ASSESSMENT OF PURPLE PASSION FRUIT ORCHARD MANAGEMENT AND FARMERS' TECHNICAL EFFICIENCY IN EMBU, MERU AND UASIN-GISHU COUNTIES, KENYA

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DECLARATION

I Charles Gichimu Karani (A103/21596/2010) declare that this thesis is my original work and has not been presented for the award of a degree in any other university or any other award.

Signature …………………………………………………………………….

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Supervisors' approval

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and has been submitted with our approval as university supervisors.

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DEDICATION

Dedicated to my loving mother, my siblings and the fond memories of my late father.

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ABBREVIATIONS AND ACRONYMS

ASDS	-	Agricultural Sector Development Strategy
CBO	-	Community Based Organization
COLEACP	-	Europe-Africa-Caribbean-Pacific Liaison Committee
DEA	-	Data Envelopment Analysis
Df	-	Degrees of Freedom
FPEAK	-	Fresh Produce Exporters Association of Kenya
Ha	-	Hectare
HCDA	-	Horticultural Crops Development Authority
HDC	-	Horticulture Development Centre
KAPAP	-	Kenya Agricultural Productivity and Agribusiness Project
KARI	-	Kenya Agricultural Research Institute
KENGAP	-	Kenya Good Agricultural Practices
KG	-	Kilogram
KHCP	-	Kenya Horticultural Competitiveness Program
KHDP	-	Kenya Horticultural Development Program
KM	-	Kilometre

Ksh	-	Kenya shilling
m	-	Meters
MASL	-	Metres Above Sea Level
MDG	-	Millennium Development Goal
MLE	-	Maximum Likelihood Estimates
MoA	-	Ministry of Agriculture
MT	-	Metric Tonnes
n	-	Sample Size
NAFIS	-	National Farmers Information Service
NGO	-	Non-Governmental Organization
OLS	-	Ordinary Least Squares
PSDA	-	Private Sector Development in Agriculture
RoK	-	Republic of Kenya
SPSS	-	Statistical Packages for Social Sciences
Stata	-	Statistics and Data
TE	-	Technical Efficiency

OPERATIONAL DEFINITION OF KEY CONCEPTS AND TERMS

High market value crop – refers to high value crops i.e. crops that fetch high prices per unit. In this study passion fruit is a high market value crop.

Management analysis – refers to the process of awarding management scores at a scale of 1-5 for each farmer through observation (weeding, training of vines and pruning, disease management, manure and fertilizer application, watering) of the main orchard and then determining their performance. Score of 1 and 5 represented poor and excellent management respectively.

Production efficiency – refers to how well farmers utilize the available resources in the production process, otherwise referred to as efficiency of production.

Productivity- It is a measure of efficiency of production computed herein as a ratio of purple passion fruit output to the inputs required to produce it, output is in kilograms per hectare of land under purple passion fruit.

Small scale farmers – refers to farmers having 0.04 to 3.00 ha of their land under purple passion fruit.

Technical efficiency – refers to the measure of input-output transformation or ability of a purple passion fruit farmer to transform the available amount of inputs to marketable (quality) output (ranges from 0 to 1). It is an indicator of productivity and production efficiency.

ABSTRACT

Horticulture industry sustains millions of livelihoods in Kenya. Over the last decade, passion fruit has emerged as an important high market value horticultural crop following the establishment of new and expansion of existing large scale beverage producers that use local fruits for juice extraction. There has also been growing export markets and increasing numbers of health conscious consumers. Currently, the productivity levels are low, at 8 ton ha^{-1} compared to potential of 24 ton ha^{-1}. Purple passion fruit production is mainly done by small scale farmers (with land holding as low as 0.04 ha). The primary objective of this study was to assess purple passion fruit orchard management and technical efficiency of small-scale farmers in Embu, Meru and Uasin-Gishu Counties. Cross-sectional data from 123 randomly selected farmers was collected using a personally administered semi-structured questionnaire. In the analysis, descriptive statistics, stochastic frontier and multiple regression models were used. The results showed that the purple passion fruit production input elasticity was 0.95 which represented decreasing returns to scale. Orchard age, credit amount used, non-passion fruit income and County variables significantly and positively influenced TE at 5% level. The level of education, extension advice use frequency and market access positively and significantly influenced technical efficiency at 10% level. The overall mean technical efficiency was 59%. This indicated production costs saving estimate of 32% for the average farmer in attaining the TE of the most technically efficient purple passion fruit farmer (86%). The gamma parameter (γ) was 0.86 which indicates that 86% of the total variation in purple passion fruit output was due to technical inefficiencies. Farmers in Meru had the highest technical efficiency (65%) followed by Uasin Gishu (57%) while Embu had the lowest (47%). Mean management scores for the five practices (training of vines and pruning, weeding, watering, manure/fertilizer and pest/disease management) evaluated also followed the above trend across the Counties. Based on the results, increased emphasis on farmer update on farming trends through participatory methods (lead farmer approach, training, farm visits and demonstrations) is recommended. There is need for up-scaling orchard management practices among farmers to reduce the orchard age effect and prolong their lifespan. Credit access and use could be enhanced through increased formation and operations of services provision oriented farmers' associations. Farm and non-farm income activities diversification should be encouraged to a level that farmers can adequately manage so as to promote enterprises monetary inter-dependence. The study further recommends promotion of County cross-border farmer linkages in tapping the economic potential from passion fruit. This is expected to offer a platform for sharing ideas and success experiences thus increasing farmers' production efficiency and improving livelihoods.

CHAPTER ONE: INTRODUCTION

1.1 Background

Local and export horticultural markets generate income for millions of Kenyans. Horticultural exports sustain the livelihoods of approximately 1.20 million people and are an important source of foreign exchange in Kenya, accounting for 14% of total export earnings (HCDA, 2011). In 2010, Kenya earned Kshs. 77.70 billion from horticultural exports (HCDA, 2011). Aside from exports, a large portion (96%) of horticultural produce is consumed locally (Kibe, 2011). Approximately 80% of horticultural producers are small holder farmers (Namu, 2007).

In 2010, passion fruit (*Passiflorae edulis*) was ranked third (at 8%) after avocado (62%) and mango (26%) in Kenya in terms of foreign exchange earnings (HCDA, 2011). Its major markets are domestic and regional (HCDA, 2012). Kenya is the market leader of fruit juice exports in East Africa and also among the large producers of passion fruit in African (KHCP, 2011). In Kenya, passion fruit has emerged as an important high market value horticultural crop. This has been influenced by the establishment of new (Kevian and Valley orchard among others) and expansion of existing (Delmonte and Coca Cola) large scale processors of fruit juice. In addition, there has been increasing numbers of health conscious consumers (Wangungu, 2012) and growing opportunities in export markets. In 2010, passion fruit contributed Kshs. 1.9 billion which accounted for 1.19% of the domestic value of the total horticultural produce (Republic of Kenya, 2010[b]; HCDA, 2011). Uganda is a major regional market for passion fruit produced in Kenya (Sebstad and Snodgrass, 2008).

There are two passion fruit varieties, the purple and yellow (Appendix 2). Most fresh fruit consumers prefer purple variety to yellow because of its flavour (Morton, 1987). Purple passion fruit (*Passiflorae edulis* var *purpla)* is a high market value crop and can realize high yields more regularly since it is in production for at least 6 months (two seasons 3 months each) annually thus a suitable enterprise for smallholder farmers. The fruit production is mostly done on orchards measuring from 0.25 to 2 acres (Mbaka *et al*., 2006; Otipa *et al*., 2009). According to Anderson (2003), and Gockowski and Michel (2004), small holder farmers are faced with limitations such as capital, management skills and storage facilities. Therefore, they need not produce surplus in order to minimize wastage. Timely sale of farmers' produce ensure their little resources are replenished thus enabling provision of capital for other enterprises.

Purple passion fruit enterprise has good returns compared to cabbage, maize, wheat, tomatoes and beans (Kibet, 2011) if production is carried out efficiently especially in the first production year with expected increase in returns during the second and third years of production (Fintrac, 2009). According to Fintrac (2009) the enterprise can attain a gross margin of Ksh. 629,850 per hectare. Therefore, the enterprise presents a quick avenue to poverty alleviation, creation of employment and improved food security (Kibet *et al*., 2011[b]). However, inadequate levels of inputs application (Sibiko, 2012) and weak management capacity present a challenge towards attaining production efficiency (Kleemann *et al.*, 2010) among small scale farmers.

In Kenya, the purple passion fruit enterprise operates below potential thereby realizing low average yields of 8-9 ton ha^{-1} in contrast to 19-24 ton ha^{-1} in South Africa and Australia (HDC, 2005; Mbaka *et al*., 2006). Over the last seven years, passion fruit production in Kenya has recorded fluctuations in output. Passion fruit production increased from 2005 to 2007, declined from 2008 to 2009 and then rose minimally in 2010. Productivity has been on decline from 2005 to 2010 (Table 1). The Rift region passion fruit output has had the highest decline from 2006 to 2010. Central, Western and Nyanza regions also recorded fluctuations in the fruit output from 2006 to 2010 (HCDA, 2011).

Table 1: Passion fruit productivity in Kenya between 2005 and 2010.

Year	Production area (ha)	Output ('000' Kg)	Yield (kg/ha)	Value ('000' Kshs)
2005	3958	53396	13490.65	1601850
2006	6986	61440	8794.73	1843185
2007	8168	71283	8727.11	2138475
2008	5605	49662	8860.30	1513440
2009	5187	44137	8509.16	1435757
2010	6745	55094	8168.12	1873925

Source: Republic of Kenya (2010[b]) and HCDA (2011)

The data of Kenya's passion fruit productivity (Table 1) portrays significant deviation from the potential. Instances of output increase are associated with expansion of land under passion fruit rather than improved productivity per unit area. Increasing productivity of purple passion fruit like other crops would be crucial in addressing the challenges of growing population and increasing land fragmentation in the producing areas. Therefore, with the rising local and export importance of purple passion fruit there is necessity to maximize the benefits from the fruit. The production, productivity and unmet demand of the fruit should be the point of reference for economic empowerment in the fruit growing regions. Accordingly, national level (policy) and farm level (resource use) interventions are required towards achieving the productivity potential.

1.2 Problem statement

Despite the significant economic importance of purple passion fruit, its production has been on a decline with the average yields being relatively low at 8 ton ha^{-1} compared to a potential of 24 ton ha^{-1} (Mbaka *et al*., 2006; KENGAP, 2011). Currently, the demand for the fruit highly exceeds supply. The supply-demand gap is expected to persist due to low yields. Most past studies have largely focussed on pest and diseases management and provision of planting materials of the purple passion fruit; Mbaka *et al*. (2006), Otipa *et al*. (2008), Amata *et al.* (2009), Gaturuku and Isutsa (2011), Gachanja and Ochieng' (2011) and Wangungu (2012). However, it is not clear why farmers in the producing Counties are not attaining their productivity potential which would be important in offsetting the existing demand-supply gap. Therefore, assessment of purple passion fruit orchard management and technical efficiency among farmers in the producing Counties would be important in understanding resource use and productivity of the fruit under the existing socioeconomic and institutional arrangements. The assessment would also be crucial in formulating interventions for enhancing and sustaining purple passion fruit productivity.

1.3 Objectives

1.3.1 General objective

To assess purple passion fruit orchard management and technical efficiency of small-scale farmers in Embu, Meru and Uasin-Gishu Counties in order to explore avenues for enhancing and sustaining purple passion fruit productivity.

1.3.2 Specific objectives

1. To determine the technical efficiency of the small scale purple passion fruit farmers so as to understand resource use efficiency.
2. To assess socioeconomic and institutional factors that influence technical efficiency of the small scale purple passion fruits farmers in order to identify avenues for enhancing the fruit productivity.
3. To examine management practices and socioeconomic-institutional characteristics of small scale purple passion fruit farmers in relation to their technical efficiency scores.

1.4 Hypotheses

- Purple passion fruit small scale farmers in the study regions are not technically efficient.
- Socioeconomic and institutional factors do not significantly influence the technical efficiencies of the small scale purple passion fruit farmers.
- Management practices and socioeconomic-institutional characteristics of small scale purple passion fruit farmers are not positively related to farmers' technical efficiency.

1.5 Significance of the study

Despite the economic importance of purple passion fruit farming, efficiency and management status of small scale farmers who are the main producers in the study regions has been unknown. The study was crucial in establishing the technical efficiency and management status of small scale farmers and consequently informing policy recommendations. Policy recommendations such as orchard management, farming income diversification, information systems, farmer education and linkages will be communicated to the stakeholders through collaborative activities. Once the appropriate recommendations are availed it is expected that farmers will utilize them to improve their yields. Improved yields would contribute to purple passion fruit value chain profitability and sustainability through increased fruit supply and invigorated chain activities. The results of the study will attract farmers who had withdrawn as well as new participants at the farm level which will contribute to narrowing the existing demand-supply gap. Improved livelihoods will contribute towards alleviation of poverty (first MDG). In addition, the study sets an important basis for assessment of productivity under the devolved system of government in the 47 Counties of Kenya. Information generated from this study will contribute to the available literature on purple passion fruit especially the TE knowledge gap.

1.6 Conceptual framework

The conceptual framework was based on production theory (Figure 1) where $y = f(x_s)$, y being the output (yield) and x_s are production factors (Cobb and Douglas, 1928). The conceptual framework was organized in terms of influence and feedback mechanisms of farm level production efficiency. The framework focuses on input-output transformation efficiency, policy recommendations, and effects thereof. Production factors (seedlings, farm size, fertilizers, manure, labour and pesticides) were used as inputs in the purple passion fruit production process. It was anticipated that as more inputs were used by the farmer, fruit yields would increase on one hand but this may have a negative effect in cases of overuse. Therefore, optimality was crucial in deciding the level of inputs to be applied. Yield levels were affected by efficiency of production of a farmer. This perspective was supported by the notion that for a production process to be efficient, the manner of utilization of the available resources is important in realization of maximum output from a given set of inputs (its technical efficiency). The production function was presented as:

$$Y = \beta_0 + \sum \beta_i X_i + v - \mu \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

Where: *Y* is the purple passion fruit output, *x* are inputs utilized, β are the unknown parameters, μ is the non-negative random variable which is assumed to account for technical inefficiency in production (one-sided), and *v* being a random variable (which is symmetric in nature).

