	Labour used in tomato production in man-days	+
Fertilizer	Quantity of inorganic fertilizer used in Kgs	+
Foliar	Quantity of foliar sprayed in litres	+
Insecticides	Quantity of insecticides sprayed in Kgs	+
Fungicides	Quantity of fungicides sprayed in Kgs	+
Manure	Quantity of animal manure applied in Kgs	+
Seeds	Quantity of seeds applied in Kgs	+

3.5.3 Tobit model

The technical efficiency estimates obtained by the methods described in sections 3.5.1 and 3.5.2 were regressed on selected socio-economic and institutional characteristics by use of the Tobit model. This approach has been used widely in efficiency literature (Nyagaka *et al.,* 2010; Obare *et al*., 2010). The socio-economic and institutional factors regressed here included age, education, household size, farming experience of the farmer, land tenure, off-farm income, extension contacts, cost of greenhouse items, distance to the market, group membership and credit. The choice of these variables was intuitive although they have been found to have an effect on technical efficiency among smallholder farmers. The structural formula of the Tobit model is shown in Equation 8.

$$y_i^* = X_i\beta + \varepsilon_i \quad \text{………………………………………………………… Equation 8}$$

where y_i^* is a latent variable for the ith greenhouse tomato farm that is observed for values greater than τ and censored for values less than or equal to τ. The Tobit model can be generalized to take account of censoring both from below and from above. *X* is a vector of independent variables postulated to influence efficiency. The β's are parameters associated with the independent variables to be estimated. The ε is the independently distributed error term assumed to be normally distributed with a mean of zero and a constant variance. The observed y is defined by the generic measurement Equation 9.

$$y_i = y^* \; if \;\; y^* > \tau$$

$$y_i = \tau_y \; if \;\; y^* \leq \tau \qquad \text{...} \; \textit{Equation 9}$$

Typically, the Tobit model assumes that $\tau = 0$ which means that the data is censored at zero. However, farm-specific efficiency scores for the greenhouse tomato farms range between 0-1. Thus we substitute τ in Equation 9 to give Equation 10.

$$y_i = y^* \; if \;\; 0 < y^* < 1$$

$$y_i = 0 \; if \;\; y^* \leq 0$$

$$y_i = 1 \; if \;\; y^* \geq 1 \qquad \text{...} \; \textit{Equation 10}$$

Therefore the model assumes that there is an underlying stochastic index equal to $(X_i\beta + \varepsilon_i)$ which is observed only when it is some number between 0 and 1; otherwise y_i^*qualifies as an unobserved latent (hidden) variable. The dependent variable is not normally distributed since its values range between 0 and 1. The empirical Tobit model for this study therefore takes the form in Equation 11.

$$y_i^* = \beta_0 + \sum_{n=1}^{11} \beta_n X_i + \varepsilon_i \qquad \text{...} \; \textit{Equation 11}$$

Where: X_1 = age (years); X_2 = farming experience (years); X_3 = education (years); X_4 = household size; X_5 = off-farm income (KES); X_6 = distance to the input market; X_7 = Credit; X_8 = Group membership; X_9= land tenure; X_{10}= Extension, X_{11}= Cost of greenhouse items. It is important to mention that estimating the model using OLS would produce both inconsistent and biased estimates (Gujarati, 2004). This is because OLS underestimates the true effect of the parameters by reducing the slope (Goetz, 1995). Therefore, the maximum likelihood estimation is recommended for Tobit analysis.

Table 2: Variables used in the Tobit regression model

Variable	Description	Expected sign
Dependent (u)	Technical efficiency of the i^{th} farm	
Age	Number of years of household head	-
Education	Education level of the household head in years	+/-
Experience	Number of years of farming of the household head	+
Extension	Number of extension contacts received	+
Offinc	Amount of off-income received in KES	+
Distance	Proximity to the nearest input dealer in Km	-
Grpmship	Membership in a producer group (1=Yes; 0= No)	+
Credit	Amount of credit borrowed for farming activities in KES	+
Greenhouse items cost	Cost of greenhouse equipment in KES	+
Household size	Number of household members	+
Land tenure	Land ownership by title deed (1=with title deed; 0= otherwise)	+

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter presents findings from the research which was done to evaluate the levels of technical efficiency of greenhouse tomato production among smallholder farmers in three Sub Counties of Nakuru County, Kenya. The presentation is divided into three sections. The first section discusses in detail Descriptive results on the socio-economic and greenhouse tomato production characteristics of smallholder greenhouse tomato farmers. The second section presents stochastic frontier results on technical efficiency of smallholder greenhouse tomato farmers. Finally, the third section presents the two-limit Tobit results on factors influencing technical efficiency of smallholder greenhouse tomato farms in Nakuru County.

4.1 Descriptive results

4.1.1 Socio- economic Characteristics of smallholder greenhouse tomato farmers

The socio-economic characteristics presented in this section include: gender of the household head, age, education, Household size and amount of off-farm income. The summary statistics of these socio-economic characteristics are as shown in table 3 below.

Table 3: Summary statistics of the household socio-economic attributes by Sub County

	Means				ANOVA by Sub Counties	
Variables	**Njoro**	**Nakuru**	**Rongai**	**Overall**	**F/Chi-square value**	**Sig**
% of male headed HHs	78.95	53.33	86.27	75.00	11.127***	0.004
Age (years)	58.00	43.97	50.78	50.11	8.69***	0.000
Education (years)	14.11	13.43	14.96	14.34	3.760**	0.027
HH size (number)	5.95	2.73	4.41	4.20	20.51	3.721
Off-farm income (KES)	7973.68	12766.70	12122.55	11527.51	1.35	0.265

*** Significant at 1% level and ** significant at 5% level.

Source: Field survey data (2011)

In general, 75% of the households were male headed (Table 3). Specifically, majority of the households in Rongai (86.27%) and Njoro (78.95%) were male headed compared to Nakuru who were 53.33%. In addition, Chi-square results showed that sex of the household head was statistically significant; indicating that male headed households were more than the female headed households across all the Sub Counties in the study area. The low number of female headed greenhouse farmers can be explained by the fact that the majority of the female headed households have limited land and labour resources which limits them from generating sufficient income to engage in commercial activities (Kherallah *et al*., 2001).

The mean *age* was about 58, 44 and 51 years for farmers from Njoro, Nakuru and Rongai Sub Counties respectively. Overall the respondents had an average age of 50 years. Result of ANOVA test showed an F-value of 8.69, significant at 1% level indicating that there was a significant variation in terms of age across the three Sub Counties. According to Ali (1995) and Bravo *et al.,* (1994), age is one of the factors that affect the efficiency of carrying out farm activities.

The respondents had an average education level of about 14 years. Farmers in Njoro, Nakuru and Rongai had a mean education level of about 14, 13 and 15 years respectively. ANOVA test results also indicated an F-value of 3.76, significant at 5%; hence, there was significant variation in terms of education across Sub Counties. Literacy level plays a role in management. In most cases low literacy levels limit the farmers' managerial ability (Mangisoni, 1989).

4.1.2 Farm Size and production characteristics

Table 4: Average quantities of greenhouse tomato production inputs used and total production costs by Sub County

	Means				ANOVA by Sub Counties	
Variables	**Njoro**	**Nakuru**	**Rongai**	**Overall**	**F-value**	**Sig**
Farm size (Ha)	2.25	0.27	4.30	2.70	5.88**	0.004
crop land (Ha)	1.34	0.16	1.88	1.26	1.86	0.198
Seed (Kgs/Ha)	5.33	10.66	2.46	5.74	4.81***	0.011
Planting Fertilizer (Kgs/Ha)	420.25	393.20	822.46	628.53	5.96***	0.004
Manure (Tons/Ha)	45.73	1,058.98	51.17	352.48	12.92***	0.000
Insecticide (Kgs/Ha)	29.52	46.33	52.48	46.33	11.46***	0.000
Fungicide (Kgs/Ha)	19.68	48.79	66.42	52.48	2.86*	0.062
Weekly Irrigation water (Litres/week/Ha)	130,717.02	2,692,161.27	81,386.64	873,991.67	17.27	3.850
Yield (Kgs/Ha)	81,395.66	85,717.47	123,085.28	103,966.16	4.39**	0.015
Total production Costs/Ha (000's KES)	3,384,849.42	3,250,795.10	4,098,759.2	3,708,727.10	2.20	0.116

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

Source: Field survey data (2011)

The respondents had an average farm size of about 2.70 hectares (Table 4). Farmers in Njoro, Nakuru and Rongai Sub Counties had a mean farm size of about 2.25, 0.27 and 4.30 hectares respectively. Result of ANOVA test showed an F-value of 5.88, significant at 1% indicating that the variation in farm size across Sub Counties was statistically different. The results indicate that land distribution among greenhouse tomato farmers in the study area was uneven.

The mean for seed rate was 5.7 kilograms per hectare. In terms of Sub Counties, farmers had a mean of 5.33, 10.66 and 2.46 kilograms per hectare in Njoro, Nakuru and Rongai Sub

Counties respectively.Further ANOVA test showed an F-value of 4.81, significant at 1% indicating that seed application rates varied across Sub Counties.

Planting Fertilizer application had an overall mean of 628.53 kilograms per hectare. Across Sub Counties, farmers had a mean of 420.25, 393.2 and 822.46 kilograms per hectare in Njoro, Nakuru and Rongai respectively. In addition, there was a significant variation at 1% level in terms of planting fertilizer application rates across Sub Counties. Manure application had an overall mean of 352.48 tons per hectare. Across Sub Counties, farmers had a mean of 45.73, 1058.98 and 51.17 tons per hectare in Njoro, Nakuru and Rongai respectively. ANOVA test results also indicated that the variation in manure application rates across Sub Counties was statistically significant at 1%.