Socioeconomic and institutional factors were expected to influence farmers' efficiency. Socioeconomic factors that were anticipated to influence technical efficiency included age of the decision maker and the main orchard, gender, farming experience, education level, use of irrigation, and source of planting materials. Institutional factors such as amount of credit used, extension service frequency, market access and membership to passion fruit growers associations were hypothesized to influence TE. The influence relationship was expected to follow equation 2.

$$\mu_i = \delta_0 + \sum \delta_i Z_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2)$$

Where: μ_i being technical inefficiency, δ_0 and δ_i the unknown parameters that were to be estimated while Z_i represented the inefficiency variables of farmer i.

The management practices of farmers were hypothesized to play an important role in the conceptualized efficiency model but were embedded in the production, institutional, and socioeconomic aspects. The technical efficiency and its influencing factors as well as management practices across the study areas were expected to influence policy which the study had proposed to recommend. Once the policies were recommended the outcome was expected to have a feedback effect in improving technical efficiency and production levels. Ultimately, improved income levels and livelihoods were anticipated. Improved incomes among the purple passion fruit farmers were expected to have a feedback effect on production, socioeconomic and institutional factors through informed and improved use of inputs, accessibility of institutional services and alteration of the current socioeconomic aspects of the farmers.

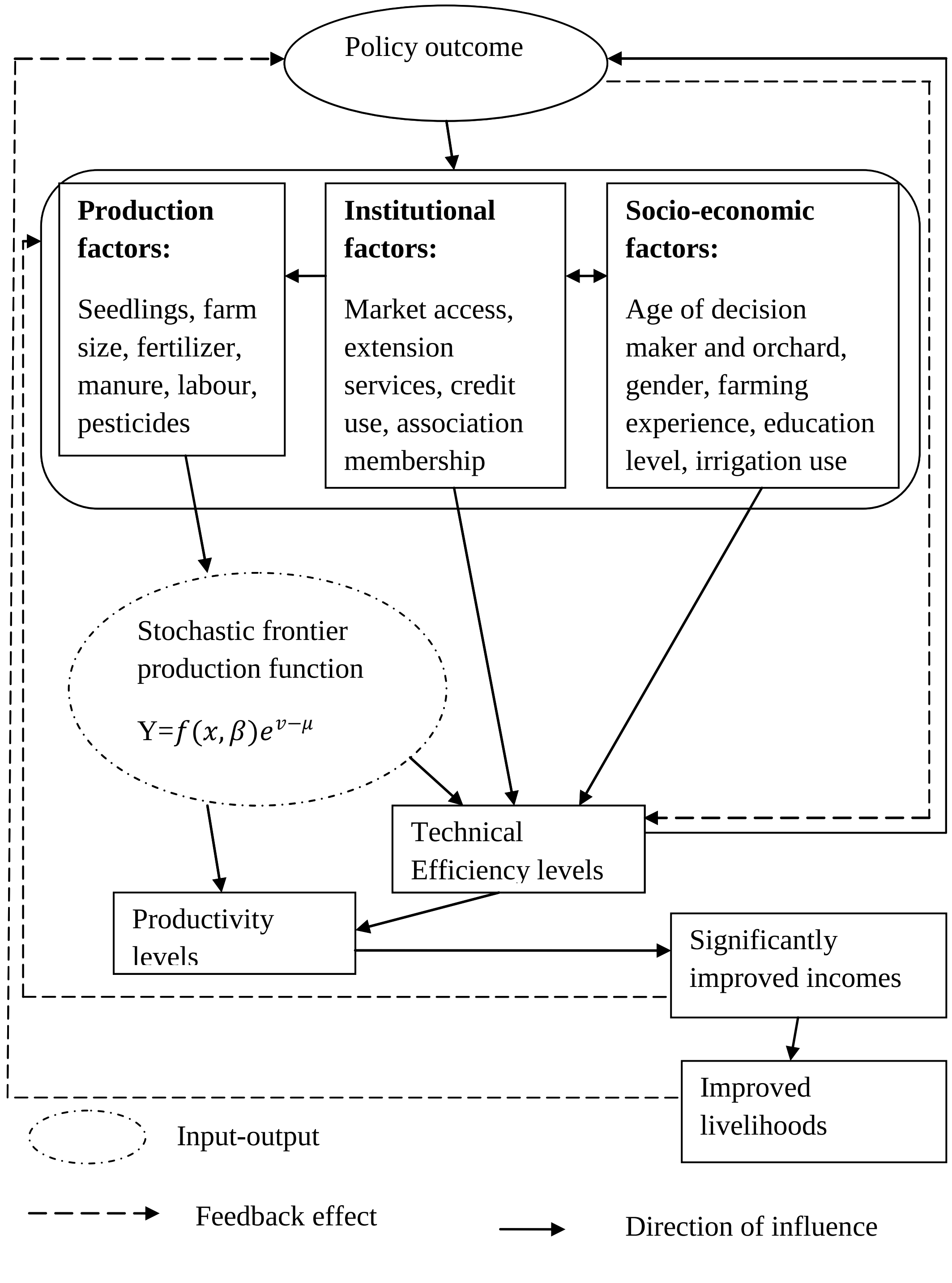


Figure 1: Conceptual framework.

Source: Modified from Cobb and Douglas (1928) and Sibiko (2012)

1.7 Scope of the study

The study involved small scale purple passion fruit farmers in Embu, Meru and Uasin Gishu Counties of Kenya who were in production. One year (2012) cross sectional data was used in this study. According to Kenya's Agricultural Sector Development Strategy (ASDS) small scale farmers carry out production on farms measuring 0.20 to 3.00 ha (Republic of Kenya, 2010[a]). However, due to high returns of purple passion fruit farming, farms with an average size of 0.10 acres (0.04 ha) were considered. Therefore, the study covered farmers with 0.04 to 3.00 ha of their farm under purple passion fruit.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

The chapter reviews literature that is important for the purposes of this research. The reviewed literature covers the major issues in purple passion fruit farming and management aspects. In addition, the chapter also reviews methods of measuring technical efficiency as well as identifying influencing factors. A critical review of empirical studies on technical efficiency is included. The research gap is eventually identified.

2.1 Purple passion fruit growing, management and challenges

The purple passion fruit is considered to have originated from southern Brazil through Paraguay to northern Argentina (Acland, 1971; Morton, 1987). In Kenya, purple passion fruit farming was introduced around 1920s and was expanded in the mid 20th century. The fruit is mainly grown in Rift Valley (Elgeyo-Marakwet and Uasin Gishu Counties), Eastern (Meru and Embu Counties), Central (Murang'a and Kiambu Counties), Western (Bungoma County) and Nyanza (Kisii County) regions (Amata *et al.*, 2009 and HCDA, 2012). These areas are characterized by an altitude of 1200-2200m ASL, rainfall of 1800-2800mm per annum and temperatures averaging 18^{o}C (Otipa *et al*., 2008).

Purple passion fruit cultivation is well suited in the subtropics with a frost-free climate. It is a strong, climbing vine that grips by tendrils to nearly any support. It can grow 15 to 20ft high per year once established and needs strong support. Its lifespan is 5 to 7 years (Acland, 1971; Morton, 1987). *Passiflorae edulis* var *purpla* grows and produces well at altitudes of 1200m above sea level and temperature range from 8 to 28°C. The plant remains productive all year round in more tropical areas (Republic of Kenya, 2003).

The purple passion fruit plant is highly susceptible to strong winds and high amounts of rainfall. Therefore, it requires wind protection and well distributed rainfall. The plant requires annual rainfall of between 1000 and 2500mm but can also do well at 900 mm. High rainfalls during the flowering period is destructive to the flowers and limits activities of insects thus hindering pollination. Its vine is shallow-rooted thus prone to drought stress. This effect may culminate into poor quality fruits, low yields as well as economic losses to farmers (Republic of Kenya, 2003; Gaturuku and Isutsa, 2011).

From 1960s large plantations were overwhelmed by infectious diseases and pests, for instance brown spot, *Fusarium wilt*, thrips, mites among others. These challenges led to a shift towards small holdings which could be better managed (KENGAP, 2011). Currently, in Kenya, the recently emerged die back disease is estimated to cause high produce loss due to infections (Wangungu, 2012).

The economic contribution of passion fruit to household income continues to diminish due to decline in production in Kenya. Since 2006, passion fruit production has declined from 61,440 to 44,137 MT in 2009

(HCDA, 2012). Kenya is one of the leading producers of passion fruit in Africa. Other large producers world-wide include Hawaii, Brazil, Australia, Columbia, Zimbabwe and South Africa.

Purple passion fruit require regular water supply during dry periods, a good management of the numerous diseases and pests that attack and defoliate vines and a commitment to maintain the vines. In addition, proper equipment for spraying of vines, regular disinfection of pruning tools and adequate knowledge in crop nutrition requirements are important (KENGAP, 2011).

Insufficient knowledge on good agricultural practices as well as pest and disease management are major challenges in addition to the inaccessibility of pathogen-free planting materials (Mbaka *et al*., 2006; Kleemann *et al.,* 2010; Wangungu *et al*., 2010). Farmers are mostly attracted by the high prices of the fruit which leads to investment decision based on partial information; some therefore fail to take note of the challenges faced in growing the crop. Management of the purple passion fruit orchards differ from one area to another. This may be influenced by the climate of an area, availability of information, financial ability, infrastructure development, among others (Dirou, 2004).

Further, purple passion fruit has been facing marketing arrangements and value chain development challenges. Value chain development is crucial in purple passion fruit enterprise development and for this to happen, trust among the value chain actors is key in ensuring value chain efficiency. Several organizations mainly Private Sector Development in Agriculture (PSDA), Technoserve, Kenya Business Development Services (KBDS) and Kenya Horticultural Development Program (KHDP) have empowered farmers to bypass the brokers in some areas through enhancing market linkages to sell directly to the export markets and juice processing factories (PSDA, 2011). However, the efforts are still inadequate in the fruit producing areas. Additionally, a deficiency exists in the purple passion fruit value chain since horizontal cooperation among the passion fruit farmers has accentuated linkages to the produce buyers more than linkages to supporting markets. Passion fruit supporting markets are still underdeveloped and there are limited extension services which are provided largely through non-commercial (usually government and non-governmental) service providers (Sebstad and Snodgrass, 2008; Kibet *et al*., 2011[b]).

2.2 Measurement of technical efficiency

Efficiency of a farm is explained by how best the available inputs are converted to output(s) which represents productivity. Farrell (1957) did the first analysis of efficiency measure and proposed division of efficiency into two: allocative and technical efficiency. Allocative efficiency is the ability of a farm to optimize use of inputs, given their prices and available technology while technical efficiency is the ability of a farm to produce maximum output from a given level of inputs (Anandalingam and Kulatilaka, 1987). Technical efficiency assesses whether maximum transformation of inputs is being realized to achieve maximum output (Msuya *et al*., 2008); it thus involves assessing the production efficiency of a farmer. The combination of allocative and technical efficiency represents economic efficiency (Bravo-Ureta and Pinheiro, 1997).

Farmer's technical efficiency evaluation emanates from the estimation of a frontier production function (Ajibefun, 2002). Parametric and nonparametric approaches are used in assessing efficiency. The nonparametric approach employs envelopment technique, mainly the Data Envelopment Analysis Method (DEA). The method is based on linear programming and involves estimation of a production frontier through a convex envelop curve formed by line segments joining observed efficient production units (Khai and Yabe, 2011). Under this method no functional form is imposed on the production frontier and no assumption is made on the error term (Nchare, 2007).

The use of DEA has been found to have several deficiencies in many studies. For example, it does not take measurement errors and random effects into account, in fact, it supposes that every deviation from the frontier is due to the firm's inefficiency; it is very sensitive to outliers, and lacks the statistical procedure for hypothesis testing (Kibaara, 2005; Nchare, 2007). The absence of random error tends to exaggerate the level of technical inefficiency. The assumption that all the deviations from the frontier are due to inefficiency is highly unacceptable keeping in mind the variable nature of agricultural production (Amaza *et al*., 2006).

The parametric estimation is based on the empirical estimation of a production frontier whose functional form is determined beforehand (Kibaara, 2005). The stochastic frontiers method is the most popular parametric estimation method. Unlike the DEA, stochastic frontiers method takes into account measurement errors. However, this method is criticized based on its need to specify in advance the functional form of the production function and the distributional form of the inefficiency term (Nchare, 2007).

2.3 Identifying technical efficiency determinants

In using the stochastic frontiers method, alternatively called the Stochastic Frontier Production Model, two main approaches can be used in identifying and analyzing the factors influencing technical efficiency: the two-step and one-step approaches (Njeru, 2010). In the two-step approach, the stochastic frontier production model is estimated to determine technical efficiency indicators. The indicators obtained thereof are regressed on explanatory variables that will be a representation of the farm's and farmer's specific characteristics, using the Ordinary Least Squares (OLS) (Li and Liu, 2009). However, the two-step approach has a major weakness in that the first step assumes inefficiency effects (μ_i) to be independently and identically distributed in order to predict the value of technical efficiency indicators (Nchare, 2007).

The one-step approach was developed to address the inconsistencies associated with the two-step approach where a model was developed. In this approach, the inefficiency effects are defined as an explicit function of specified factors of the farm where all the parameters to be measured are estimated in one-step using Maximum Likelihood (MLE) Method (Kumbhakar *et al.,* 1991; Reifschneider and Stevenson, 1991). According to the one-step approach, the technical efficiency effects model would be expressed as:

$$\mu_i = \delta_0 + \sum \delta_i Z_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where δ_0 and δ_i are the unknown parameters to be estimated while Z_i are the inefficiency variables/characteristics of farmer i. The one-step approach facilitates estimation of the frontier production function parameters simultaneously with those of an inefficiency model; the technical inefficiency effects are specified as a function of other variables (Njeru, 2010; Kachroo *et al*., 2010).

In this study, the one-step approach was adopted due to the limitations of the two-step approach. The former helped in hypothesis testing on the production structure and level of efficiency. A factor of importance is that the one-step approach is less open to criticism at statistical level.

2.4 Critical review of empirical studies on factors influencing technical efficiency

One of studies done in Kenya on measuring technical efficiency was on maize by Kibara (2005). The study involved high, medium and low potential areas where there were differing technical efficiency levels within and across the areas. Management practices and socio-economic characteristics were assessed on their influence on technical efficiency. Purchase of hybrid seeds, tractor use, school years and high potential area variables positively and significantly influenced technical efficiency of farmers. However, the findings lacked the assessment of cost implication on technical efficiency as in the case of Nyagaka *et al*. (2010). This would have boosted the literature on technical efficiency in relation to cost implication which is still limited.

In assessing technical efficiency in resource use among potato farmers in Nyandarua-Kenya, Nyagaka *et al*. (2010) estimated TE at 67%. The researcher employed stochastic frontier analysis. Education, access to extension services, access to credit and membership in farmer groups were found to significantly influence technical efficiency. The study addressed the cost implication of technical efficiency improvement. However, it lacked a robust assessment of extension services effect where the researcher addressed the aspect of access to extension rather than use. Extension access was a weaker measure compared to extension service use; access may not translate to use. Mogues *et al*. (2009) in the study of agricultural extension in Ethiopia through a gender and governance lens noted that effective extension services would ideally translate to a certain extent to farmers adopting new farming practices, growing new crops, or adopting inputs they didn’t previously use. Therefore, the aspect of actual use of extension services supersedes access.

On the other hand, Njeru (2010) in a study on wheat in Uasin Gishu Kenya using SFA found that small scale farmers were technically more efficient than their large scale counterparts. They scored TE of 88 and 86%, respectively. Access to credit was found to significantly influence TE. However, the study lacked an aspect of actual use of credit. The assessment of access to credit presented a limited and unreliable measure of influence of TE. The 'access' characteristic was weaker than the 'use' aspect because access does not translate into greater use of credit services (Pande, 2010).

Most recently, Sibiko (2012) in the study of common bean productivity and efficiency in Uganda employed stochastic frontier model. Technical efficiency ranged from 0.91 to 85% and a mean of 48%. In this study, age, farming experience, distance to the market, extension service and group membership significantly influenced TE. In the study the researcher took a different approach from the norm on credit assessment where he assessed credit amount used rather than access to credit. Amount of credit used influenced TE negatively in this study. However, in assessing extension service the traditional aspect was taken by evaluation of access of extension service rather than use.

In Uganda, Bagamba *et al.* (2007) employed SFA to measure the technical efficiency of banana production of smallholders. The researchers assessed banana productivity through emphasis of soil fertility and labour. In the study, rent and remittances were found to influence TE negatively. These results were contradictory to those of Feng (2008) where the expectations would mainly be that receipt of remittances would make a banana producer to have increased access to the required resources to aid farming thus improved productivity and technical efficiency.

In China, Feng (2008) undertook a study to assess the effect of land rental market participation, land tenure contracts and off-farm employment on the TE in rice production in the rural areas. The TE scores ranged from 36 to 97% with a mean of 82%. Feng found that farmers that rented land were more technically efficient than those who owned or had contracted plots. These findings were consistent with Bagamba *et al.* (2007) in the study of smallholder banana producers in Uganda.

In the study of pig farming in Greece, Galanopoulos *et al*. (2005) argued that increasing the TE of a farm meant less input usage, lower production costs and ultimately, higher returns, which he cited as the driving force for most farmers in adoption of an enterprise. However, this may not be entirely the case since efficient management by a farmer is crucial in increasing efficiency. In the same way, Galanopoulos' notion of increasing technical efficiency could be achieved through better management practices thus optimal input usage rather than lesser usage which would lower production costs and eventually increase profit margins.

Amaza *et al*. (2006) in the study of food crop production in West Africa estimated technical efficiency at 68%. The TE scores ranged from 2 to

90%. Age, education, credit, crop diversification and extension significantly influenced technical efficiency. A rare aspect in measurement and influence of technical efficiency was taken where crop diversification was found to influence TE negatively. However, the study assessed access to extension services rather than extension services use frequency.

Technical efficiency has also been employed in Micro-finance where their impact on micro-enterprises was assessed in Cape Coast by Bhasin and Akpalu (2001). Age of an enterprise was found to influence technical efficiency negatively. Business experience, level of education and credit variables were found to influence TE positively. Hairdressers, dressmakers and wood-processors had 76, 83 and 89% TE respectively. A surprising outcome was observed in age and business experience which had a negative and positive effect on TE respectively. This was rather unusual in some way because having specialized in a micro-enterprise for a long time meant the owner had higher business experience and at the same time older. Therefore, the two variables would have at least had a similar influence on TE scores which the authors failed to explain.

Tijani (2006) in technical efficiency analysis of rice farms in Nigeria used a Trans-log stochastic frontier production function. The TE scores ranged from 30 to 98% and a mean of 87% was established. The study deviated from the common assessment of socioeconomic factors in the influence of TE. The researcher looked at a rather new aspect of technical efficiency in using traditional methods to frighten birds. Traditional methods used by farmers were found to influence technical efficiency positively. A summary of literature reviewed on technical efficiency is presented in Appendix 3.

2.5 Criticism and Research gap

In view of the reviewed literature, no study was found to have assessed orchard management, technical efficiency and factors influencing TE in purple passion fruit production. Most studies in passion fruit production have been on the agronomic aspects, mainly production, pest and disease management. These studies include Mbaka *et al*. (2006), Otipa *et al*. (2008), Amata *et al.* (2009), Gaturuku and Isutsa (2011), Gachanja and Ochieng' (2011) and Wangungu (2012) among others.

It was established that most studies among them Kuria *et al*. (2003), Nyagaka *et al*. (2010), and Sibiko (2012) assessed extension access while Kibaara (2005), Nchare (2007), and Njeru (2010) assessed credit access in their influence of technical efficiency. However, the access aspect was found to be unrealistic and unreliable (Mogues *et al*., 2009; Pande, 2010) when assessing its influence on technical efficiency since access may not translate to use among farmers. Therefore, the actual effect of extension and credit could only be established through actual use of extension advice and credit in an enterprise(s). In addition, most studies such as Kuria *et al*. (2003), Kibaara (2005), Nchare (2007), Njeru (2010) and Sibiko (2012) failed to explain the implication of technical efficiency on production cost which constraints farmers. What would be the implication on production cost if farmers improved their TE? What if farmers reduced their input application? What about if they attained the TE of the most efficient farmer? This would be important in guiding a farmer (mostly the small scale farmer) on the effects on costs since they are resource constrained. Therefore, this study was undertaken to assess the orchard management and efficiency of small scale purple passion fruit farmers in Embu, Meru and Uasin Gishu Counties while paying attention to the identified gaps, above.

CHAPTER THREE: MATERIALS AND METHODS

3.0 Introduction

This chapter highlights the key aspects of the research methodology for this study. It covers the study area, sampling design, research instruments and data analysis. Importantly, the chapter identifies and justifies the study area selected as well as tools used in the research and analysis.

3.1 Study area

The study was conducted in Embu, Meru and Uasin Gishu Counties (maps in Appendix 4) which are among the major purple passion fruit producing areas in Kenya (HCDA, 2012). The areas are suitable for passion growing due to favorable climatic conditions. The farmers in the selected Counties differ in management practices (emanating from farm management differences like irrigation and use of production factors) on fruit orchards which made them suitable for assessing efficiency. The areas also had experienced high production withdrawal rates by farmers. In addition, the areas had been selected for the KAPAP project which aimed at improving incomes for smallholder farmers and other value chain actors through enhanced productivity of passion fruit. This study was undertaken under the larger KAPAP project. The various parameters of the three Counties are described in Table 2.

Table 2: Description of the study area.

Parameter	Uasin Gishu	Embu	Meru	Source
Area (km^2)	3345.20	2,818	6,936	Kenya Open Data (2012)
Population	894,175	516,212	1,356,301	Kenya Open Data (2012)
Urbanization (percent)	39	16	12	Kenya Open Data (2012)
Households	202,291	131,683	320,616	Kenya Decides (2012)
Altitude (m.asl)	Above 1800	Above 1050	Above 1200	Kibet *et al.* (2011[a]); Kenya
Rainfall in mm	500-1800	500-1495	500-2600	Kenya Decides (2012)
Temperature range (^oc)	8.4-27	12-27	16-23	Kenya Decides (2012)

3.2 Sampling design

Since the population of the farmers undertaking purple passion fruit farming in the respective Counties was unknown, the study determined the desired sample size for the Counties together. Then a proportionate sample for each County based on its population was determined from the total sample size. The sampling frame comprised of purple passion fruit farmers. Multi stage sampling was employed. In the first and second stages, three Counties and two districts from each County were purposively selected based on their importance as major passion fruit growing areas. Eldoret East and West, Embu East and West, and Meru Central and Imenti South districts were selected from the three Counties. All the divisions within each selected district formed the clusters for the study. Simple random sampling method was used to select two divisions from each district. Systematic random sampling at an interval of 1 respondent was used to select a sample from each district for the study that is every second purple passion fruit farmer was selected. Respondents were identified with the assistance of Ministry of Agriculture extension officers.

The required sample size was determined by sampling methodology according to Anderson *et al.* (2007) as in equation 4.

$$n = \frac{pqZ^2}{E^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (4)$$

Where; n = Sample size; Z= confidence level (α=0.05); p = proportion of the population containing the major attribute (purple passion fruit farmers) and q = 1-p, E= allowable error. Since the proportion of the population is not known, p= 0.5, q= 1-0.5=0.5, E = 0.09, and from tables Z (α=0.05) = 1.96.

$$n = \frac{0.5 * 0.5 * 1.96^2}{0.09^2} = 118.57 \approx 119$$

This presents a minimum sample of approximately 119 respondents although this was increased to a total sample size of 130 to cater for any likely incomplete data. Seven questionnaires were incomplete thus 123 were used for analysis. Using the farming households of each County, a proportionate sample of Uasin Gishu (39), Embu (22) and Meru (58) was derived from the estimated sample size. However, due to the sampling method chosen for the study and inadequacy of farmers practising purple passion fruit farming in Meru County, only 53 were selected while in Uasin Gishu more farmers were selected to substitute the deficit in Meru. Therefore, sample size for Meru was 53, Uasin Gishu 48 and Embu 22.

3.3 Research instruments

The study used both primary and secondary data. Primary data was collected through interviews with the help of a semi-structured questionnaire (Appendix 1) that was personally administered to farmers. In cases where farmers had incomplete information on inputs and market, nursery operators, marketers and input suppliers were consulted. Secondary data was obtained from publications and institutions such as MoA and HCDA (located in the study areas) and was used for literature review and boosting the study discussion.

3.4 Empirical model specification and data analysis

Since presence of heteroscedasticity (non-constant error variance) makes the estimated coefficients to be inefficient and unreliable, there was need to test and correct it. In order to test for heteroscedasticity, analysis of variance of the cross sectional data from the study was done first then subjected to Breusch-Pagan / Cook-Weisberg test to establish its reliability (Berry and Feldman, 1985); that is, were the estimated coefficients efficient? Then natural logarithms were used to correct heteroscedasticity.

Normality test was also done to further check the reliability of the data since estimation of technical efficiency requires the inefficiency effects (μ_s) to be stochastic and have a particular distributional specification. It was therefore important to establish whether the inefficiency variable (μ) was normal. μ was assumed to be non-negative truncations of N (0, σ_μ^2) with half normal distribution. A kernel density function was plotted in Stata to assess the correctness of the assumption. A normal curve was superimposed on the kernel density curve to test for normality.

Based on the reviewed literature and weaknesses associated with the Data Envelopment Analysis (DEA) method, Stochastic Frontier Analysis (SFA) was used in this study. The choice was made on the basis of the variability of agricultural production which is attributed to climatic conditions, insect pests, and diseases, on one hand. On the other hand, data gathered from small scale farmers is usually inaccurate because they do not keep up to date records; accuracy depends on the farmer's recall capability. The stochastic frontiers method simultaneously took into account the random error and the inefficiency component in estimating a frontier function (Bravo-Ureta and Pinheiro, 1997). The Cobb Douglas functional form of the stochastic frontier was employed because of its appropriateness in computation and interpretation. The Translog functional form could also have been used but suffers from multi-collinearity and degrees-of-freedom problems. The functional and distributional assumptions as well as the values of unknown coefficients in equations 6, 7 and 8 (that is βs, δs, μ and v) were estimated using the maximum likelihood estimates method (MLE) in STATA 11 which makes use of the specific distribution of the error term and is more efficient than OLS. In addition, descriptive statistics (mean, standard deviation and charts) were used. A management score scale of 1-5 was used where one and five represented poor and excellent orchard management practices, respectively. The scale was used to assess the management status of small scale purple passion fruit orchards. STATA 11, SPSS 17 and Microsoft Office Excel software programs aided the analysis.

3.4.1 Analysis of Objective 1 and 2 data

Objectives one and two were analyzed simultaneously using Stochastic Frontier Analysis (SFA) method. Data for the first objective was analyzed using stochastic frontier production model to determine the relationship between the purple passion fruit output and the inputs used by selected farmers. The technical efficiency of each selected farmer was also determined (Appendix 8). The second objective was analyzed using an inefficiency model where technical inefficiency (μ) was the dependent variable and the inefficiency factors were the independent variables (Table 4).

The stochastic frontier model adopted in the study was as used by Aigner *et al*. (1977) based in an imperfect world (world with errors) which is an extension of the basic production function. It is comprised of output and input(s). The function is expressed as;

$$Y_i = f(x_i;\, \beta) + \varepsilon_i \quad \text{.......} \quad (6)$$

Where i=1, 2… N

Using Stata, the stochastic frontier production model used is as shown in equation 7 which is basically input-output transformation model while equation 8 was the inefficiency model.

$$\mathrm{LnY} = \mathrm{LnA} + \sum_{I=1}^{7} \mathrm{B_i LnX_i} + \mathrm{V} - \mu$$

$$\mathrm{LnY} = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + (v - \mu) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (7)$$

Inefficiency model

$$\mu_i = \delta_0 + \sum_{i=1}^{14} \delta_i Z_i$$

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + \delta_{12} Z_{12} + \delta_{13} Z_{13} + \delta_{14} Z_{14} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

Where:

ε (error term) = v_i-μ_i (upon decomposition), μ ranges from 0 to 1.