Fungicide application had an overall mean of 52.48 kilograms per hectare across sub counties. Respondents in Njoro, Nakuru and Rongai sub counties had a mean of 19.68, 48.79 and 66.42 kilograms per hectare respectively. Result of ANOVA test showed an F-value of 2.86, significant at 10% indicating that the variation in fungicide application across Sub Counties were statistically significant. The mean overall yield was 103,966.16 kg per hectare. Across Sub Counties, the respondents had a mean yield of about 81,395.66 Kilograms per hectare in Njoro Sub County, 85,717.47 Kilograms per hectare in Nakuru Sub County and 123,085.28 kilograms per hectare in Rongai Sub County. Result of the ANOVA test showed an F-value of 4.39, significant at 1% indicating that there was a significant variation in greenhouse tomato yields across Sub Counties.

Table 5: Distribution of Greenhouse farmers by land use, land tenure and major food crops cultivated by Sub County

Characteristic	Category	Sub County (Percentage)			Overall	Chi-square	Sig
		Njoro	Nakuru	Rongai			
Land use	Forest	63.2	10.3	46.9	39	32.13***	0.000
	Subsistence crops	31.6	44.8	46.9	43		
	Cash crops	5.3	41.4	2.0	15		
	Livestock	0	3.4	4.1	3		
Land tenure	Without title	31.6	16.7	27.5	25	1.71	0.425
	With title	68.4	83.3	72.5	75		
Major food crops cultivated	Maize	89.5	13.3	39.2	41	77.36***	0.000
	Beans	5.3	3.3	0	2		
	Kales	5.3	6.7	0	2		
	Tomatoes	89.5	76.7	60.8	55		

*** Significant at 1% level

Source: Field survey data (2011)

Results in Table 5 show that 39% of the respondents had allocated their land under forest, 43% under subsistence crops and 15% under cash crop production while 3% under livestock production. Results of a chi-square were statistically significant at 1% indicating that there was a significant variation among the three Sub Counties in terms of land allocation.

With respect to land tenure, 75% of the respondents owned land with a title deed while 25% owned land without a title deed. The chi-square analysis was insignificant indicating that there was no significant variation with respect to land tenure across the Sub Counties.

Four major crops were identified in the study area as shown in Table 6. From the results, 41% of the respondents planted maize, 2% planted beans and 2% planted kales while 55% planted tomatoes. Results of a chi-square were statistically significant at 1% indicating that there was a significant variation with respect to the types of crops grown across the three Sub Counties in the study area.

4.1.3 Inputs and extension services

Table 6: Average access to inputs and extension services by greenhouse farmers in each Sub County

	Means				ANOVA by Sub Counties	
Variables	**Njoro**	**Nakuru**	**Rongai**	**Overall**	**F-value**	**Sig**
Credit (KES)	32 368.42	12 500.00	43 725.49	32200.00	5.29***	0.007
Extension Contacts p.a.	2.42	2.30	2.29	2.32	0.01	0.986
Distance to input dealer (Km)	16.79	18.38	27.71	22.84	5.74***	0.004

*** Significant at 1% level

Source: Field survey data (2011)

The overall mean for credit access was KES 32200.00 (Table 6). Farmers from Rongai Sub County accessed more credit with a mean of KES 43 725.49, followed by KES 32368.42 for farmers from Njoro. However, farmers from Nakuru accessed the least credit with a mean of KES 12 500.00. The subsequent ANOVA test results showed an F-value of 5.29, significant at 1% indicating that the variation in the amount of credit accessed was statistically significant across Sub Counties.

Distance to the nearest input dealer had an overall mean of about 22.84 kilometres. Respondents from Njoro, Nakuru and Rongai Sub Counties registered a mean distance of 16.79, 18.38 and 27.71 kilometres respectively. Furthermore, ANOVA test results turned out significant at 1% implying that there was a significant variation across Sub Counties in terms of the distance to the nearest input dealer.

Table 7: Distribution of greenhouse farmers by credit sources and purpose of credit by Sub County in Nakuru County

Characteristic	Category	Sub County (Percentage)			Overall	Chi-square	Sig
		Njoro	Nakuru	Rongai			
Source of credit	Bank	37.5	40	40.7	16	7.01	0.725
	AFC	12.5	0	14.8	5		
	NGO	37.5	0	3.7	1		
	SACCO	12.5	60	33.3	15		
	Relative/friend	37.5	0	7.4	1		
	Group	12.5	0	40.7	2		
Purpose of credit	Crops	66.7	100	28.6	19	14.00*	0.082
	Livestock	33.3	0	25.0	10		
	Bought land	0	0	14.3	4		
	Education	0	0	21.4	6		
	Green house	0	0	10.7	3		

* Significant at 10 % level
Source: Field survey data (2011)

Results in Table 7 showed that, respondents accessed credit from five different sources for various uses. Nineteen (19%) of the respondents who accessed credit used it for crop production, 10% used for livestock production, 4% used it to buy land, 6% used it to pay school fees for their children, while 3% used it to build a green house. Results of the chi-square tests were statistically significant at 10% level indicating that there was a significant variation with respect to the purpose of credit across the three Sub Counties in the study area.

4.1.4 Climatic characteristics

Table 8: Distribution of greenhouse farmers across various Agro-ecological Zones and soil types by Sub County

Characteristic	Category	Sub County (Percentage)			Overall	Chi-square	Sig
		Njoro	Nakuru	Rongai			
Agro	LH1	10.5	0	0	2	122.25***	0.000
Ecological	LH2	31.6	0	0	6		
Zone	LH3	26.3	0	49	30		
	LH4	5.3	26.7	19.6	19		
	LH5	15.8	66.7	0	20		
	UM4	10.5	6.7	27.5	16		
	UM3	10.5	0	3.9	5		
	UH2	31.6	0	0	2		
Soil Type	Sandy loam	52.6	100	47.1	64	42.46***	0.000
	Clay Loams	47.4	0	15.7	17		
	Loam	0	0	17.6	9		
	Volcanic Ash	0	0	19.6	10		

*** Significant at 1% level

Source: Field survey data (2011) and GoK (2008)

Table 9: Average rainfall and temperatures by Sub County

Characteristics	Sub County (Mean)				F-value	Sig
	Njoro	Nakuru	Rongai	Overall		
Average rainfall in mm p.a	989.47	906.67	923.53	931.00	0.420	0.659
Average temp in degrees c	14.68	22.00	20.69	19.94	48.57***	0.000

*** Significant at 1% level

Source: GoK (2008)

Eight agro-ecological zones were identified as shown in Table 8. From the results, 2% of the respondents were found in LH_1, 6% were in LH_2, 30% were in LH_3, 20% were in LH_5, 16% were in UM_4 and 5% were in UM_3 while 2% found in UH_2. Results of the chi-square tests were statistically significant at 1% level indicating that there was a significant variation with respect to agro-ecological zones across the three Sub Counties.

Soil type was found to be different in various places in the study area. Results indicated that 64% of the respondents had their farms covered with sandy loams, 17% had clay loams and 9% had loam soils while 10% had volcanic ash. Results of the chi-square tests were statistically significant at 1% level indicating that there was a significant variation across the three Sub Counties in terms of soil type.

With respect to temperature, an average of 19.94 ^{0}C was experienced (Table 10). Njoro, Nakuru and Rongai Sub Counties had a mean temperature of about 14.68 ^{0}C, 22.00 ^{0}C and 20.69 ^{0}C respectively. Further ANOVA test results showed an F-value of 48.57, significant at 1% implying that temperatures varied significantly from one Sub County to the other.

4.1.5 Principle component and cluster analysis

4.1.5.1 Principle component analysis by household socio-economic characteristics

The principle component analysis methodology was used to identify components that explain the interrelationships between a set of selected variables which included; sex of the household head, household size, age of household head, farming experience, off-farm income, and education level of the household head, farm size, extension contacts and credit amounts.

Table 10: Rotated correlation coefficient factor pattern for household's socio-economic characteristics

Variables	Principle components			
	1	2	3	4
	Labour availability	Farming Experience	Assets base	Extension Access
Sex of head of household head (1=Male; 0=Female)	0.741	0.252	0.197	0.017
Household size (Number)	0.851	0.243	-0.071	-0.088
Age of head of Household (Years)	0.181	0.807	-0.007	0.170
Farming experience (Years)	0.242	0.820	0.059	-0.019
Off-farm income (KES)	0.077	-0.265	0.151	-0.757
Education (Years)	-0.258	0.364	0.664	-0.247
Farm size (Hectares)	0.125	-0.023	0.664	0.246
Extension (Contacts within the last 12 months)	-0.003	-0.093	0.256	0.756
Credit amount (KES)	0.496	-0.139	0.616	-0.006
Bartlett's Test of Sphericity	Approx. Chi-Square			148.72
	Degrees of freedom			36
	Sig			0.000***
Kaiser-Meyer-Olkin (KMO)				0.563

*** Significant at 1% level

Source: Field survey data (2011)

With respect to the socio-economic characteristics, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.563 which exceeds the minimum requirement of 0.50 for the overall measure of sampling adequacy (Table 10). According to the index, high values between 0.5 and 1.0 indicate that factor analysis is appropriate (Schwarz, 2011). In addition, the Bartlett's test (for sphericity) results indicate a Chi-square of 148.72 which was strongly significant at 1% level. Thus the hypothesis that variables are uncorrelated in the population was accepted implying that each variable correlates perfectly with itself but has no correlation with other variables.