A and Bi = parameters to be estimated (i = 1, 2...7)

β = is a vector of unknown parameters and X_i = the vector of (transformations of the) ith input used by jth farm/ (firm)

Y = dependent variable (output); Xs = independent variables; μ and v = error term; β_s = parametric estimates and β_0 = the intercept term.

V = random variables and μ = non-negative random variables which are assumed to account for technical inefficiency in production

Z_i = inefficiency variables and δ_0 and δ_i = parameters to be estimated (i = 1, 2...14) together with the variance parameter.

Ln = natural logarithms; used to reduce the effect of heteroscedasticity.

Gamma (γ) which is also referred to as variance ratio that is $\{\sigma_\mu^2/(\sigma_\mu^2+\sigma_v^2)$ or (σ_μ^2/σ^2) was calculated to assess the level of inefficiency in the variance parameters, which range from 0 to 1. In addition, Lambda (λ) that is $\{\sigma_\mu/\sigma_v\}$ was also computed to assess goodness of fit and correctness of the specified normal/half-normal distribution assumption. It was also used to explain the disparities of purple passion fruit output among farmers. Marginal effects were also computed as {δ (lny/lnx)} at the mean of the independent variables values. Cost savings were computed to explain the implication of technical efficiency improvement as shown in equation 9.

$$\text{Cost savings } \% = 1 - \frac{\text{Mean Technical efficiency}}{\text{TE of the most efficient farmer}} * 100 \ldots (9)$$

Person-days were computed according to the rule that one adult male, one adult female and one child (< 18 years) working for one day (8 hours) equal one person-day, 0.75 person-days, and 0.50 person-days respectively as used by Onumah *et al*. (2009). The ratios were also employed by Battese *et al*. (1996) and Coelli and Battese (1996).

The hypothesized relationships for the production and inefficiency functions were as shown in Table 3 and 4.

Table 3: Description of the production variables (Xs) and expected signs.

Variable (Xs)	**Units of Measure**	**Expected sign**
Output (Y)	Kilograms (kg)	
Number of seedlings	Number	+
Farm size under passion fruit	Hectares (ha)	+
Fertilizer	Kilograms (kg)	+/-
Manure	Kilograms (kg)	+
Pesticides	Kilograms/litres	+/-
Hired labour	Person-days	+
Family labour	Person-days	+

Table 4: Description of the inefficiency variables (Zs) and expected signs.

Variable (Zs)	**Units of Measure**	**Expected sign to TE**
Technical inefficiency (μ)	0-1	
County	1=Embu, 2=Meru and 3=Uasin Gishu	+/-
Gender	Male=1 and Female=0	+/-
Age	19-35=1, 36-50=2 and over 50=3	+/-
Education	None=0; primary=1, secondary=2 and tertiary=3	+/-
Farming experience	Number of years	+
Household size	Persons	+/-
Orchard age	Number of years	+/-
Seedlings source	Own=1; local nursery=2, and Research institution=3	+/-
Extension frequency	Number	+
Farmer group	1=yes, 0=no	+/-
Market access	Kilometres to factor and output market	+/-
Irrigation	None=0, sprinkle=1, drip=2 and manual=3	+
Credit amount used	Kshs	-
Non-passion fruit income	Kshs	+

3.4.2 Analysis of Objective 3 data

Data for objective three was analyzed using descriptive statistics and multiple regressions. Management practices scores, socioeconomic and institutional characteristics of the purple passion fruit farmers were also examined in relation to technical efficiency scores trends. Orchard management scores for each sampled farmer from the Counties were determined using a management scale of 1-5 to award scores, where one and five represented poor and excellent orchard management, respectively. Scores were awarded to various management practices (training of vines and pruning, weeding, pest/disease management, watering and manure/fertilizer application) in the three Counties. Mean management scores were separated using Tukey's B test at 5% level of significance due to its ability to show significant differences decisively.

In order to determine whether orchard management practices influenced passion fruit farmers' technical efficiency, a multiple regression was run. Farmers' TE (determined using stochastic frontier model) was the dependent variable while management practices were the independent variables. T-test at 1, 5 and 10% significance levels was used to test the hypothesized relationship. The hypothesized relationship was as follows;

$$TEi = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \beta 4x4 + \beta 5x5 + \varepsilon i$$

$$TEi = \beta\_0 + \beta\_1 \text{ training of vines and prunning} + \beta\_2 \text{ weeding} + \beta\_3 \text{ disease management} + \beta\_4 \text{ watering} + \beta\_5 \text{ manure}\backslash \text{fertilizer application} + \varepsilon\_i. \ldots \ldots \ldots \ldots . (10)$$

CHAPTER FOUR: RESULTS

4.0 Introduction

The chapter reports the results from data analysis. Descriptive and inferential statistics were used in the analysis. Descriptive statistics results for the production, socioeconomic and institutional characteristics, technical efficiency and management practices scores are presented in this chapter. Further, validation tests, stochastic frontier production functions and inefficiency models results are also presented.

4.1 Descriptive results

4.1.1 Production, socioeconomic and institutional characteristics of Embu, Meru and Uasin Gishu Counties

The results of production, socioeconomic and institutional characteristics of farmers from the study area were computed as shown in Table 5. Most of the farmers had relatively small land sizes at an average of 0.22 ha; the farmer with the smallest piece of land under purple passion fruit had 0.04 ha, the largest had 1.21 ha and the median was 0.16 ha.

An average yield of 1,907 kg of purple passion fruit per farmer was recorded in the study Counties. This was realized by cultivating 0.22 hectares, where an average of 464 seedlings, 58 kg of fertilizer, 3,164 kg of manure, six kg of pesticides, 36.90 of hired and 57 family person-days were applied. In addition, 94, 86, 94, 72 and 98% of the fruit farmers used fertilizer, manure, pesticides, hired and family labour, respectively, in their orchards.

Table 5: Overall descriptive statistics for the variables assessed (n=123).

Variables	Mean	Std Dev	Minimum	Maximum
Output (kg)	1,906.94	5,216.17	2	48,000
Seedlings (number)	464.27	533.92	26	3,000
Farm size under passion fruit (ha)	0.22	0.52	0.04	1.21
Fertilizer (kg)	57.99	84.73	0	509
Manure (kg)	3,164.15	4,080.83	0	24,000
Pesticides (kg)	6.06	13.74	0	105
Hired labour (person-days)	36.9	69.52	0	525
Family labour (person-days)	56.72	75.80	0	580
Farming experience (years)	3.48	2.50	0.90	20
Household size (persons)	4.55	2.82	1	14
Credit used (kshs)	8,573.58	17,855.60	0	100,000
Age of the main orchard (years)	1.57	0.73	0.90	5
Extension frequency (times)	1.78	2.61	0	13
Market access (km)	3.05	4.07	0	18
Non-passion fruit income (kshs)	194,122.23	121,071	2,000	700,000

Most of the purple passion fruit farmers used seedlings from local nurseries. Local and own (self-propagation) sources were used by 53 and 39% of the farmers, respectively. Only 8% of the farmers planted seedlings sourced from research institutions. Approximately 34, 38 and 28% were youths (19-35), middle aged (36-50) and elderly (>50), respectively. Out of 123 farmers selected for this study 120 farmers (98%) had attained formal education. Out of the 123 sampled farmers, 37% had attained primary, 46% secondary and

15% tertiary education. The respondents who were the owners of the orchards constituted 73% men and 27% women.

The average household size was five members. The smallest household had one member while the largest had 14 members. The selected farmers had an average experience of 3.48 years in purple passion fruit farming, the least being 0.90 years while the highest was 20 years. The age of the orchards ranged from 0.90 to five years.

Among the farmers in the study, 41% used credit in their purple passion fruit orchards. The amount of credit used in purple passion fruit farming averaged Kshs. 8,573, the highest amount used was Kshs. 100,000. The non-passion fruit income ranged from Kshs. 2,000 to 700,000 with an average of Kshs. 194,122 per annum.

Out of the 123 farmers selected for the study, only 39% were members of passion fruit farmers groups. The study recorded an average frequency of 2 times that farmers received and used extension advice (from extension agents and trained farmers among others) on their purple passion fruit orchards per annum. Approximately 55% of the farmers irrigated their orchards. Out of the farmers that irrigated their orchards, 29 and 25% used sprinkler and manual irrigation methods, respectively. An average distance of 3.05 kilometres to the market was recorded (Table 5). In some areas of Meru County, farmers had to travel up to 18 kilometres to access market for their produce (Table 6).

Majority of farmers (45%) from Embu County were more than 50 years old. Farmers from both Meru and Uasin Gishu Counties were mainly middle aged at 38 and 42%, respectively. The largest source of seedlings was local at 48, 58 and 51% in Uasin Gishu, Meru and Embu Counties, respectively. Self-propagation followed at 48, 34 and 32% in Uasin Gishu, Meru and Embu Counties, respectively.

In Meru, Uasin Gishu and Embu Counties 58, 56 and 32% of the farmers were members of farmer groups. Less than 50% of farmers in all the three Counties used credit in purple passion fruit farming; Meru recorded 45%, Embu 32% and Uasin Gishu 40%. Meru County recorded the highest use of pesticides at 98% of the farmers followed by Uasin Gishu at 92% while Embu had the lowest users at 86%.

The means of selected production, socioeconomic and institutional variables were separated and tested for significance at 5% level using Tukey's B test (Table 6 and Appendix 6-detailed). Output was significantly different between Embu and Meru as well as Embu and Uasin Gishu. Uasin Gishu County had the highest average output (2,275 kg) followed by Meru (2,051 kg) while Embu had the lowest (756 kg). Among the three Counties average levels of manure, fertilizer and family labour use were significantly different; they were highest in Uasin Gishu followed by Meru while Embu had the lowest use. Farming experience for Uasin Gishu County was significantly higher compared to Embu and Meru Counties. The amount of credit used in

Meru County was significantly different from the other Counties. Credit use was highest in Meru while Uasin Gishu and Embu had significantly lower use than Meru.

Table 6: Descriptive results of three passion fruit producing Counties.

Variable	Embu County	Meru County	Uasin Gishu County
Output (kg)	756.09[a]	2,050.98[b]	2,275.35[b]
Number of seedlings (number)	326.05[a]	473.21[a]	517.75[a]
Farm size under passion fruit (ha)	0.18[a]	0.21[a]	0.26[a]
Fertilizer (kg)	31.87[a]	44.04[ab]	85.38[b]
Manure (kg)	1,662.27[a]	2,553.59[ab]	4,526.67[b]
Pesticides (kg)	5.07[a]	3.48[a]	9.36[a]
Hired labour (person-days)	32.05[a]	29.23[a]	47.60[a]
Family labour (person-days)	32.36[a]	45.22[ab]	80.59[b]
Farming experience (years)	3.03[a]	2.73[a]	4.51[b]
Household size (persons)	4.45[a]	4.28[a]	4.90[a]
Orchard age (years)	1.54[a]	1.56[a]	1.60[a]
Extension frequency (times)	2.27[a]	2.02[a]	1.29[a]
Market access (kilometres)	5.75[b]	3.86[b]	0.92[a]
Credit used (kshs)	6,318.18[a]	11,582.10[b]	6,285.42[a]
Non-passion fruit income (kshs)	152,155.00[a]	210,660.00[a]	189,688.00[a]

Means followed by a different letter along the row are significantly different at p=0.05; n=22, 53 and 48 for Embu, Meru, and Uasin Gishu Counties.

4.2 Empirical results

4.2.1 Validation tests

4.2.1.1 Heteroscedasticity test

The results for heteroscedasticity test were computed using Breusch-Pagan / Cook-Weisberg test as shown in Appendix 5. There was heteroscedasticity in the output variable where the chi-square value of 231.75 was significant at 1% significance level and different from zero. Most of the chi-square values of the explanatory variables in the stochastic frontier production and inefficiency models were statistically significant thus concluding presence of heteroscedasticity.

The presence of heteroscedasticity was evident in number of seedlings, farm size under passion fruit, fertilizer, manure, pesticide, family labour, gender, household size, irrigation and County variables whose chi-square values were statistically significant at 1% level. Further, farming experience and farmer group variables indicated presence of heteroscedasticity; the chi-square values were statistically significant at 5% level. Heteroscedasticity was also present in education and credit amount used; they were statistically significant at 10% level. On overall, presence of heteroscedasticity was confirmed in the survey data; the chi-square value was 306.58 for the simultaneous parameter and was strongly significant at 1% level.

4.2.1.2 Correction of heteroscedasticity

The established presence of heteroscedasticity in the cross-sectional data required correction. The data was transformed into natural logarithms, at a base of 10. Breusch-Pagan / Cook-Weisberg test for heteroscedasticity was then used to test for presence of heteroscedasticity as shown in Appendix 5. The heteroscedasticity that had been observed in the output variable was solved. The chi-square value for output was 0.18 and the p-value was 0.67 thus not significant; hence absence of heteroscedasticity. The overall chi-square value of the simultaneous parameter was not statistically significant. Results (Appendix 5) confirm absence of heteroscedasticity in the data of the variables used for the study.

4.2.1.3 Normality test

A kernel density function plotted in Stata assessed the correctness of the normality assumption as shown in Appendix 5. A normal curve was superimposed on the kernel density curve to test for normality. The normality test figure in Appendix 5 confirms that μ had fairly normal distribution. Therefore, technical efficiency estimation in the study was made possible.

4.2.2 Determination of technical efficiency

4.2.2.1 Stochastic Frontier Production Model Results

The stochastic frontier production function results for Embu, Meru and Uasin Gishu Counties are as shown in Table 7 and Appendix 12. Seven production variables were identified as the major inputs in purple passion fruit production; number of seedlings, farm size under passion fruit, fertilizer, manure, pesticides, hired labour and family labour. The log likelihood for the fitted model of Embu County was 22.91 and the chi-square was 1,835.91 and was strongly significant at 1% level. The log likelihood for the fitted model of Meru County was -45.12 and the chi-square was 55.99 and was strongly significant at 1% level while the log likelihood for the fitted model of Uasin Gishu County was -32.07 and the chi-square was 67.17 and was strongly significant at 1% level.

In Embu County, out of the seven input variables, five were significant. Number of seedlings, manure, pesticides and family labour were significant at 1% significance level while pesticides and farm size under passion fruit were significant at 5% level. Number of seedlings, manure, pesticides and family labour had positive signs while farm size under passion fruit had a negative sign.

In Meru County, number of seedlings and fertilizer had positive and significant effect on purple passion fruit output (yield) at 1% level. Family labour had negative and significant effect on output at 10% level. Uasin Gishu County had number of seedlings and manure being positive and significant at 5 and 1% significance levels respectively. Farm size under passion fruit, fertilizers, pesticides and hired labour had negative relationship to output whereas family labour had a positive relationship. Only number of seedlings was significant in all the Counties.

The technical efficiency range for Uasin Gishu County was 17 to 85% with a mean of 57%. In Meru County, the farmer with the lowest technical efficiency had 18% while the most efficient farmer had 86% TE and mean was 65%. In Embu County, the farmer with the highest technical efficiency had 67% while the lowest had 23% against a mean of 47% for the County (Table 7 and Appendix 8). The lambda (λ) values for Embu, Meru and Uasin Gishu Counties were 19.55, 3.59 and 3.07 respectively. The σ_μ values were higher than σ_v values across the three Counties. Embu had the highest γ value followed by Meru and Uasin Gishu.

Table 7: Stochastic frontier production function results for individual Counties.

County	**Embu**		**Meru**		**Uasin Gishu**	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Output						
Number of seedlings (number ha^{-1})	1.59***	0.51	1.18***	0.27	1.02**	0.42
Farm size under passion fruit (ha)	-1.89**	0.75	-0.37	0.28	-0.26	0.20
Fertilizer (kg ha^{-1})	-0.28	0.15	0.37***	0.12	-0.21	0.17
Manure (kg ha^{-1})	0.11***	0.03	-0.01	0.05	0.71***	0.27
Pesticide (kg ha^{-1})	0.10**	0.05	0.16	0.25	-0.23	0.21
Hired labour (person-days ha^{-1})	0.20	0.13	-0.01	0.01	-0.06	0.10
Family labour (person-days ha^{-1})	0.29***	0.10	-0.28*	0.15	0.01	0.14
_cons	-0.10	0.70	0.77	0.61	-1.38*	0.81
lnsig2v_cons	-7.90***	0.85	-2.77***	0.76	-2.84***	0.51
lnsig2u_cons	-7.62	132.17	-0.21	0.33	-0.60	1.00
Variance Parameters						
sigma_v {σ_v}	0.02**	0.07	0.25**	0.10	0.24**	0.06
sigma_u {σ_μ}	0.43	1.47	0.90**	0.15	0.74**	0.37
sigma2 {σ^2}	0.19**	0.07	0.88**	0.24	0.61	0.40
lambda	21.50	1.49	3.60**	0.22	3.08**	0.56
Mean technical efficiency (County)	46.94 %		65.24 %		56.76 %	

*, ** and *** significant at 10, 5 and 1 % significance levels respectively

In the overall stochastic frontier production model for the study Counties number of seedlings, farm size under passion fruit, manure application and hired labour variables were significant. The log likelihood for the fitted model of study Counties was -117.61 and the chi-square was 74.99 and was strongly significant at 1% level.

Number of seedlings and hired labour had a positive and significant relationship with purple passion fruit output at 5% significance level. Manure and farm size under passion fruit had a positive and negative significant relationship with output at 1% level respectively. Fertilizer had a positive relationship to output while pesticides and family labour showed a negative relationship.

On the overall, TE of small scale passion fruit farmers ranged from 17 to 86%. The mean technical efficiency for the farmers in the study was 59%. Therefore, a mean technical inefficiency of 41% was prevalent among the small scale purple passion fruit farmers in the study area. The gamma (γ) coefficient was 0.86 in the overall study area while the lambda (λ) value was 2.42 as shown in Table 8 and Appendix 10.

Table 8: Overall Stochastic Frontier Production Function Results.

Variable	**coefficient**	**standard error**
Output		
Number of seedlings (number ha^{-1})	0.80**	0.37
Farm size under passion fruit (ha)	-1.15***	0.45
Fertilizer (kg ha^{-1})	0.14	0.11
Manure (kg ha^{-1})	0.88***	0.28
Pesticide (kg ha^{-1})	-0.07	0.19
Hired labour (person-days ha^{-1})	0.37**	0.17
Family labour (person-days ha^{-1})	-0.03	0.14
_cons	-2.84**	1.30
lnsig2v _cons	-1.85***	0.58
lnsig2μ_cons	-0.59	0.43
Variance parameters		
sigma_v	0.31**	0.04
sigma_μ	0.75**	0.25
$sigma^2$	0.65**	0.20
lambda (λ)	2.42**	0.35
gamma (γ)	0.86	
Mean technical efficiency (overall)	58.66 %	

** and *** significant at 5 and 1 % significance levels respectively

4.2.2.2 Marginal effects

The marginal effects and marginal change in output of the three Counties were computed (Table 9). Marginal effects of farm size under passion fruit on output were negative while number of seedlings was positive in all the three Counties. Manure and hired labour had negligible negative marginal effect on output in Meru County. On the other hand, fertilizer had negative marginal effects on output in Embu and Uasin Gishu Counties. The highest positive and negative marginal changes in output were due to number of seedlings and farm size under passion fruit respectively. Meru had the highest purple passion fruit productivity levels followed by Uasin Gishu while Embu had the lowest.

Table 9: Marginal effects for Embu, Meru and Uasin Gishu Counties.

	Marginal effects			Marginal change in output per hectare (Kg ha^{-1})		
Variables	**Embu**	**Meru**	**Uasin Gishu**	**Embu**	**Meru**	**Uasin Gishu**
Number of seedlings	1.59	1.18	1.02	66.79	115.25	89.26
Farm size under passion fruit	-1.89	-0.37	-0.26	-79.39	-36.14	-22.75
Fertilizer	-0.28	0.37	-0.21	-11.76	36.14	-18.38
Manure	0.11	-0.01	0.71	4.62	-0.98	62.13
Pesticide	0.10	0.16	-0.23	4.20	15.63	-20.13
Hired labour	0.20	-0.01	-0.06	8.40	-0.98	-5.25
Family labour	0.29	-0.28	0.01	12.18	-27.35	0.88

Average productivity for Embu = 4,200.50 kg ha^{-1}, Meru = 9,766.57 kg ha^{-1} and Uasin Gishu = 8,751.35 kg ha^{-1}

On overall, number of seedlings and hired labour had positive and significant elasticities at 5% level as shown in Table 10. Manure application and farm size under passion fruit had positive and negative significant influence on output at 1% significance level, respectively. The passion fruit farm size, hired and family labour variables negatively influenced the level of output.

Manure quantity and number of seedlings had the highest positive elasticity on output respectively. The highest negative marginal effect of -1.15 was recorded for passion fruit farm size. The highest negative and positive marginal change on output was due to farm size under passion fruit and manure with a marginal change in output of -99.68 and 76.28 kg, respectively.

Table 10: Overall marginal effects of efficiency measuring variables on productivity.

Variable	Marginal effect/elasticity	Percent marginal Δ output	Marginal change in output per hectare (Kg ha^{-1})
Number of seedlings	0.80	0.80	69.34
Farm size under passion fruit	-1.15	-1.15	-99.68
Fertilizer	0.14	0.14	12.14
Manure	0.88	0.88	76.28
Pesticide	-0.07	-0.07	-6.07
Hired labour	0.37	0.37	32.07
Family labour	-0.03	-0.03	-2.60

Average productivity for Embu, Meru and Uasin Gishu Counties = 8,667.91 kg ha^{-1}

4.2.3 Factors influencing technical efficiency among small scale purple passion fruit farmers

In Embu County, education, farming experience and market access variables were significant at 1% level as shown in Table 11 and Appendix 13. Age, seedlings source and non-passion fruit income variables were significant at 5% while farmer group membership was significant at 10% level. In addition, age, education, farming experience, seedlings source, farmer group membership and non-passion fruit income negatively influenced technical inefficiency. Market access positively influenced technical inefficiency.

In Meru County, gender, extension advice frequency, amount of credit used and non-passion fruit income variables were significant. Credit use on purple passion farming was significant at 1% significance level. Gender and non-passion fruit income variables in the farming households were significant at 5% level. Extension advice frequency variable was significant at 10% significance level. Gender variable influenced technical inefficiency positively. On the other hand, amount of credit used, non-passion fruit income and extension frequency variables significantly influenced technical inefficiency negatively.

In Uasin Gishu County, orchard age, seedlings source, market access and gender variables were significant. Orchard age, seedlings source and market access were significant at 5% significance level while gender was significant at 10%. Market access variable significantly influenced technical inefficiency positively. Seedling source, orchard age and gender negatively and significantly influenced technical inefficiency.

Table 11: Inefficiency Models Results of Individual Counties.

County	Embu		Meru		Uasin Gishu	
Variable	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Technical inefficiency (μ)						
Gender (1=male)	-13.52	33.56	2.32**	1.01	-1.45*	0.83
Age (years)	-48.33**	21.54	0.27	0.35	0.15	0.63
Education	-18.15***	5.80	0.43	0.43	-0.05	0.53
Farming experience (years)	-99.60***	30.28	-0.30	0.64	-1.56	1.81
House hold size (persons)	-57.00	124.18	0.92	1.06	0.16	2.06
Orchard age (years)	37.86	107.14	-0.96**	1.51	-6.40**	3.18
Seedling source	-29.11**	12.52	0.58	0.48	-1.21**	0.57
Extension frequency (times)	1.46	4.10	-0.18*	0.11	-0.57	0.53
Farmer group	-55.75*	33.60	-0.39	0.63	0.26	0.80
Market access (km)	83.58***	25.77	0.13	0.61	3.86**	1.93
Irrigation	24.88	26.59	0.15	0.35	-0.07	0.50
Credit used (kshs)	-5.08	14.31	-0.46***	0.16	-0.26	0.24
Non-passion fruit income (kshs)	-79.79***	13.06	-0.52**	0.23	-1.46	1.61
_cons	0.92	1.57	-2.70	3.08	12.75**	7.91

*, ** and *** significant at 10, 5 and 1% significance level respectively

In the overall study area, the County, orchard age, credit amount used, non-passion fruit income, extension advice frequency and education variables significantly influenced technical inefficiency at various significance levels. County, orchard age, credit used and non-passion fruit income were significant at 5% level. At 10% significance level education, market access and extension frequency were significant. The results are presented in Table 12 and Appendix 11.

Table 12: Overall inefficiency model results for the study Counties.

Variable	Coefficient	Std. Error
Technical inefficiency (μ)		
County	-2.19**	1.02
Gender	2.24	1.65
Age (years)	0.74	0.73
Education	-1.04*	0.56
Farming experience (years)	4.30**	1.84
House hold size (persons)	0.84	1.37
Orchard age (years)	-16.70**	8.03
Seedling source	-1.62	1.04
Extension frequency (times)	-0.85*	0.51
Farmer group	1.80	1.25
Market access (km)	-1.75*	1.75
Irrigation	-0.15	0.51
Credit used (kshs)	-0.22**	0.07
Non-passion fruit income (kshs)	-2.39**	0.92
_cons	-0.16**	5.66

* and ** significant at 10 and 5% significance level respectively

4.2.4 Descriptive results of empirical analysis

4.2.4.1 Technical efficiency descriptive results

The results of technical efficiency percent range and spread were computed by use of frequency percentages as shown in Table 13 and Figure 2.

In the study, 52% of the farmers had over 50% technical efficiency. Only 6% of the farmers recorded a technical efficiency of 0-25%. Embu County had the highest portion of its farmers with 0-25% TE followed by Uasin Gishu while Meru had the lowest portion at 9, 6 and 4% respectively.

On the higher side, 30% and 10% of farmers in Meru and Uasin Gishu Counties had 76-100% technical efficiency respectively. In Embu County, none of the farmers had 76-100% TE and 59% of its farmers had technical efficiency of below 50%. Meru and Uasin Gishu Counties had 87 and 63% of their farmers with more than 50% technical efficiency. On overall, 69% of the farmers in the study had TE of above 50%.

Table 13: Range of Technical Efficiency (TE) by County.

Range of TE (%)	Embu (%)	Meru (%)	Uasin Gishu (%)	Total (%)
0-25	9.09	3.77	6.25	5.69
26-50	50.00	9.43	31.25	25.21
51-75	40.91	56.61	52.08	52.03
76-100	0.00	30.19	10.42	17.07
Total	100.00	100.00	100.00	100.00

Key: 100% = 22 farmers in Embu, 48 in Uasin Gishu, 53 in Meru and 123 in the entire study area.