The information in nine socio-economic factors extracted was represented by four uncorrelated principle components (Table 10). The first component was labeled *'labour availability'* and it comprised of two variables; gender of household head and the size of the household. This component explained 74.1% and 85.1% of the variation in gender and household size respectively. The average size has a bearing on labour availability considering that most smallholder farmers rely on family labour in most of the farm operations (Edriss and Simtowe, 2003). Household size is positively related to technical efficiency in that; smaller household sizes experience labour constraints and thereby rendering them inefficient (Wang *et al*., 1996).

The second component labeled '*farming experience*' also represented two variables; age and farming experience of the household head. This component explained 80.7% and 82.0% of the variation in age and farming experience (respectively). Age is one of the factors that affect the efficiency of carrying out farm activities Ali (1995) and Bravo *et al.,* (1994). Age is also associated with farmer experience in farming since they gain experience over time.

The third component labeled *'Assets base'* explained the greatest relationship in the data and comprised; education, farm size and the amount of credit. This component explained 66.4%, 66.4% and 61.6% of the variation in education, farm size and credit respectively. Education is a social asset that can impact positively on the ability of the household head to allocate resources more efficiently (Kuwornu *et al.,* 2012). According to Mangisoni (1989), educated people can understand agricultural instructions quite well and can apply the skills imparted to them better than the uneducated. According to Musebe et al., (1993) as household gets more formal education, the probability of acquiring credit increases. In addition, according to Emerole (2004), increase in farm size necessarily requires the employment of more inputs which in turn require additional capital for their purchase. Large farms have higher probabilities of being credit constrained arising from the need to acquire more inputs which in turn leads to greater demand for more credit (Omonona et al., 2008).

Finally, the fourth component which was labeled *'extension contacts'*, explained 75.6% of the variation in agricultural extension contacts and 75.7% of the variation in off-farm income.

Table 11: Rotated component matrix for production characteristics

Variable	Principle components		
	1 Soil Fertility Improvement	2 Disease Control	3 Irrigation Water
Seed (Kgs)	-0.736	-0.029	0.31
Fertilizer (Kgs)	0.762	-0.14	0.257
Manure (Kgs)	0.646	0.237	0.191
Fungicide (Kgs)	0.092	0.89	-0.231
Cost of irrigation water(per day per litre)	0.325	-0.114	0.767
Foliar feed (Litres)	-0.018	0.706	0.451
Insecticide (Kgs)	0.055	-0.069	-0.569
Bartlett's Test of Sphericity	Approx. Chi-Square		134.39
	Degrees of freedom		21
	Sig		0.003***
Kaiser-Meyer-Olkin (KMO)			0.525

*** Significant at 1% level

Source: Field survey data (2011)

The seven extracted production factors were represented by three principle components (Table 11). The first component, labeled *'Soil fertility improvement'*, explained 73.6%, 76.2% and 64.6% of the variation in the quantity of seed, fertilizer and manure applied respectively. The second component labeled 'disease control' explained 89.0% and 70.6% of the variation in the quantity of fungicides and foliar feed applied respectively. Lastly the third component labeled 'Irrigation water' explained 76.7% and 56.9% of the variation in the amount of water used for irrigation and the amount of insecticide used respectively.

Table 12:Total variance explained by the principle components

Component	Initial Eigenvalues for socio-economic factors			Initial Eigenvalues for production factors		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.374	26.373	26.373	1.855	26.503	26.503
2	1.350	15.001	41.374	1.357	19.386	45.889
3	1.329	14.770	56.144	1.197	17.101	62.990
4	1.023	11.362	67.506	0.963	13.753	76.743
5	0.844	9.381	76.886	0.782	11.167	87.910
6	0.766	8.512	85.398	0.524	7.485	95.395
7	0.620	6.892	92.290	0.322	4.605	100.000
8	0.368	4.090	96.380			
9	0.326	3.620	100.000			

Source: Field survey data (2011)

The results in Table 12 indicate eigenvalues derived from the PCA, which represent the total variance explained by each principle component. For both the socio-economic and production factors, the cumulative proportion of variance criteria was met since the components were able to explain more than 60% of the total variance in the data. The four socio-economic components explained 67.51% of the total variance in socio-economic factors; while 62.99% of the total variance in production factors was explained by the three production components

4.1.5.2 Cluster analysis results

Through principle component and cluster analysis, the greenhouse tomato farmers were categorised into three clusters based on their level of productivity as shown in Table 13.

Table 13: Cluster analysis by production

Variable	**Cluster**		
	1	**2**	**3**
	Low **Production**	High **Production**	Medium **Production**
Production in Kgs	31,110.74	2,470,966.15	330,121.08
Household Socio-economic factors			
Sex of head (1=male, 0=female)	1	1	1
Age (years)	50	50	53
Education (years)	14	14	16
Household size (number)	5	4	5
Farming experience (years)	18	17	17
Farm size (Ha)	2.05	1.98	9.03
Off-farm income (KES)	13443.18	10566.19	13850.00
Credit (KES)	75000.00	4705.88	125000.00
Extension (contacts)	2.91	2.06	2.80
Production factors			
Seed (Kgs)	0.17	0.01	0.03
Fertilizer (Kgs)	11.41	10.00	7.50
Manure (Kgs)	1482.93	3000.00	500.40
Fungicide (Kgs)	1.07	2.00	1.00
Cost of irrigation water (per day)	1690.24	1000.00	1500.00
Foliar feed (Litres)	1.42	3.00	5.00
Insecticide (Kgs)	13.12	1.00	0.51

Source: Field survey data (2011)

The second cluster labelled ‘High Production’ had the highest mean Production of 2,470,966.15Kgs per hectare, followed by the third cluster (labelled ‘Medium Production’) then the first cluster (Labelled ‘Low Production’) with a mean of 330,121.08Kgs and 31,110.74Kgs respectively (Table 13). The second cluster showed the highest Production, in spite of the small farm sizes, low credit access, low off-farm income as well as a low access to extension services. The high Production levels may have been achieved through optimal utilization of seed, fertilizer and irrigation water. In addition, the farmers in this cluster maximized the use of manure and fungicides which may have improved their soil fertility and reduced fungal diseases in their tomato crop. On the other hand, farmers in the first cluster, who had the lowest Production, had the highest utilization levels for seed, fertilizer, irrigation water and insecticides. This suggests that they may have over applied the seed which may have resulted in competition for nutrients among tomato plants, fertilizer which may have lowered the soil PH making it unsuitable for tomato production.

4.2. Technical efficiency of greenhouse tomato farmers in Nakuru County

4.2.1 Factors influencing green-house tomato production

A stochastic frontier production function was estimated to identify the factors affecting greenhouse tomato production, and the results are presented in Table 14.

Table 14: Factors influencing green-house tomato production in Nakuru County

Variable	Coefficient	Std. Error	P>|z|
Yield (Ha^{-1})			
Crop land (Ha)	0.460	0.075	0.000***
Seed ($KgHa^{-1}$)	-0.303	0.042	0.000***
Fertilizer ($KgHa^{-1}$)	0.062	0.011	0.000***
Animal manure ($KgHa^{-1}$)	0.017	0.077	0.828
Foliar ($litresHa^{-1}$)	0.187	0.476	0.694
Insecticide ($KgHa^{-1}$)	0.659	0.146	0.000***
Fungicide ($KgHa^{-1}$)	-0.882	0.137	0.000***
Labour (man-days)	-0.450	0.282	0.110
Constant	13.360	0.722	0.000***
(σ_v)	3.022	0.000	
(σ_u)	6.264	0.454	
(σ^2)	39.233	5.693	
(γ)	0.160		
Number of observations = 95	Wald chi^2 (12) = 1.7766		
Log likelihood = -243.2526	Prob> chi^2 = 0.0000***		

Source: Field survey data (2011) *** Significant at 1% level

Five variables (crop-land, seeds, planting fertilizer, insecticide and fungicide) were found to significantly affect greenhouse tomato productivity. The log likelihood for the fitted model was -243.25 while the chi-square was 1.78 and it was strongly significant at 1% level. Thus the overall model was correctly estimated and the explanatory variables used collectively explained the variations in tomato production. Further results show that the variance of the technical inefficiency parameter γ is 0.16 which is given as $\gamma = \sigma u/\sigma^2$ (Greene, 2011). This implies that 16% of the variations in tomato production were due to technical inefficiency.

The elasticities generated from the stochastic frontier production estimation were as follows: Insecticide (0.659), crop-land (0.460), foliar (0.187), fertilizer (0.062), animal manure (0.017), seed (-0.303), labour (-0.450) and fungicide (-0.882). Hence, the resulting returns to scale parameter obtained by summing these input elasticities is -0.250. This indicates that greenhouse tomato production in Nakuru County exhibits diminishing returns to scale and diseconomies of scale, implying that farmers in the study area need to reduce the units of seed, labour and fungicide being applied since there is overutilization of these inputs in greenhouse tomato production. On the other hand, insecticide had the largest elasticity, followed closely by crop land. This suggests that any interventions to increase insecticide application and the cultivated area would create significant achievements in greenhouse tomato productivity in Nakuru County.