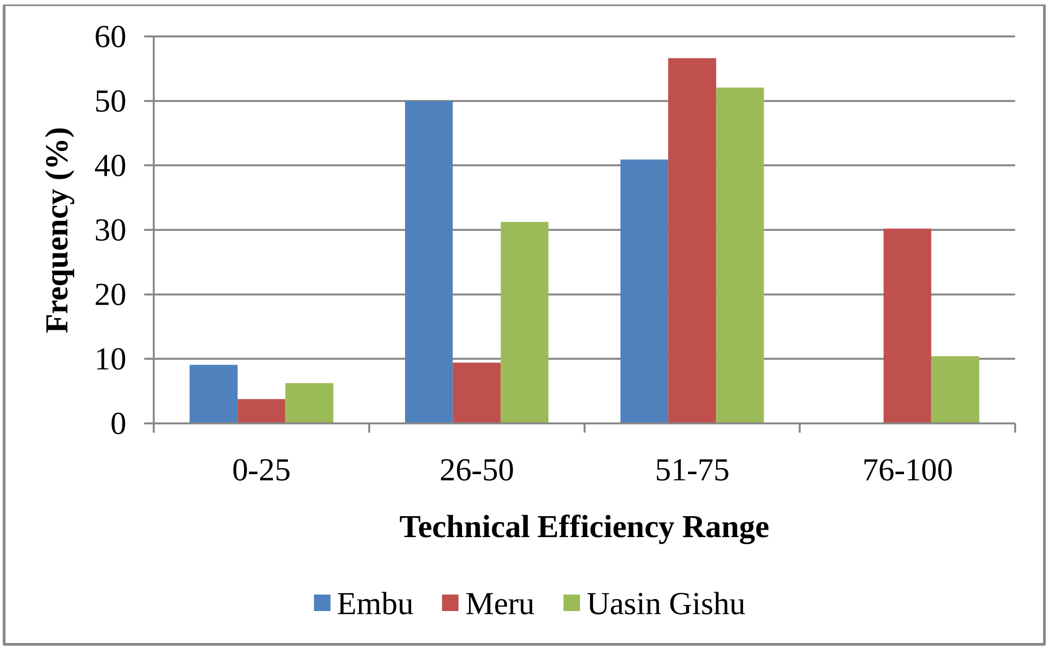


Figure 2: Technical efficiency range of individual Counties.

4.2.4.2 Comparison of technical efficiency scores to socioeconomic and institutional characteristics.

The results of technical efficiency (TE) versus socioeconomic and institutional variables are presented in Table 14. The age categories of farmers performed differently in terms of TE. The ‘more than 50 years’ age category of farmers was least efficient attaining 56% TE. The farmers with ages 36-50 years had 60% TE and were the most efficient.

Female farmers had 60% TE compared to male’s 58%. Farmers who sourced their seedling materials from research institutions had the least TE of 54% compared to own and local sources with the highest TE of 59%. Orchards TEs increased with age up to age of 4. Orchards with age of between 4 and 5 had the lowest TE.

Farmers with and without formal education performed significantly differently. Farmers with formal schooling had TE of between 58 and 60% while those without education had 47% TE. Purple passion fruit farmers who were members of a farmers' association were more technically efficient (59%) than non-members (58%). Farmers who used credit were more efficient than those who did not use at 59 and 58% TE, respectively.

Table 14: Comparison of technical efficiency scores to selected socioeconomic and institutional characteristics.

Variable	Description	TE %
Age (years)	18-35	59.08
	36-50	60.45
	>50	55.86
Gender	male	58.03
	female	60.39
Orchard age (years)	0-1	52.61
	1.1-2	61.61
	2.1-3	63.64
	3.1-4	75.34
	4.1-5	68.22
Seedling source	own	58.70
	local	59.41
	research institution	53.59
Education level	none	46.50
	primary	58.13
	secondary	59.86
	tertiary	58.95
Farmer group	members	59.26
	non-members	57.73
Credit amount used (Kshs)	0	58.32
	>0	59.15

4.2.4.3 Orchard management analysis results

The results for assessment of management practices of purple passion fruit orchards are presented in Table 15 and Figure 3. On overall, weeding recorded the highest mean followed by training of vines and pruning at 3.48 and 3.41 points respectively. Disease management recorded the lowest mean management score of 2.45. Watering followed disease management closely with a score of 2.50; manure and fertilizer application scored a mean of 2.96 points.

In individual Counties, Meru attained the highest management score of 4.25 in training of vines and pruning, 3.94 in weeding, 3.46 in manure and fertilizer application, 3.30 in watering and 2.54 in disease management. Embu County recorded the lowest mean orchard management scores of between 1.41 and 2.68 points. Watering of orchards recorded the lowest score in Embu County among the five assessed management practices. Uasin Gishu County scores came second to those of Meru County. The scores for Uasin Gishu County ranged from 2.10 to 3.33. Watering and disease management had the lowest scores of 2.10 and 2.53 respectively in Uasin Gishu. Weeding (3.33 points) had the highest management score in Uasin Gishu.

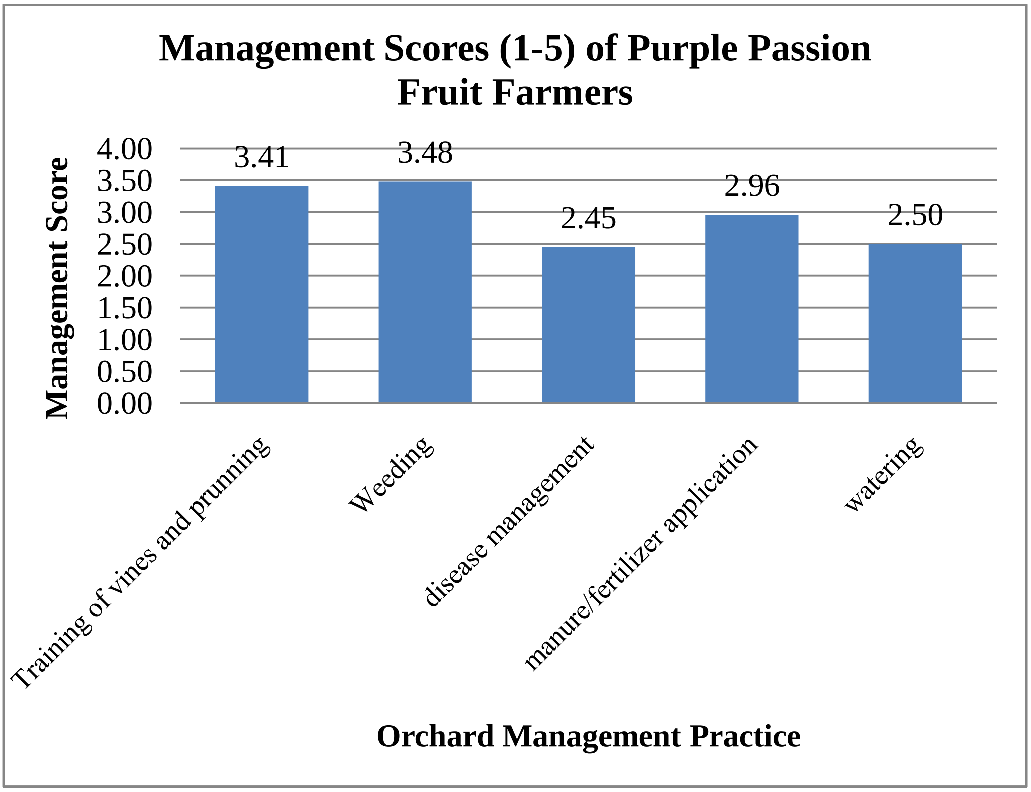


Figure 3: Overall orchard management scores for purple passion fruit farmers.

The management score means were separated and tested for significance using Tukey's B test as shown in Table 15 and Appendix 7 (detailed). Training of vines and pruning, weeding and watering mean scores were significantly different among the three Counties at 5% significance level; Meru had the highest mean followed by Uasin Gishu while Embu had the lowest mean. Manure and fertilizer application scores were significantly different between Embu and Uasin Gishu as well as Meru and Embu; Meru County had the highest mean followed closely by Uasin Gishu while Embu had the lowest. Disease management practice was similar among the three Counties.

Table 15: Results for orchard management practices analyzed using Tukey's B Test.

Management practice	Embu	Uasin Gishu	Meru
Training of vines and pruning	2.36(0.17)^{a}	2.96(0.14)^{b}	4.25(0.14)^{c}
Weeding	2.68(0.29)^{a}	3.33(0.21)^{b}	3.94(0.22)^{c}
Disease management	2.09(0.29)^{a}	2.53(0.21)^{a}	2.54(0.22)^{a}
Manure/fertilizer application	2.05(0.23)^{a}	2.89(0.13)^{b}	3.46(0.19)^{b}
Watering	1.41(0.18)^{a}	2.10(0.15)^{b}	3.30(0.22)^{c}

Means followed by a different letter (a, b and c) along the row are significantly different at p=0.05; Figures in parenthesis represent standard errors

The differing orchard management practices scores at the farm level were compared to individual passion fruit farmers TEs (Table 16). The multiple regression results (Table 16) showed that all the orchard management practices significantly influenced TE but at varying significance levels. Training of vines and pruning (p=0.001), and watering (p=0.002) practices positively influenced TE at 1% significance level. Weeding (p=0.045) and manure/fertilizer application (p=0.075) positively influenced TE at 5% and 10% significance levels, respectively. Only disease management (p=0.091) had a significant negative influence on TE, at 10% level.

Table 16: Multiple regression results for orchard management practices and farmers' technical efficiency.

Variables	Coefficient	Standard Error	P>t
TE			
Training of vines and pruning	4.47	1.37	0.001
Weeding	0.34	0.13	0.045
Disease management	-1.76	0.95	0.091
Manure/fertilizer application	2.21	1.14	0.075
Watering	3.02	0.93	0.002
_cons	35.39	4.79	0.000
R-Squared	0.59		

CHAPTER FIVE: DISCUSSION

5.0 Introduction

This chapter covers the interpretation of the results of the study. The results of the study are discussed from individual Counties context and in general. The chapter also looks at the findings in view of what has been reported in literature with the aim of trying to assess the underlying factors that possibly explain the observed trends and outcomes. In the chapter existing gaps are identified and sets a basis for recommending the necessary policies to address the identified gaps.

5.1 Determination of technical efficiency

The log likelihoods for the individual Counties and the overall study area models were different from zero while the chi-square values were strongly significant at 1% which implied that the explanatory variables used in the models were collectively able to explain the variations in purple passion fruit productivity.

Four out of seven production variables (number of seedlings, passion fruit farm size, manure quantity and hired labour) significantly influenced the purple passion fruit yield. Therefore, the four factors of production were the major determinants of mean technical efficiency and productivity in the study area. This meant that their intervention would influence the resultant TE and productivity. The gamma (γ) coefficient indicated that 86% of variations in purple passion fruit output among the farmers were caused by technical inefficiencies, that is, factors within the farmer's control especially in the use of inputs and general orchard management. The large lambda (λ) value was an indication that the one sided error term (μ) dominated the symmetric error (v). Therefore, the disparities in the actual purple passion fruit output emanated from differences in farmers' practices rather than random variability. The large value of λ also indicated goodness of fit and correctness of the specified normal/half-normal distribution assumption as observed by Kibaara (2005).

Number of seedlings per hectare was identified to be one of the major constraints in achieving the potential yield. Results showed that an increase in the number of seedlings by 10% per hectare would increase output by 8% thus improved productivity. This suggests that an increase in the number of seedlings per hectare would increase the usage of the 3m*2m spaces recommended for purple passion fruit farming. The results concurred with those of Gachanja and Ochieng' (2011) who found out that total and marketable passion fruit outputs increased with narrower spacing between the rows, less than the recommended 3m. However, this would constrain management operations such as weeding, spraying and pruning. This could explain why farmers undertaking purple passion fruit farming practice intercropping with other short stature crops in order to maximize the use of limited area (Lima, 2002). In addition, the average number of seedlings per hectare in the study area were 1,146 against the recommended 1,734

(3m*2m); indicating underuse in number of seedlings. This presents an avenue for enhancing purple passion fruit productivity.

Manure had the highest positive influence on yields. A 10% increase in the quantity of manure applied translated to an increase in output of purple passion fruit productivity by 9%. The result for this variable presents nutrients as the major and important constraints to the improvement of the fruit yield. The results were consistent with those of Nelly-Kelly (2010) that application of aged and well prepared manure enhances passion fruit production. However, the results were contradictory to the findings of Kibaara (2005) and Sibiko (2012) who established manure use as not being significant in determination of yields. This inconsistency could be due to high dependence of maize on compound fertilizers in Kenya while beans are leguminous (nitrogen fixation) thus productive without manure.

Hired labour had a positive and significant influence on yields at 5% level. The results showed that a 10% increase in hired labour person-days would lead to an increase of the fruit output by 4% among the purple passion fruit farmers. These results were consistent with those of Amaza *et al*. (2006) in study of food crop and Ogunniyi and Ajao (2011) study on swine technical efficiency in Nigeria who found out that hired labour was a significant determinant of food crop and swine performance. Further, the results suggest that use of more hired labour significantly increase productivity. This may imply that hired labour effect is higher due to full employment unlike the family labour which is mostly under-employed. The family labour is compensated in kind (food, cloth, education, shelter provisions among others) rather than monetary terms. Therefore, family labour mode of working tend to deviate from the norm of hired labour who work for a certain period of time or finish a given task in order to be paid. Family labour tends to be non-committal on a working schedule which makes them less productive compared to hired labour. From the study it was clear that as more hired labour than family labour is used the output would increase. However, optimality of hired labour in the orchards should be considered to avoid underuse.

According to the results, an increase of farm size under passion fruit by 1% would on average reduce purple passion fruit yield by 1%. This suggests that as more land is put under purple passion fruit, the lesser the yields per hectare. This means that currently farmers have put purple passion fruit production in land sizes that they are unable to adequately manage. The implication of this is that farmers with smaller pieces of land are able to adequately cater for the management needs of the plants which require regular observation. The results were consistent with the findings of Zaeske (2012) in the study of aggregate technical efficiency and water use in United States of America.

The issue of land area in relation to productivity has also been widely discussed and most authors like Amaza *et al*. (2006) in food crop research in Nigeria and Teryomenko (2008) in the study of farm size and productivity in

Ukraine who established a positive relationship between farm size and productivity up to 120 ha, beyond which a decline was recorded. The result suggests that farmers would ensure higher productivity under smaller pieces of land. This would ensure intensive management of the orchards since the fruit requires routine management practices like weeding, pest and disease management and training of vines and pruning among others. Better management practices would increase technical efficiency.

Average purple passion fruit productivity of 4201, 9767 and 8751 kg ha^{-1} were recorded for Embu, Meru and Uasin Gishu Counties, respectively. Farmers were realizing 47, 65 and 57% productivity potential in Embu, Meru and Uasin Gishu Counties, respectively. Productivity followed the mean technical efficiency trend for the Counties, an indication of input-output transformation efficiency.

A mean technical efficiency of 59% implied that the farmers were operating at 41% technical inefficiency level. Most farmers could therefore nearly double their yield by operating at efficient level (100%). These results show that currently the farmers are unable to convert the available inputs to output thereby attaining less than 100% TE.