The results indicate that *crop-land* had a positive and significant influence at 1% level. An increase in the area of land cultivated by 1% led to an increase in greenhouse tomato yields by 46%. This suggests that the more farm land a farmer allocated to the enterprise, the higher were the yields obtained. Goni *et al.* (2007) also found similar results among rice farmers in Nigeria. It has been argued that agricultural production is partly hampered by under-utilization of available farming land, as a result of various factors such as; limited access to other farming inputs, farmers' risk averseness and rainfall fluctuations brought about by climate change. However, Ugwumba (2010) observed that land was underutilized mainly due to land tenure problems associated with land fragmentation. Garibaldi *et al.* (2011) also indicated that further conversion of land into cultivation and human settlement brings about the risk of eroding ecosystem services. Therefore based on the results it is implied that as the sizes of land holding continue to decline, it is increasingly going to become difficult to increase agricultural productivity through expansion in farm land but only through improved land productivity per unit area. This can be achieved through efficient use of farm inputs such as seed, fertilizers, and agrochemicals.

Seed was also statistically significant at 1% level, with a negative influence on greenhouse tomato yields contrary to the hypothesis. It was found out that an increase in the quantity of seed applied by 1% resulted in a yield decrease of 30.3%. This implies that over-application of seeds hampers greenhouse tomato productivity, since it results into congestion of sprouting plants and lowers nutrient utilization per plant. The negative influence could also be attributed to the fact that tomato seeds may have been of poor quality. Reardon *et al.* (1997) also stressed the importance of seeds in determining crop productivity, although it is important to note that for seed to make its full contribution to tomato productivity in Sub-Saharan Africa, small-scale farmers need to use certified seeds which have an assurance of quality.

Tomato production was positively influenced by the amount of *fertilizer* applied. This input was significant at 1% significance level. It was found out that an increase in the quantity of fertilizer applied by 1% led to an increase in greenhouse tomato yields by 6.2%. The results are consistent as hypothesised suggesting that tomato yields can be improved significantly by increasing fertilizer use, through which soil fertility is restored. Similarly, Reardon *et al.* (1997) also found a positive effect of fertilizer application on crop productivity in case studies from Bukina Faso, Senegal, Rwanda and Zimbabwe. In addition, Tchale (2009) found out that fertilizer was a key factor in production of major crops grown by smallholder farmers in Malawi. However, due to the high cost of fertilizer in most developing countries, particularly Kenya, FAO (1980) suggest that farmers need to weigh the expected increase in value of output, resulting from the additional application of plant nutrient, with the cost of the fertilizer. As such, they should spend money on purchasing fertilizer up to a point where it ceases to be profitable.

Further results indicate that *insecticide* was statistically significant at 1% level, with a positive influence on greenhouse tomato output. An increase in insecticide by 1% led to a yield increase by 65.9%. These results imply that greenhouse tomato farmers face a huge challenge of pests and they are forced to use insecticides to protect their crop. Foti and Chikuvire (2000) also found that smallholder cotton farmers derived a value of marginal product of $2.03 for each additional unit of pesticide used. Suggesting that there were potential benefits from increasing pesticide use. However, most farmers lack adequate training on the safe use of insecticides, while many others are unable to afford the required insecticides. Appropriate and timely pest management makes all the difference in determining if the farmer will realize a good harvest or experience total crop failure. In addition, proper identification of pests is critical for effectiveness of insecticides. It is also imperative to note that the benefits from increased insecticide use presented by these results may be viewed as an overstatement, if the externalities to human beings and the environment were to be taken into account (Foti and Chikuvire, 2000).

Fungicide use also showed a statistically significant influence on greenhouse tomato production. However, the effect was negative contrary to the hypothesis. The findings reveal that a 1% increase in fungicide applied reduced tomato yields by 88.2%. This negative influence could be attributed to incorrect application methods or due to fungicide resistance. Dutky (1965) documents that in the event of fungicide resistance, as could be the case for the greenhouse tomato farmers, other plant disease management techniques may be used such as breeding for resistance, vector control, field sanitation, crop rotation, alternating the types of fungicide used or through using biological fungicides. Pests and diseases remain the greatest challenge in tomato farming even in Kenya. Furthermore, the largest number of plant diseases is caused by fungi (Dutky, 1965); hence efforts to address the negative effect of fungicides will significantly improve tomato yields in the study area.

4.2.2 Technical efficiency levels for greenhouse tomato farms in Nakuru County

A stochastic frontier production function was used to analyse the second objective; to evaluate the levels of technical efficiency of greenhouse tomato farms, from which the technical efficiency scores for each farm were obtained (table 15)

Table 15: Farm-specific technical efficiency levels per Sub County

Technical efficiency	**Overall (%)**	**Sub Counties**		
		Njoro (%)	**Nakuru (%)**	**Rongai (%)**
Mean	28.71	26.26	29.47	29.1
Std deviation	19.95	23.92	19.43	19.11
Minimum	0	0.01	0	0.02
Maximum	70.53	66.32	69.04	70.53
Mean: Female	32.31	37.82	27.16	41.57
Male	27.56	23.79	31.5	27.32
t-value; Sig.	0.973; 0.337	1.005; 0.384	-0.613; 0.545	1.745; 0.088*
ANOVA	0.156			
Sig.	0.855			

Source: Field survey data (2011) *Significant at 10% level

The results in Table 15 show the farm-specific technical efficiency levels for greenhouse tomato farms in Nakuru County. The mean technical efficiency level for all the sampled greenhouse tomato farms was 28.71% indicating that the average greenhouse tomato farmer in the study area produce on the average only 28.71% of potential output given the current technology. Farms from Nakuru Sub County had the highest mean technical efficiency of 29.47%, followed by those in Rongai with a mean of 29.1% and Njoro with 26.26%. ANOVA results, however, indicated that there was no significant variation in terms of technical efficiency across the three Sub Counties. Furthermore, the t-tests by gender revealed that the mean difference in technical efficiency was statistically significant among the farms in Rongai Sub County while it was statistically insignificant in the other two Sub Counties. This suggests that female farmers in Rongai have a significantly higher level of technical efficiency compared to their male counterparts.

The highest level of technical efficiency among all the greenhouse tomato farms was 70.53% whereas there were some farms which were absolutely inefficient at 0% level. Thus it is evident that, there is a very huge gap between the two extreme farms in terms of technical efficiency. However, if an average greenhouse tomato farm were to achieve the level of technical efficiency shown by the most efficient farm, then it could realize an increase of 59.29% in terms of yields per hectare [(1-**(**28.71/ 70.53**)**) x 100].

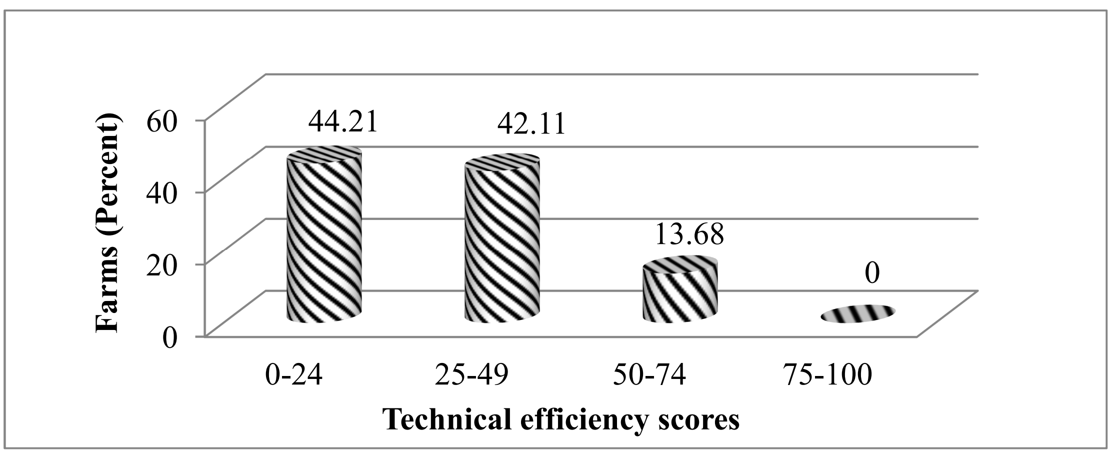

Figure 4: Distribution of technical efficiency among greenhouse tomato farms
Source: Field survey data (2011)

It is further evident in Figure 4 that a total proportion of 86.32% of the greenhouse tomato farms exhibited efficiency levels lower than 50%, while only 13.68% of them showed efficiency scores higher than the 50% level. It is therefore implied that almost all the farms are in the lower two classes and will require comprehensive interventions to improve their technical efficiency levels to that showed by the most efficient farm. Thus there are prospects of increasing greenhouse tomato production in the study area through efficient allocation of production inputs.

4.3 Factors influencing technical efficiency of greenhouse tomato farms in Nakuru County

The results in Table 16 show the estimates from the two-limit Tobit regression of selected explanatory socio-economic and institutional-support factors against predicted technical efficiency scores.

Table 16: Factors influencing technical efficiency of greenhouse tomato farms in Nakuru County

Variable	ey/ex	Coefficient	Std. Error	P>|z|	X
Age (years)	-0.7929	-0.0053	0.4558	0.082*	50.39
Education (years)	0.298	0.0302	0.4253	0.484	3.32
HH size (number)	-0.2237	-0.0180	0.2443	0.36	4.18
Farming years	-0.1257	-0.0061	0.0535	0.019**	6.90
Land tenure d* (title deed)	0.4142	-0.0002	-0.2627	0.115	-851.6
Off-farm income (KES)	-0.051	-0.0025	0.1876	0.786	6.96
Credit (KES)	0.0542	0.0038	0.0976	0.578	4.80
Extension contacts (number)	-0.0394	-0.0058	0.0852	0.644	2.27
Group membership d* (yes/no)	0.0198	0.0094	0.1802	0.912	0.71
Distance (Km)	-0.2614	-0.0037	0.1572	0.094*	23.42
Greenhouse items cost (KES)	1.0825	0.0320	0.4994	0.030**	11.35
Constant		0.0632			
Sigma		0.3178			
Number of obs	95		Prob> chi^2		0.080*
LR $chi^2(11)$	18.080		Pseudo R^2		0.255
Log likelihood	-26.428				

** Significant at 5% level; * significant at 10% level; d* denotes dummy variable

Source: Field survey data (2011)

The chi-square from the estimation was 18.08 and it was significant at 10% level, hence, the model was appropriately estimated. In addition, the pseudo R^2 was 25.5%, against the recommended level of 20%. Thus the explanatory variables chosen for the model were able to explain 25.5% of the variations in technical efficiency among greenhouse tomato farms. Among the selected explanatory variables, four were found to have a significant contribution on technical efficiency namely: age, farming years, distance and greenhouse items' cost.

The results indicate that the *age* of the household head had a negative influence on the level of technical efficiency and was statistically significant at 10% level. It was found that an increase in the farmer's age by 1% influenced a decline in the level of technical efficiency by 0.79%. This implies that the older farmers were less technically efficient in greenhouse tomato farming compared to their younger counterparts. Older farmers are generally less willing to embrace new techniques of doing things, such as greenhouse technology, hence they exhibit lower levels of productivity compared to their younger counterparts. The findings are consistent with those by Battese and Coelli (1995) among paddy rice farms in India who concluded that older farmers were less efficient than the younger ones. On the contrary, Illukpitiya (2005) in Sri-lanka observed that elderly farmers had a wealth of experience and therefore were technically more efficient in production than their younger counterparts. It is however, reckless to assume that old age is always equivalent to higher experience.

Farming years also significantly influenced the level of technical efficiency at 5% level. It was found out that an increase in farming years by 1% resulted in a decline in the level of technical efficiency among greenhouse tomato farmers by 0.13%. These findings are contrary to the hypothesis, since it is implied that the highly experienced tomato farmers were less technically efficient. Wilson *et al.* (1998) also found out that the number of years of experience was negatively correlated with technical efficiency among small scale potato producers in the UK. However, Awudu and Richard (2001) found out that the level of farming experience contributed positively to production efficiency. Wilson *et al.* (2001) also found contradicting results that farmers who had more years of managerial experience were associated with higher levels of technical efficiency in wheat production in Eastern England. Therefore, different authors have realized mixed results with respect to farming experience. Nonetheless, the negative influence in this study may be attributed to the fact that farmers who have many years of experience tend to be rigid to adopt new farming techniques, instead they prefer to hold on to the traditional farming methods that have been successful, hence, they become more technically inefficient in the long run.

Further results indicate that *distance* to the nearest input dealer showed a negative and significant influence at 10% level. It was found out that an increase in distance by 1% led to a decrease in the level of technical efficiency by 0.26%. The location of the farm from the input dealer determines the transaction cost of obtaining farming inputs which influences the amount applied, hence, influencing the level of technical efficiency. Farms located relatively closer to the input dealer benefit from lower production costs and are able to apply optimal amounts of farming inputs as compared to those located far away. The findings coincide with those by Bagamba *et al.* (2007) who found that households located nearer to the factor markets showed higher technical efficiency than those located in remote areas. The authors argued that nearness to the factor market increased farmers' ease of accessing farming inputs and extension trainings from which they could attain information and skills for better crop management hence increasing their technical efficiency.

The *cost of greenhouse items* at the farmer's disposal was also found to influence the level of technical efficiency. The results reveal that there is a positive and significant correlation between the cost of greenhouse items and the level of technical efficiency. According to the findings, a 1% increase in the cost of greenhouse items resulted in a 1.08% increase in technical efficiency. The cost of greenhouse items is a proxy of the quality of the greenhouse items and the level of financial investment into the enterprise, which has a direct influence on the level of commitment that a farmer will offer to the enterprise. In other words, farmers who have incurred more in the greenhouse items will be keener to ensure they get profit from it and in so doing, they will show higher levels of technical efficiency. A similar relationship is portrayed by farmers who pay remittances for farming. Feng (2008) observed that farmers who paid remittances, such as land rent, achieved higher technical efficiency than those who did not pay any remittances. The decision to invest more or less in an enterprise is largely dependent on ones perceived expected return from the venture.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The objectives of the study were: to characterize smallholder greenhouse tomato farmers in Nakuru County; to determine the levels of technical efficiency of smallholder greenhouse tomato production in Nakuru County and finally to analyse factors influencing the levels of technical efficiency among smallholder greenhouse tomato farmers in Nakuru County. To achieve these objectives, primary data was collected from a whole population of smallholder greenhouse tomato farmers using observations and interviews with the help of a semi-structured questionnaire. In the analyses, descriptive statistics, PCA and cluster analysis were used to achieve the first objective; while the stochastic frontier production function and two-limit Tobit regression model were used to achieve objectives two and three respectively.

Through PCA, nine socio-economic and seven production factors were identified. The socio-economic factors were represented by four principle components labelled labour availability, farming experience, assets base and extension access. In addition, the production factors were represented by three principle components labelled Soil fertility improvement, disease control and irrigation water. The nine socio-economic and seven production factors were then used to cluster greenhouse tomato farmers into three clusters based on their levels of tomato productivity.

The stochastic frontier production results indicated that greenhouse tomato production was significantly influenced by the size of land under crop production, the amount of seed planted as well as the amount of fertilizer, insecticides and fungicide applied. In addition, crop land, fertilizer and insecticide had a positive influence as hypothesised. However, seed and fungicide inputs negatively influenced the level of greenhouse tomato production. Moreover, the return to scale parameter was found to be -0.25, implying that greenhouse tomato production in the study area exhibits diminishing returns to scale. Furthermore, insecticide showed the largest elasticity followed closely by crop land. The mean technical efficiency among greenhouse tomato farms was 28.71%. Farms from Nakuru Sub County had the highest mean technical efficiency of 29.47%, followed by those in Rongai with a mean of 29.1% and Njoro with 26.26%. However, there was no significant variation in terms of technical efficiency across the three Sub Counties. Furthermore, only farms in Rongai Sub County showed a significant mean difference in technical efficiency in terms of gender of the household head.

The two-limit Tobit regression results revealed that technical efficiency was positively influenced by the cost of various greenhouse items (at 5% level) and negatively influenced by age (at 10% level), distance to the input dealer(at 10% level) and farming experience (at 5% level).

5.2 Recommendations

In the context of greenhouse tomato production, there is need for the various stakeholders, such as the Ministry of Agriculture and private sector agencies dealing with agricultural extension to sensitize farmers on the appropriate input application rates, particularly for seed and fungicides. This is because it was found that over-application of seed and fungicide inputs impede greenhouse tomato productivity, thus resulting in diseconomies of scale.

With respect to technical efficiency in greenhouse tomato production, there is need to sensitize older and experienced farmers through extension and training programmes on efficient and innovative ways of production to enhance their level of productivity. In addition incentives should be provided to private investors to expand their agro-input shops to rural markets where farmers can easily access farm inputs thus reducing costs and saving on time thereby increasing time available for farm work. Alternatively, greenhouse tomato farmers should be encouraged to take advantage of the existing farmer groups to purchase farm inputs collectively to enjoy economies of scale in inputs prices and transportation costs. Finally, the government needs to put in place measures and processes that will ensure that the dealers of greenhouse equipments supply affordable quality items to farmers for increased efficiency of greenhouse tomato production.

5.3 Areas of further research

The study mainly assessed the levels of technical efficiency in smallholder greenhouse tomato production. However further research avenues to be explored exist such as; To assess the levels of economic efficiency in greenhouse tomato production. This will provide evidence as to whether the farmers are minimizing their production costs as they maximize their tomato production.

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APPENDIX 1: QUESTIONNAIRE

Questionnaire No………………………….. ………. Date…………………………………

Enumerator' name………………………………….. Tel. No……….....................................

A. GENERAL INFORMATION

Sub County………………………………   Division………………………………………

Location……………………………...   Sub-location …………………………………..

Village …………………………………..

Area of residence……………   Urban [ ]   Peri-urban [ ]   Rural [ ]

Agro ecological zone …………………   Soil type………………………

Average rainfall (mm) per annum……………

Average Temperatures …….......^{0}C   Min………^{0}C   Max ……^{0}C.

B. HOUSEHOLD SOCIOECONOMIC INFORMATION

Name of the Respondent…………………................................

Relationship to the household head……………………………..