5.1.1 Cost interpretation of technical efficiency

The computed individual farmers' technical efficiency ranged from 17 to 86% and a mean of 59% was recorded which represented significant production inefficiency. This implies that purple passion fruit farmers could attain the current levels of output by reducing their inputs by 41% through improving on the existing technical efficiency levels. Therefore, the selected farmers would reduce their production costs and ultimately increase the profit margins in purple passion fruit production. The current mean technical efficiency of 59%, indicates that if an average farmer in the study attained the TE level of the most efficient counterpart, then the average farmer could realize a 32% cost savings which was consistent with the study of irish potatoes in Kenya by Nyagaka *et al*. (2010) .

In Meru, Embu and Uasin Gishu Counties, the average farmer would attain a cost reduction of 24, 30 and 34% respectively through improved technical efficiency. On the other hand, for the least efficient farmers in Embu, Uasin Gishu and Meru Counties to attain the TE of the most efficient farmers in their respective Counties they would attain cost savings of 66, 81 and 79%, respectively. Hence, the current technical efficiency levels present considerable leeway for enhancing profitability among the small scale purple passion fruit farmers.

5.1.2 Elasticity/marginal effects

There was evidence of overuse of farm size under passion fruit in Embu, Meru and Uasin Gishu Counties. This indicated that the farmers across the three Counties did not optimally use the available land. Embu purple passion fruit farmers were the most inefficient in resource use followed by Meru and Uasin Gishu respectively. It would have been expected that the smaller the land a farmer owned the higher the efficiency in its use. However, this is not necessarily the case keeping in mind that Uasin Gishu farmers owned bigger lands compared to farmers in the other Counties. The results of the study showed that Embu farmers had small land sizes but were more inefficient in their use compared to Uasin Gishu farmers thus consistent with the study of production cost and size by Ahern *et al*. (1993).

There was also an aspect of overuse of fertilizer in Embu and Uasin Gishu Counties. Pesticides and hired labour were overused in Uasin Gishu Counties while family labour was overused in Meru County. The overuse of inputs could be attributed to lack of information on the specific quantities to be applied on purple passion fruit plants. On one hand, overuse in pesticides could be attributed to ignorance since pesticides are sold with manufacturers' leaflets containing instructions on their use (Ngowi *et al*., 2007). On the other hand, overuse could be attributed higher pest incidences which influence the farmers to apply more chemical quantities to improve effectiveness (Wangungu, 2012) which eventually leads to resistance (Watts, 2010) and increased residues (Jeyanthi and Kombairaju, 2005).

The input elasticities for Embu and Uasin Gishu Counties were 0.12 and 0.98 (which is <1) respectively which represented decreasing returns to scale (DRS). This meant that for every one unit set of inputs used in purple passion fruit 0.12 and 0.98 units of output resulted. On the other hand, Meru County had inputs elasticity of 1.04 (which is >1) which represented increasing returns to scale (IRS). This implied that for every one unit set of inputs utilized in purple passion fruit production it resulted to 1.04 units of output.

In the study area, the sum of the input elasticities of the overall study area was 0.95 which represents decreasing returns to scale (DRS) in purple passion fruit production. This implied that for every one unit set of inputs utilized resulted to 0.95 units of output purple passion fruit. This implied that most farmers employed production techniques which had become redundant over time (Sibiko, 2012).

In the overall study area, farm size and manure had the highest negative and positive elasticities respectively. This meant that the best approach to increasing fruit output was through manure and farm size interventions. A negative elasticity implied overuse of an input whereas positive elasticity indicated a potential increase in the level of yields if more of that input could be used (Zaeske, 2012). Therefore, farm size, pesticides and family labour were overused in the study areas. Farmers were aware that pesticides use would decrease purple passion production losses however they translated this to mean more pesticides application would guarantee higher yields which eventually led to overuse (Watts, 2010). The production variables were mostly inelastic (had a value of <1). This meant that a one unit of input led to production of less than one unit of output.

The average farmer productivity was 8668 kg ha^{-1} which confirmed the findings of the existing literature on passion fruit productivity as being 8-9 ton ha^{-1} (HDC, 2005; Mbaka *et al*., 2006; KENGAP, 2011). The marginal effect for farm size was -1.15 which meant that the output level would reduce by 99.68 kg due to an increase of farm size by 1% (0.01ha). The smaller farm sizes under purple passion fruit would result into higher productivity than the large ones.

5.2 Factors influencing technical efficiency

The productivity disparities observed across the three Counties under study could be explained by the varying technical efficiency levels. The differing technical efficiency scores of Embu, Meru and Uasin Gishu were high ranging from 8 to 18% which implied that each of the Counties' input-output transformation process were different.

In Embu County, age had a positive and significant influence on technical efficiency. This indicated that if a farmer attained a higher age category, TE would increase by 0.48. The findings were inconsistent with those of Nchare (2007) in coffee and Richman (2010) in cocoa who found out that age influenced technical efficiency negatively. However, this study further established that the technical efficiency initially increases up to the mid age category (36-50 years) then declines for farmers at higher age bracket (>50 years). Therefore, age eventually influenced technical efficiency negatively. This could be attributed to resistance to change attitude as age advanced whereby the higher age bracket farmers managed their orchards like in the past which might have been ineffective.

A surprising observation of the study was that the farmers who sourced their seedlings from research institutions (mainly KARI) were the least technically efficient compared to those who sourced from own and local sources. This could signify that farmers understood the importance of obtaining clean planting materials from agricultural research institutions due to their expertise. However, they did not invest adequate resources (inputs) and good management practices in the administration of their orchards thus low TE levels. This could also be attributed to acquisition of seeds and seedlings through farmers' associations leaders who might not have had carried out enough training to the association members on proper management of the fruit plants. Further, those who sourced their seedlings from research institutions could have been absentee farmers hence failing to make necessary follow up to ensure proper management.

The results indicated that by buying seedlings from local sources in Embu and Uasin Gishu Counties TE would improve by 29% and 1% respectively. However, a farmer using seedlings/seeds from a research institution did not have a guarantee for higher technical efficiency and productivity.

Farmer group variable had a negative and significant influence on technical inefficiency which meant that it had positive influence on TE. This implied that membership to a purple passion fruit farming group in Embu County would improve TE of a farmer. A farmer who was a member of purple passion fruit farmer group had a probability of increasing technical efficiency by 0.56. The observations were consistent with those of Shehu *et al*. (2010) and Sibiko (2012) who found out that group membership had positive influence on TE. The findings of this research could be attributed to provision of a platform for training, sharing of farming ideas and experiences among group members. In addition, some farmer groups provided monetary and inputs credit. The farmers are therefore empowered with better understanding of good management practices, up to date farming information as well as technology adoption. Further, farmer groups could be marketing produce collectively and thus have a self enforcing mechanism to ensure product quality and good prices.

Market access also had a significant negative influence on TE in Embu and Uasin Gishu Counties. This implied that lesser market access decreases TE of purple passion fruit farmers, that is, the longer the distance to the market the limited the access thus lesser TE. An increase of distance by one kilometre to the market would reduce TE levels by 4% in Uasin Gishu County. The findings were consistent with those of Bagamba *et al.* (2007) among smallholder banana producers in Uganda. The authors observed that proximity of banana farming households to the market led to higher technical efficiency than those located in remote areas. The findings of this study could be due to increased farmers' access to the factor and output market which could have ensured timely access to factors of production and disposal of the harvest. Of the fourteen variables that had been selected for the inefficiency model in study Counties, eight significantly influenced farmers' technical efficiency. These were County, farming experience, education, non-passion fruit income, credit used, orchard age, market access and extension frequency.

The County variable which represented the region from which the farmers under the study practiced their farming was significant and negatively influenced technical inefficiency. This implied that County variable positively influenced technical efficiency and was consistent with the hypothesis. In this study, farmers from Meru were more technically efficient than those from Uasin Gishu and Embu. Generally, this observation indicated that a farmer from Meru County was likely to be more technically efficient than a counterpart from another County. The findings were consistent with Kibaara (2005) and Msuya *et al*. (2008) that the region in which a farmer practiced farming had influence on TE.

Negative and significant influence of farming experience on technical efficiency meant that it reduced TE among the fruit producers. This was inconsistent with the hypothesised relationship. The results revealed that an increase of purple passion fruit farming experience by 1 year reduced technical efficiency levels by 4%. This means that farmers with more years of farming experience in purple passion fruit production were less technically efficient compared to the less experienced ones. This observation was inconsistent with Bhasin and Akpalu (2001) in their study of microfinance enterprises in the Cape Coast, Igbekele (2002) in the study of policy issues in technical efficiency of small scale farmers in Nigeria and Aman (2011) in the study of rose cut-flower in Oromia Ethiopia who found that previous accumulated experience in an enterprise increased technical efficiency. These findings among the small scale purple passion fruit farmers in Embu, Meru and Uasin Gishu Counties of Kenya could be attributed to frustrations and challenges (diseases, pests and marketing arrangements among others) experienced in the past by farmers in the fruit farming. Further, farmers could have employed the same management practices year after year in changing environments whereas the practices may no longer have been effective such as use of Sporekill™ for control of diseases but has been found ineffective in passion fruit (Rheinlander *et al*., 2009). The "resistance to change" attitude could be rampant in pesticides application and disease management practices which changes regularly.

Education level positively influenced technical efficiency as was expected. This meant that farmers who attained an extra level of education would improve their technical efficiency by an average of 1.04%. Results on the education variable showed that farmers who attained at least primary education were more efficient than those with no formal education. The farmers that had primary, secondary and tertiary education scored almost equal TE levels.

These results on the effect of education were consistent with the findings of Nchare (2007) in Arabica coffee study in Cameroon, Msuya *et al*. (2008) in small holder maize productivity research in Tanzania, Nyagaka *et al*. (2010) in the study of technical efficiency in resource use among irish potato farmers in Nyandarua-Kenya and, Khai and Yabe (2011) in rice production study in Vietnam. The positive influence of education on technical efficiency indicates a positive impact of increased human capital on productivity. Education may have increased farmers' awareness and decision making in relation to farming technology. Basic education may have set a basis for better use of inputs and general management of orchards. In addition, Shehu *et al*. (2011) in the study of yam production and technical efficiency in Nigeria and Aman (2011) in Ethiopia were in agreement with the findings. However, Njeru (2010) in wheat study in Uasin Gishu District Kenya and Sibiko (2012) in common bean productivity study in Uganda found education level to be insignificant factor in influencing technical efficiency.

The findings showed that non-passion fruit income influence on technical efficiency was positive. The results were consistent with the hypothesized relationship. This meant that if the farmer non passion fruit income increased by 1% then TE would improve by 2%. As non-passion fruit income increased, the level of technical efficiency among purple passion fruit farmers increased. Therefore, farmers with alternative sources of income tended to be more technically efficient compared to those without. These results were in agreement with Msuya *et al*. (2008) findings in Tanzania. This implied that farmers with other income sources were able to finance the running of purple passion fruit farming which is a high capital consumer during the initial stages and later (after 9 months) pay back. The maintenance of the fruit orchard was ensured with alternative sources of income thus higher efficiency.

Due to limited credit access, other farmer income sources may have been used to raise money which they required as working capital. However, as noted by Msuya *et al*. (2008) in the long run this practice might not foster specialization leading to a negative impact on efficiency. Farmers would therefore be advised to undertake a trade-off farm enterprise assessment, take up those that they could adequately manage to avoid distraction and neglect of the purple passion fruit orchards upon diversification. However, Kibaara's (2005) findings on Maize study in Kenya were in contradiction with the results, off-farm income was significant but had a negative influence on TE. Sibiko (2012) found off-farm income to be insignificant in explaining technical efficiency.

The study results showed the amount of credit used to have significant and positively influenced technical efficiency. This implied that credit use increased technical efficiency which was inconsistent with the expectations. The results shows that an increase of 1% in amount of credit used on purple passion fruit orchards would increase TE by 0.22%. Farmers who used credit in their purple passion fruit orchards were more technically efficient than those who did not. Most of the studies done previously tend to prefer assessing the effect of credit access rather than credit use on technical efficiency. Studies including Bhasin and Akpalu (2001) in micro-finance, Kuria *et al*. (2003) in rice production in Mwea-Kenya, Amaza *et al*. (2006) in food crop technical efficiency research in Nigeria, Njeru (2010) in wheat and Nyagaka *et al*. (2010) in irish potatoes research in Kenya found out that access to credit had positive influence on technical efficiency.

In this study, a different approach to assess credit on purple passion fruit orchards. Amount of credit used was employed since it represented a more realistic approach unlike access to credit with the base argument that you may have access to credit and not apply or even if accessed not use it (Pande, 2010) on an enterprise. Therefore, 'access to credit' presents a limited and an unrealistic approach as a measure of influence on technical efficiency. Sibiko (2012) also used the same approach although amount of credit borrowed for farming was not significant in common bean productivity. For this study, the higher technical efficiency recorded for credit users signify that the obligation to account for debt acquired could have pushed farmers to be more technically efficient. The indebted farmers could have felt the need to work harder in order to meet their debt obligation and also make a profit. Further, when debt is acquired in lump sum the farmer can more timely cater for the running expenses of purple passion fruit orchards thus increased efficiency.

Purple passion fruit orchard age variable results showed that it had a positive influence on technical efficiency as had been hypothesised. For every one additional orchard year technical efficiency would improve by 17%. The older orchards were more technically efficient than the younger ones. However, when the orchards attained the age of 4 years their technical efficiency started to decline. The results were consistent with the findings of Tchango *et al*. (1999) who established that the age of plantain (*Musa* spp.) affected its productivity. The results in this study could be explained by the increasing yields of purple passion fruits as the orchards grew older up to the age of 4 years where technical efficiency scores started to decline. Technical efficiency of the fruit farmers followed a sigmoid curve as the years advanced. Best management practices may therefore be adopted to reduce the negative effect of age on production and productivity.