(B.1) Information of the household head

Sex	**Age in Yrs**	**Marital status**	**Formal education**	**Household size**	**Source of energy most frequently used**	**Source of water**
1=Male 0=Female		1=Married 2=Single 3=Divorced 4=Widowed 5=Other (specify)	1=None 2=Primary 3=Secondary 4=Tertiary 5=others (specify) __________	People living in the homestead over the last one year	1=Charcoal 2=Fuel 3=Wood 4=Electricity 5=Solar 6=Petroleum products 7=Other(specify) __________	1=River 2=Bore–hole 3=Tap water 4=Rain water 5=Roof catchment 6=Other (Specify) __________
[ ]		[ ]	[ ]		[ ]	[ ]

(B.2) Household Composition

	Household Member's Name	Sex	Age (Years)	Relationship to the household head	Highest level of Formal education attained	Experience in farming
1		[]	[]	[]	[]	
2		[]	[]	[]	[]	
3		[]	[]	[]	[]	
4		[]	[]	[]	[]	
5		[]	[]	[]	[]	
6		[]	[]	[]	[]	
7		[]	[]	[]	[]	
8		[]	[]	[]	[]	
9		[]	[]	[]	[]	
		1=Male 2=Female		1=Household head 2=Spouse 3=Daughter 4=Son 5=Other relative 6=Other non-relative (Specify)__________	1=No formal education 2=Primary 3=Secondary 4=Tertiary 5=Other (Specify) __________________ __________________	Number of years in farming

(B.3) Farm size (in acres)

	Size in Acres	**Rental Price (KES) Per acre**	**Approximate Value (KES) Per acre**	**Land tenure**
1=Owned				
2=Rented				
3= Leased				
4=Others (specify) ____________________				

Codes for land tenure: 1=Freehold with certificate/title deed; 2= Freehold without certificate/title deed; 3= other (specify) ______________________

(B.4) Land Use

Land use	**Size in Acres**	**Years in Same use**
1. Homestead		
2. Forest		
3. Subsistence Crops		
4. Cash crops		
5. Livestock		
6.Other (specify) ____________		

(C) INCOME SOURCES, AMOUNTS AND EXPENDITURE

SOURCE	**Livestock and livestock Products** (KES) **Per Month**	**Crops** (KES) **Per Year**	**Home industries** (KES) **Per Month**	**Agro forestry products** (KES) **Per Month**	**Off-farm employment** (KES) **Per Month**	**Remittances** (KES) **Per Month**	**Other , Specify** _______ (KES) **Per Month**	**Expenditure** (KES) **Per Year in Food, School fees and Health**
AMOUNT								

(D). INSTITUTIONAL FACTORS

(D.1) Credit Access

Did any member of the household apply for credit?

1. Yes [] 2. No []

Was the credit availed?

1. Yes [] 2. No []

If No, Why?

1. Had outstanding loan []
2. Did not need []
3. Didn't know it is there []
4. No security []
5. Others, specify []

If yes, fill the details in the table below

Item of credit	Source of credit	Purpose of credit	Amount (KES)	Interest rate in %	Repayment period in years	Repayment conditions	Sources of information On credit
1=cash **2=Kind** **(specify)** ______	1= Bank 2=AFC 3= NGO 4=Informal money lender 5=Sacco (specify) ___________ 6=Relative/ Friend 7=Group 8=Others (Specify) _____________	1=crops (specify) ___________ 2=Livestock (specify)____ _______ 3=Other (specify) ___________				1= Daily 2= Weekly 3=Monthly 4=Yearly	1=TV/Radio 2=Newspaper /Magazines 3=Extension officers 4=Politician 5=Internet 6=Other (Specify) __________
[]	[]	[]	[]			[]	[]

(D.2) Extension Services

(D.2.1) who is the main extension service Provider of?

1. crop production extension []
2. Crop protection extension []
3. Irrigation services []
4. marketing information []

Codes: 1=Public extension agent, 2= NGO, 3=Neighbour/Farmer, 4=Private extension, 5=CBO 6=radio/Television, 7=Mobile phone, 8= Private engineer, 9=Farmer organization/Cooperative 10=other, specify ____________

(D.2.2). In the last one year have you been visited by: 1. Yes 2. No

1. Public extension agent []If yes how many times …………
2. NGO [] If yes how many times …………
3. Neighbour/Farmer [] If yes how many times …………
4. Private extension [] If yes how many times …………
5. CBO []If yes how many times …………
6. Farmer organization/Cooperative [] If yes how many times …………
7. Private Engineer []If yes how many times …………
8. Other specify []If yes how many times …………

(D.3) Climate and Weather Information

Did you receive any form of Weather information in the last 12 months?

1. Yes [ ] 2. No [ ]

If yes, fill the details in the table below

Type of information	Source of information	Mode of receiving the information	Frequency of getting the information	Were you able to use the information? 1= Yes , 2=No	If Yes, What aspects of farming did you change as a result of this information?	If No What are the challenges of using this information?
Forecast of drought	[ ]	[ ]	[ ]	[ ]		
Forecast of floods	[ ]	[ ]	[ ]	[ ]		
Forecast of other Extreme events	[ ]	[ ]	[ ]	[ ]		

Forecast of pest and disease outbreak	[ ]	[ ]	[ ]	[ ]		
Forecast of start of long rains	[ ]	[ ]	[ ]	[ ]		
Forecast of long rains amounts and duration	[ ]	[ ]	[ ]	[ ]		
Forecast of short rains amounts and duration	[ ]	[ ]	[ ]	[ ]		

Codes for sources of information

1=TV/Radio

2=Newspapers/Magazines

3=Extension officers

4=Research institution

5=NGO

6=Provincial administration

7=Internet

8=Other (Specify)

Codes for frequency of receiving information

1= Weekly

2= Fortnightly

3=Once a month

4=Once in three months

5=Once in six months

6=Once a year

7=others (Specify) ______

Codes for the mode of receiving information

1= Farm visits

2= Group visits

3= Field days

4=Office visits

5= Barazas

6=other (specify_________

(D.4) Membership infarmer organizations

(D.4.1) Is anybody in the household a member of a farmer group? 1. Yes [ ] 2.No [ ]

(D.4.2) If yes, fill the details in the table

Group type	**Number of Members**	**Year started**	**Group activities**	**Number of Meetings per month**	**Savings per month** (KES)	**Benefits of being a member**	**What services do you get from the organization**	**Required Collateral for loans**
1=Self Help group 2=Welfare group 3=Cooperative Society 4=Women group 5=CIG, Specify ____________ 6=NGO, specify ____________ 7=Other, Specify ____________	Males= _______ Females= _______		1=Farming 2=Business 3=HIV/AIDS 4=Advocacy 5=Others (specify)			1=Information on farming 2=Advise on credit 3= Credit and savings 4=Merry go round 5=Other, specify __________	1=Loans 2=Fertilizer 3=Labour 4=Credit 5=Vet services 6=Extension 7=Other, specify _______	
[ ]			[ ]			[ ]	[ ]	

(D.5) Roads Infrastructure

(D.5.1) what is the distance, road type and time taken to get to the nearest service providers listed below?

	Distance (Km)	Road type 1=Murram 2= Tarmac 3= Foot path 4= Dry weather	Time (Hours)
1. The nearest farm inputs stockist	[]	[]	[]
2. The nearest Extension service provider	[]	[]	[]
3. The nearest crop production service provider	[]	[]	[]
4. The nearest Drip irrigation service provider	[]	[]	[]
5. The nearest market place for farm produce	[]	[]	[]
6. The nearest tomato processing factory	[]	[]	[]
7. The nearest health centre	[]	[]	[]
8. The nearest piped water source	[]	[]	[]
9. The nearest source of pasture in dry season	[]	[]	[]
10. The nearest fuel wood	[]	[]	[]
11.The nearest tarmac road	[]	[]	[]
12.The nearest Electricity supply	[]	[]	[]
13.The nearest livestock market place	[]	[]	[]

(D.6) HOUSEHOLD ASSETS

Which of the following assets does the household own at the moment? Use the codes below

Item(s)	**Item Specification**	**Year of purchase or built**	**Number of units**	**Unit cost** (KES)	**Useful life in Years**	**Recovery cost**	**Salvage value**(KES)
[]							
[]							
[]							
[]							
[]							

Codes for Items

1=Animal traction plough
2=Bicycle
3=Borehole /shallow well
4=Car
5=Cart trailer tractor
6=Cell phone
7=Combine harvester
8=Computer
9=Donkey
10=Drip irrigation kit
11=Generator
12= Television
13= Water pump
14=Green house
15=Grinding mill
16=Houses
17=Improved stove
18=Irrigation equipment
19=Motor cycle
20=Ploughs for tractor
21=Radio
22=Spray pump
23= Wheel barrow
24= Water tank
25=Zero-grazing Unit

(E). CLIMATE CHANGE ADAPTATION IN THE FARM

(E.1) Data on climate change hazards effects, coping and adaptation strategies on; crops, Livestock, Food security and other livelihoods.

(E.1.1) What are the Climate change hazards effects, coping and planned adaptation strategies on crops?

Hazard	Three Vulnerable crops in order of vulnerability (1=Most vulnerable)			Three crops not Vulnerable in order of non vulnerability (1=Least vulnerable)			Effects of the hazard on crops (1= Highest Effect))			Crops Coping strategies for the hazard in terms of effectiveness (1=Most effective)			Crops Planned adaptation strategies for hazard in terms of effectiveness (1=Most effective			Sources of information on planned adaptations for crops		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Codes for climate change Hazards on crops

1=Delayed onset of rain
2= Drought,
3=Floods,
4=Frost
5=Hailstorms
6=Heat stress,
7=Low rainfall
8=other, specify________________

Codes for crops

1=Avocado
2=bananas
3=beans
4=Brinjals
5=Cabbages
6= Capsicums
7=Carrots
8=Cassava
9=Cowpea leaves
10=Finger millet
11=French beans
12=Kales
13=Local vegetables
14=Maize
15=Maize

16=Onions
17=Oranges
18=Passion fruit
19=Sorghum
20=Soya beans
21=Spinach
22=sweet potatoes
23=Tomatoes
24=other, specify__________

Codes for Effects of the hazards on crops:

1=Crop loss
2=Crop Pests outbreaks
3=Decline in crop yield
4=Disease outbreaks
5=High operation costs
6=Land degradation
7=Loss of assets (specify) ______
8=Loss of income
9=New invasive Plants
10=Reduced soil fertility
11=Soil erosion
12=Water scarcity
13= other, specify____________

Codes for coping strategies for crops

1= Did nothing
2=Increased chemical application
3=Increased fertilizer application
4=Irrigation
5=Mulching
6= Reduced chemical application
7=Reduced fertilizer application
8=Sought off farm opportunities
9=other, specify____________

Codes for Planned adaptation strategies for crops

1=Changed to Irrigation
2=Changed to livestock farming
3=Constructed water pan
4=Diversification of crops
5=Diversified into other livelihoods
6=Dug shallow well
7=Green house cultivation
8=Improve in Water economy
9=Increased fertilizer use
10=Increased pesticide use
11=Intercropping
12=Mixed crop and livestock farming
13=Mulching
14= No adaptation
15=Planted more trees
16=Planting different varieties of same crop
17=Planting early
18=Planting early maturing varieties
19=Planting pure stands
20=Soil conservation
21=Water harvesting (Road run-off)
22=Water harvesting (roof catchment)
23=other, specify_____________

Codes for sources of information on planned adaptation strategies on crops (Specify each)

1=Government extension
2=Government Administration
3=Government Education
4=Government Research
5=Local Authority
6=NGOs
7=Church
8=Neighbour
9=Community Based Organization
10=Farmer Field school
11=Media
12=other, specify____________

(E.1.2) Climate change hazards effects, coping and adaptation strategies on Livestock

Hazard	Three Vulnerable Livestock types in order of vulnerability (1=Most vulnerable)			Three Livestock types not Vulnerable in order of non vulnerability (1=Least vulnerable)			Effects of the hazard. (1= Highest Effect)			Livestock Coping strategies for the hazard in terms of effectiveness (1=Most effective)			Livestock Planned adaptation strategies for the hazard in terms of effectiveness (1=Most effective)			Sources of information on planned adaptations for Livestock		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Codes for Hazards on livestock

1=Delayed onset of rain

2= Drought,

3=Floods,

4=Frost

5=Hailstorms

6=Heat stress,

7=Low rainfall

8=other, specify___________

Codes for Livestock types

1=Bee keeping

2=Cattle –Exotic dairy

3=Cattle –Indigenous beef

4=Dairy Goats

5=Goats for meats

6=Pigs

7=Poultry–exotic

8=Poultry–indigenous

9=Rabbits

10=Sheep- Exotic

11=Sheep indigenous

12=Other, specify __________

Codes for effects of hazards on Livestock:

1=Death of Livestock

2=Decline in livestock products yields

3=High costs of production

4=Increased conflict over water resources

5=Increased livestock pests infestation

6=Lack of Fodders crops

7=Land degradation

8=Livestock disease outbreaks

9=Loss of assets

10=Loss of income

11=Reduced Pasture yields

12=Reduced soil fertility

13=Soil erosion

14=Water scarcity

15=other, specify_______________

Codes for coping strategies for Livestock:

1=Bought more hay

2=Destocking

3=Did nothing

4=Irrigated the pastures and fodders

5=Migrate the Livestock

6=other, specify ___________

Codes for planned adaptation strategies for Livestock:

1=Construct water pan

2=Diversified into other livelihoods

3=Diversifying Livestock breeds

4=Diversifying Livestock types

5=Dug shallow well

6=Farmer to farmer extension

7=Housing livestock

8=Improved water use economy

9=Increased land for livestock

10=Insuring of livestock

11=Keeping drought resistant breeds

12=Looking for off-farm employment

13=Mixed farming

14=Planted fodder trees

15=Roof catchment Water harvesting

16=Silage making

17=Storing crop residues

18=Storing hay

19=Vaccinating livestock

20=other, specify________

Codes for sources of information on planned Adaptation strategies for livestock

1=Church

2=NGOs

3=Community Based Organizations

4=Farmer to farmer extension

5=Government Administration

6=Government Education

7=Government extension

8=Government Research

9=Local Authority

10=Media

11=other, specify_________________

(E.1.3) Climate change hazards effects, coping and adaptation strategies on Food security

1.What are the major food crops in your household? List Five

1.______________________________ **4.** ______________________________

2.______________________________ **5.**______________________________

3.______________________________

2. What t are the effects of climate changeon food security? Tick as appropriate

1. Food insecurity [ ]
2. Decline in consumption [ ]
3. Increased malnutrition [ ]
4. other, specify ___________________ [ ]

3. What are the coping strategies on food security?

1. Borrowing from relatives [ ]
2. Depending on food aid [ ]
3. Did nothing [ ]
4. Eating less [ ]
5. Food-for-work programs [ ]
6. Looking for off-farm employment [ ]
7. Sold assets (Specify) __________ [ ]
8. Sold livestock [ ]
9. Other, specify_______________ [ ]

4. What are the planned adaptation strategies on food security? Tick

1. Food storage [ ]
2. Food preservation [ ]
3. Diversify Livelihoods [ ]
4. Planting indigenous food crops [ ]
5. Other, specify__________ [ ]

5. What are the sources of information on planned adaptation strategies on food security?(Tick as appropriate and specify all)

1. Church [ ]
2. NGOs [ ]
3. Community Based Organizations [ ]
4. Farmer to farmer extension [ ]
5. Government Administration [ ]
6. Government Education [ ]
7. Government extension [ ]
8. Government Research [ ]
9. Local Authority [ ]
10. Media [ ]
11. Other, specify_________[ ]

(E.1.4) Climate change and adaptation ofalternative livelihoods

1. Is any member of the household involved in alternative livelihoods? 1=Yes, 2=No

2. If yes fill in the table below

Member of the family involved in alternative livelihood	**Name of Livelihood**	**Which year did you start engaging in this livelihood?**	**What are your Reasons for engaging in this livelihood?**	**Which times are you involved in this livelihood?**	**Sources of information on livelihood**
[ ]	[ ]				[ ]
[ ]	[ ]				[ ]
[ ]	[ ]				[ ]
[ ]	[ ]				[ ]
[ ]	[ ]				[ ]

Codes for Member of the family

1=Household head
2=Spouse
3=Daughter
4=Son
5=other relative
6=other non-relative (Specify) ____________

Codes for livelihoods

1=General shop
2=Butchery
3=Kiosk
4=Wage labour
5=Boda-Boda
6=Milk marketing
7=Farm inputs marketing
8=Sand harvesting
9=Charcoal trade
10=Cereal marketing
11=Rental houses
12= Value addition and Marketing Crop products (specify)____________
13= Value addition and Marketing animal products (specify)____________
14=Transportation Carts/Lorry/Donkey/other, specify________________
15=other, specify_______

Codes for times

1= Daily

2=When there is drought

3=When farming activities are minimal

4=During times of food scarcity in the household

5=other,specify _____

Codes for sources of information on planned adaptation strategies for livestock

1=Church

2=NGOs

3=CommunityBased Organizations

4=Farmer to farmer extension

5=Government Administration

6=Government Education

7=Government extension

8=Government Research

9=Local Authority

10=Media

11=other, specify_______

(E.1.5) what are your perceived hindrances to adaptation of modern techniques of combating climate change? Tick

1. Lack of access to water for irrigation farming [ ]
2. Lack of current knowledge on adaptation methods [ ]
3. Lack of improved seeds [ ]
4. Lack of information on weather incidence [ ]
5. Lack of money to acquired modern techniques [ ]

6 There is no hindrance to adaptation [ ]

7. Other, specify___________ [ ]

(E.2). Greenhouse Tomato Production

1. Which year did you start using the greenhouse for tomato production?	
2. What is the size of the greenhouse in M^2	
3. What is the plant population?	
4. What time of the year do you grow tomatoes in the greenhouse	

(E.2.1) Greenhouse advantages and disadvantages

What is/are your reason(s) of venturing into greenhouse production?	What are the advantages of growing tomatoes in a greenhouse compared to open field?	What are the disadvantages of growing tomatoes in a greenhouse compared to open field?	Source(s) of information on greenhouse
[]	[]	[]	[]
[]	[]	[]	[]
[]	[]	[]	[]
[]	[]	[]	[]
[]	[]	[]	[]

Codes for advantages of greenhouse
1=Low levels of Inputs
2=low Management costs
3=Reduces labour costs
4=Higher Yields per unit area
5=Improves Quality of produce
6=Reduces Pests and diseases incidences
7=Improves Profitability
8=Reduces labour costs
9=Reduces weed growth
10=Reduces crop failure
11=Reduces soil erosion
12=Allows crop production during dry season
13=Efficiency in manure use
14=Allows efficiency in fertilizer use
15=other, specify________

Codes for disadvantages of greenhouse
1= High initial Capital requirement
2=Difficult to built
3=requires knowhow and skills
4=Limited to Horticultural crops
5=other, specify_______

Codes for reason for crop in greenhouse
1=Low levels of Inputs
2=low Management costs
3=Low labour costs
4=Higher Yields
5=High Produce Prices
6=Ready Market
7=Promoted by Buyers
8=Promoted by greenhouse dealers
9=Most farmers grow the crop in greenhouse
10=Disease control
11=Pest control
12=Risk management against climate change hazards
13=Higher yields
14=High Quality
15=domestic consumption
16=Sufficient labour
17=other, specify_____

Codes for sources of information on greenhouse (Specify all)
1=Government extension
2=Government Administration
3=Government Education
4=Government Research
5=Local Authority
6=NGOs
7=Church
8=Community Based Organizations
9= Farmer to farmer extension
10=Media
11=cooperatives
12=Company/manufacturer
13=Private business people
14=Dealers
11=other, specify________

(E.2.2) Irrigation method in Greenhouse

Which irrigation method are you using in the greenhouse?	What are your main reasons for using this method?	What are the advantages of using this irrigation method?	What are the disadvantages of using this irrigation method?	Source(s) of information on irrigation method

Codes for irrigation method:
1=Furrow irrigation
2=Drip irrigation
3=Flood irrigation
4=Sprinkler irrigation
5=Bucket irrigation
6=other (specify) _______________

Codes for reasons of using the irrigation method
1= As a means to save water
2= To increase income
3= It is compatible with the crop
4= New emerging technology
5= Most farmers are using it
6=Risk management against climate change hazards
7=Higher Yields per unit area
8=Save on labour
9= other, specify _____________

Codes for advantages of the irrigation method:

1=High water use efficiency
2=Higher crop yields per unit area
3=Low initial investment costs
4=Reduces disease incidence
5=Reduces insect damage
6=Efficiency in manure use
7=Allows efficiency in fertilizer use
8=Simple and Easy to use
9=readily available locally 10=Low cost (Affordable)
11=Low operational costs
12=Low Maintenance costs
13=Spares readily available
14=Short payback period
15=Available in different sizes
16=Uniformity of irrigation application
17=Skills required to operate are not high
18=compatible with the farming system
19=Reduces labour costs
20=Improves quality of produce
21=Reduces weed growth
22=Reduces crop failure
23=others, specify _

Codes for disadvantages of this irrigation Method:

1= High initial Capital requirement
2=Difficult to install
3=requires knowhow and skills
4=crop specific
5=other, specify__________

Codes for sources of information on irrigation method

1=Government extension
2=Government Administration
3=Government Education
4=Government Research
5=Local Authority
6=NGOs
7=Church
8=Community Based Organizations
9= Farmer to farmer extension
10=Media
11=cooperatives
12=Company/manufacturer
13=Private business people
14=Dealers
11=other, specify__________

(E.2.3.0) Greenhouse Tomato Production Inputs Costs

Land preparation	Seed Type ___________		Fertilizer				Manure Type: __________	
			Planting		Top-dressing			
Amount (KES)	Qty (Kgs)	Amount (KES)	Qty (Kgs)	Amount (KES)	Qty (Kgs)	Amount (KES)	Qty (Kgs)	Amount (KES)

Insecticides Type: __________		Fungicides Type: __________		Foliar feed Type: __________	
Qty (Kgs)	Amount (KES)	Qty (Kgs)	Amount (KES)	Qty (Kgs)	Amount (KES)

(E.2.3.1) Transport costs of inputs

1. Did you incur any costs in the transportation of inputs? 1= Yes 2=No
2. If Yes Please fill in the following table

Transportation costs in Ksh.					
Seeds	Fertilizers	Manure	Foliar feeds	Pesticides	Total KES

(E.2.3.2) Labour Issues

1. Did you employ someone for greenhouse Jan-Dec 2010? 1= Yes [] 2=No []
2. What is the average wage rate per day for a farm labourer in your farm in KES? _______________

3. How many hours does a labourer spend on the following activities?

		Hrs
i.	Nursery	[]
ii.	Transplanting	[]
iii.	Weeding	[]
iv.	spraying	[]
v.	Harvesting and sorting	[]

(E.2.3.3) Water costs

1. What is the source of water for irrigation in the greenhouse?[]

(1=River 2=Bore hole 3=shallow well 4= rain water harvested 5=piped/buying

6=other specify________________

If Borehole/shallow well, what is the cost of establishment?

Item	**Cost (KES)**
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________
____________________________________	_______________

2. What is the volume of water used in the greenhouse per week? ________________Litres

3. If bought what is the cost in KES of irrigating the crop per day? ________________KES

4. What is the approximate number of days the crop is irrigated per week? _________days

5. For how many months is the crop irrigated in the greenhouse? _______________ Months

(E.2.3.4) Capital Investment costs; Greenhouse itself, greenhouse tools and Greenhouse equipments.

Item(s)	Item(s) specification	Year of purchase or establishment	No. of units	Unit cost in KES	Productive life in Years	Salvage Value in KES	Current Replacement Costs in KES
1. Green house							
2. Irrigation Pipes inside the greenhouse							
3. water Pump							
4. Water tank							
5. Thermometer							
6. Sprayer.							
7. Weighing scale							
8. Water delivery pipes to the green house							
9. Other (specify)______							

(E.2.3.5) Marketing of the greenhouse Tomatoes

1. **Which unit of measure did you use when selling the greenhouse tomatoes?** ____
2. **What was the weight (in Kg) per unit?** ________
3. **What was the price (in KES) per unit weight?** ________
4. **How much greenhouse tomato produce (Kgs) did you harvest last season?** ________

(E.2.3.5.1) Buyers of the produce

Where do you sell the Produce?	Who are the buyers of greenhouse produce?	Why do you prefer the buyer?	Are you transporting the produce to the destination?	What is the Mode of Transport?	Why do you prefer this mode?	What is the total cost of transportation? In KES
1=Sold at farm gate 2=Open air market 3=Supper Market 4=At the factory 5=Institution 6=Other, Specify _____________	1=Consumers 2=Retailers3=Middlemen 4=Wholesalers 5=Institution 6=Processor 7=Other _______	1=Regular buyer 2=Regular Payments 3=Offers Inputs 4=Volume of sales 5=Offers credit 6=other (specify	1= Yes 2= No	1=Hand cart 2=Bicycle 3= Motor cycle 4= Motor Vehicle 5=Head load 6=Sold at farm gate 7=Other __________	1=Cheaper 2=Convenient 3=The only available 4=Mostly used around 5=Owned 6=Other _____	
[]	[]	[]	[]	[]	[]	

(E.2.4). How has greenhouse impacted on increasing incomes, improving Food security, Reducing vulnerability to climate

Kindly use the options below to answer the followingquestions according to your level of agreement ordisagreement:

A=Strongly Agree **B**=Somewhat Agree **C**=I Don't Know **D**=Somewhat Disagree **E**=Strongly Disagree

1. Greenhouse production has lead to reduced pest infestation and diseases

   ____

2. Greenhouse production has lead to increased farm income

   ____

3. Greenhouse production has lead to improved food security

   ____

4. Greenhouse production has lead to reduced crop vulnerability to low rainfall hazard

   ____

5. Greenhouse production has lead to reduced crop vulnerability to delayed onset of rainfall

   ____

6. Greenhouse production has lead to reduced crop vulnerability to drought hazard

   ____

7. Greenhouse production has lead to reduced crop vulnerability to flood hazard

   ____

8. Greenhouse production has lead to reduced crop vulnerability to frosthazard

   ____

9. Greenhouse production has lead to reduced crop vulnerability to hailstorms

   ____

10. Greenhouse production has lead to reduced crop vulnerability to water scarcity

   ____

(E.2.5) Challenges and recommendations of using greenhouse

What are the major challenges of greenhouse cultivation?	Suggested solutions/recommendations
1.	
2.	
3.	
4.	
5.	

(E.2.6) Challenges and recommendations of the irrigation method used.

What are the major challenges of the irrigation method used?	Suggested solutions/recommendations
1.	
2.	
3.	
4.	
5.	

APPENDIX 2: AGRO-ECOLOGICAL ZONES NAKURU COUNTY

Agro-Ecological Zone	Divisions where the Zone covers	Altitude (m.a.s.l)	Annual rainfall range (mm. p.a)	Area(Km2) covered by the Zone	Agricultural Activity
TA	Molo, Olenguruone and Njoro.	2980-3050	1200-1900	31	Forest Zone
UH_1	Molo, M/Narok, Bahati Forest, Olenguruone	2400-2970	1200-1900	282	Sheep – dairy zone
UH_2	Molo South, Mau Summit, Keringet, Olenguruone	2310-2580	1000-1400	756	Wheat – barley
UH_3	Mau Narok, Olenguruone	2310-2400	950-1200	111	Wheat, dairy, maize
LH_2	Kaazi, Dundori, M/Narok	2070-2400	850-1100	255	Wheat, maize, barley
LH_3	Njoro, Ngata, Menengai, Naivasha, Subukia	1890-2190	800-900	834	Wheat, Maize – barley
LH_4	Rongai, Naivasha, Upper Gilgil	1890-2110	650-800	555	Cattle, barley
LH_5	Gilgil, Naivasha, Karati	1840-2000	100-1200	582	Lower highland ranching zone
UM_3	Mbogoini, Bahati	1830-1950	300-1100	49	Marginal coffee zone
UM_4	Weseges, Lower Solai, KampiYa Moto	1600-1950	700-950	662	Sunflower – maize zone
UM_5& UM_6	Lake Naivasha, Mbaruk, Longonot	1620-1820	550-700	1064	Upper midland ranching zone
LM_5 & LM_6	Mbogoini	1480-1550	650-900	9	Lower midland livestock - millet zone

Sources:

- Sub County Agriculture office Nakuru: County and Sub Counties Profiles Nov. 2010;
- Farm Management Handbook of Kenya Vol. II/B Central Kenya (Rift Valley and Central Provinces) 1983