The frequency of extension advice was significant and positively influenced technical efficiency as had been hypothesized. The results meant that an increase of extension frequency by 1% would contribute to improvement of TE by 0.85%. The results indicated that the more frequent farmers received extension advice (provided by agricultural officers and trained farmers) on purple passion fruit farming the more efficient they were. The results were in contradiction with Croppenstedt's (2005) findings in technical efficiency measure of wheat in Egypt who found that 2 or more extension visits influenced technical efficiency negatively. Most studies done in the past on technical efficiency have used a dummy (have access or no access) to assess extension rather than the extension advice use frequency. These studies include Kuria *et al*. (2003), Amaza *et al*. (2006) and Sibiko (2012) whose access to extension findings was significant and had positive influence on technical efficiency. The results may imply that the more frequent farmers received and applied extension advice, the more informed and better they became in decisions making thus the need for frequent update in farming information due to changing requirements in farming systems.

5.3 Comparison of management practices and socioeconomic-institutional characteristics to technical efficiency

The County that had the best mean operational management practices scores had the highest mean technical efficiency. Meru County consistently scored higher mean management scores than Embu and Uasin Gishu Counties which corresponded to the technical efficiency trend in the three Counties. The results were consistent with the findings of Johansson (2007) in the study of management practices of Swedish dairy farms who concluded that management practices influenced the level of technical efficiency among dairy farms.

These results suggests that higher management scores among purple passion fruit farmers indicated better use of inputs thus higher technical efficiency levels. This might be accurate because a farmer who regularly practiced weeding reduced competition between weeds and purple passion fruit plants in nutrients uptake (Joy, 2010).

Watering could have ensured that the plants were able to convert inputs into usable nutrients. It also may have enhanced assimilation and cooling thus reduced withering. This is so because purple passion fruit are shallow-rooted and prone to drought stress. Watering may have also boosted continuous flowering and fruiting and minimized fruit drops (COLEACP, 2011).

Training of vines and pruning reduces tangling and congestion, removes deadwood, increases aeration within the canopy and distribution of light (sun), and reduces pest abundance (COLEACP, 2011). Farmer adoption of these practises may have led to better performance of the plants in terms of flowering and production of high quality passion fruits.

The high scores recorded in Meru for manure/fertilizer application signifies that good knowledge in the practice ensured farmers avoided underuse as well as overuse of inputs thus guaranteeing optimality and eventually reducing wastage. Good knowledge in the management practices contributes to increased technical efficiency as observed by Bakhsh and Hassan (2006).

Disease management presented the biggest challenge among the farmers in the study area. Most passion fruit diseases (woodiness virus, *Fusarium* wilt and dieback) have been reported to be complex and highly infectious (Mbaka *et al*., 2006; Wangungu, 2012). In addition, farmers lack adequate information and skills to control these diseases (Mbaka *et al*., 2006;

Kleemann *et al.,* 2010; Wangungu *et al*., 2010). This may explain the low level of disease management scores across the three Counties.

The observation that management assessment results on purple passion fruit orchards corresponded to technical efficiency variation among the farmers signifies that management practices and skills level are crucial in increasing purple passion fruit productivity. This is in line with findings by Bakhsh and Hassan (2006) and Theocharopoulos *et al*. (2009) that management ability determined the level of efficiency. Farmers in a particular County had common characteristics which eventually led to differing mean management scores and technical efficiency.

Meru County farmers' higher TE levels could be attributed to better management practices, better market prices and past benefits from the purple passion fruit farming. Further, diversity in income sources could also be a contributing factor. A general observation across Embu, Meru and Uasin Gishu Counties showed different prices per kilogram of the fruits. Meru had the best price range of Kshs. 90-120 while Uasin Gishu and Embu Counties had a price range of Kshs. 30-80. These prices could be attributed to differing management practices which affected the quality (appearance, colour, shape, injuries, flavour and taste) of the fruits that were produced. Marketing arrangements (market access and brokers) in the respective Counties could be another reason for price differentials. NAFIS (2012) explains that watering of orchards during dry seasons contributes to improved flowering, fruiting, maturity and quality of purple passion fruit thus higher productivity, fetching higher prices and eventually more returns. Low prices in Embu and Uasin Gishu Counties could be attributed to poor management practices, that is, lower levels of irrigation, weeding, spraying, disease management and fertilizer/manure application that compromised the quality of the fruits produced compared to Meru County.

Further, the multiple regression results showed that all the five management practices significantly influenced the technical efficiencies of purple passion fruit farmers. The significant relationship between the orchard management practices and TE implied that good management practices at farm level are crucial in attaining efficiency (Bakhsh and Hassan, 2006; Galanopoulos *et al*., 2006). The negative significant relationship between management practices scores and technical efficiency implied that the current disease management methods practiced by the farmers were ineffective thus unable to enhance their technical efficiencies. Up-scaling of management practices would ensure better maintenance thus improved technical efficiency of orchards and extension of orchard's life span.

The results of the study indicated that female farmers were more technically efficient than their male counterparts. The results could be explained by the observation that most women involved in purple passion fruit farming were housewives therefore they are mainly around their farms ensuring better management of orchards. The results could also be attributed to the increasing role of women as families' breadwinners which make them to work harder (Narayan *et al*., 2000). This signifies that if more women were to be involved in the fruit production it will lead to increased production and productivity thus narrowing the demand-supply gap. However, the participation of females (27%) in purple passion fruit farming was way below that of males (73%). This could be attributed to findings that women in rural areas are more disadvantaged in terms of accessing education, land, credit, and extension services as reported by Nyanjong' and Lagat (2012). The situation is further magnified by cultural practices that limit women access to resources. This could be an important basis of women empowerment as enshrined in the Kenya's new constitution, Chapter 5 Article 60 (1) (f) pertaining to land ownership and gender discrimination and Chapter 4 Article 27 (3) in economic discrimination on gender (Republic of Kenya, 2010[c]).

The findings were consistent with those of Oladeebo and Fajuyigbe (2007) in rice study in Nigeria, Nyanjong' and Lagat (2012) in sugarcane research in Kenya and Ubokudom *et al*. (2010) in garden egg (*Solanum spp*) in Nigeria that although their input in agriculture is highly productive, women are often sidelined in decision making. Women in these studies were more technically efficient than men. This could also be a new trend and to be encouraged as it can enhance gender equity when women are provided with the required resources and are made more responsible for production management. Further, the findings for this study could be attributed to the findings that women are more efficient resources users and managers than men (Oladeebo and Fajuyigbe, 2007; Dadzie and Dasmani, 2010).

In Meru and Uasin Gishu Counties gender had negative and positive significant influence on TE respectively. Since the men portion in Meru was 85%, it meant that male farmers led to reduced TE by 2%. On the other hand, the portion for male versus female farmers in Uasin Gishu was almost equal which implied that if more female farmers were to be involved in purple passion fruit farming then TE would be improved by approximately 1%.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

The chapter presents the conclusion and recommendations for the study. The conclusions are based on the study findings for each objective. Recommendations are made based on the gaps identified and weaknesses established in resource use and management on purple passion fruit orchards. Conclusions and recommendations are targeted towards the policy makers, farmers, public and private sectors.

6.1 Conclusion

The results indicated that Embu farmers were the most technically inefficient followed by Uasin Gishu and the most technically efficient were Meru County farmers. Therefore, Embu County farmers had the highest scope in the improvement of their resource efficiency use. The average farmer could make a cost saving of 32% to the current production costs incurred through improved technical efficiency to that of the most efficient farmer.

The average yield of small scale farmers in the study areas was 8.67 ton ha^{-1} which confirmed the existing literature on national passion fruit productivity average as being 8-9 ton ha^{-1}. This presented evidence that if farmers were to be technically efficient (ideal) they would attain productivity of 14.78 ton ha^{-1} using the same technology. This would eventually reduce the demand-supply gap as well as improving livelihoods through increased returns.

A prior expectation that farm size would have the highest positive impact was proven to be opposite of the reality in purple passion fruit production. This would conclude that in order to have a higher impact in improving TE levels of individual farmers then land size under purple passion needed to be optimal; that a farmer could adequately manage.

There was satisfactory evidence of positive relationship between purple passion fruit productivity and higher use of production factors such as use number of seedlings, manure and hired labour. Overuse of some production factors was also recorded, passion fruit farm size, family labour and pesticides which had a negative relationship with yields. This meant that farmers were not operating at optimal levels.

Female farmers were more technically efficient compared to their male counterparts. However, women participation in purple passion fruit farming was low (27%). In rural Kenya women are disadvantaged in terms of resource access and ownership especially land. The study Counties were no different to this trend. This implied that if more women were involved in passion fruit farming it would contribute to improved TE.

The trends of mean management scores were similar to those of technical efficiency across the three Counties. It was evident that in order to have a positive impact on technical efficiency improvement, good orchard management practices were inevitable at the farm level. A positive link between high technical efficiencies and good orchard management practices was established.

6.2 Recommendations

Given that the results of the study showed that technical efficiency was significantly influenced by extension advice frequency, credit amount used, level of education, County and non-passion fruit income, then policies targeting these variables among others might have a positive impact on small scale purple passion fruit production and productivity.

The positive effect of extension advice frequency implies that enhancing small scale farmers' access to information will improve technical efficiency. Therefore, policy makers should focus on pioneering effective institutional arrangements that would enhance extension access by farmers through deployment of participatory methods such as lead-farmer model, use of group training approach; farmer-driven extension demand and or intensification in the use of the extensive mass media available in the regions that would supplement and complement the efforts of the few extension workers.

The positive influence of amount of credit used on technical efficiency provides a basis for provision and use of credit. The high initial capital consumption and running costs by purple passion fruit farming enterprise can be provided through credit where farmers are unable to raise the required funds. Such funds included pesticides costs in passion fruit farming cannot be postponed otherwise high losses are incurred. Therefore, credit access should be enhanced to increase use for those farmers who are unable to raise the cost involved in purple passion fruit farming. Formation of operational and services oriented passion farmer groups should be encouraged.

In consideration of the findings of this study, emphasis on at least primary schooling would have a huge impact of attaining higher efficiency levels in purple passion fruit production. However, since there are some farmers who have not acquired formal education and its impact is not immediate, the purple passion fruit stakeholders should focus on promoting best orchard management practices. Therefore, provision of non-formal agricultural education could supplement or complement formal education. This can be done through regular training of farmers, farmer forums and on-farm practical demonstrations. The education should range from input access and use and best orchard management practices (training of vines and pruning, weeding, disease management, manure/fertilizer application, watering, soil conservation and harvesting among others).

Differences in technical efficiency levels and management scores across the Counties provide a platform for sharing of ideas among farmers. Farmers from Embu and Uasin Gishu can learn from Meru County on better management practices. In addition, sharing ideas on how to enhance marketing arrangements for better prices would be crucial in improving TE. The government and private sector agencies can promote cross-border farmer linkages that would enable them to share success experiences through farm visits and demonstrations. This would provide a basis for peer discussions eventually increasing uptake and eventual adoption of purple passion fruit farming.

The higher TE of women in purple passion fruit farming could be tapped by improving access of resources to women in Embu, Meru and Uasin Gishu Counties. This would be ensured by implementing the existing land laws [Chapter 4 Article 27 (3) and Chapter 5 Article 60 (1) (f) under Kenya's new constitution] on economic discrimination, inheritance and ownership rights of land by either gender. Negative cultural tendencies on resource inheritance and ownership should be shunned to increase productivity in farming.

Non-passion fruit income positive influence on technical efficiency of small scale purple passion fruit farmers is an indicator of inter-dependence of farm enterprises. Due to limited credit access by farmers, other farmer income sources help to raise money which they need as working capital for purple passion fruit farming. However, in the long run this practice might not foster specialization leading to a negative impact on efficiency. Farmers are therefore advised to diversify income sources to a level they can adequately manage.

This study only evaluated the technical aspect of production efficiency of purple passion fruit farming. From the study, overuse and underuse of production factors was evident. Therefore, the study recommends an assessment of allocative efficiency of purple passion fruit farmers in Kenya. This would avail information on optimal levels of inputs use by farmers specifically on how to choose and employ the inputs in the fruits' production to the level where their marginal returns equals their factor prices.

Another area that could be considered for further study is on agricultural information systems in purple passion fruit sub-sector which this study did not undertake. From this study, education and market access were found to be important factors influencing the fruit productivity. This meant that farming and market information were crucial in the fruit farming. The overuse and underuse of inputs established in the study could be addressed through addressing the information systems in the fruit farming and marketing. The farming and market information systems of purple passion fruit improvement would contribute in narrowing the existing demand-supply gap.

REFERENCES

Acland J. (1971). *East African crops- introduction to production of field and plantation crops in Kenya, Uganda and Tanzania* (1st ed). London: Longman Group Ltd.

Ahern, M., Whittamer, G. and El-Osta, H. (1993). "The Production Cost-Size Relationship: Issues and Estimates for Three Major Crops," In *Size, Structure and the Changing Face of American Agriculture,* Arne Hallem. Boulder (Ed): Westview Press,107-49.

Aigner, D., Lovell, C. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Economics* 16(1): 21-37.

Ajibefun, I. (2002). *Analysis of Policy Issues in Technical Efficiency of Small Scale Farmers Using the Stochastic Frontier Production Function: With Application to Nigerian Farmers.* International Farm Management Association Congress, Wageningen, Netherland.

Aman, M. (2011). Determinants of Technical Efficiency of Rose Cut-Flower Industries in Oromia Region, Ethiopia, *Journal of Economics and Sustainable Development* 2(6): 81-88.

Amata, R., Otipa, M., Waiganjo, M., Wabule, M., Thuranira, E., Erbaugh, M. and Miller, S. (2009). Incidence, prevalence and severity of passion fruit fungal diseases in major production regions of Kenya. *Journal of Applied Biosciences* 20: 1146 – 1152.

Amaza, P., Bila, Y. and Iheanacho, A. (2006).Identification of Factors that Influence Technical Efficiency of Food Crop Production in West Africa: Empirical Evidence from Borno State, Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 107(2): 139–147.

Anandalingam, G. and Kulatilaka, N. (1987). Decomposing Technical Efficiency into Technical, Allocative and Structural components. *Journal of the Royal statistical society* 150(2): 143-151. Retrieved on 15th January 2012 from http://people.bu.edu/nalink/papers/JRSS.pdf

Anderson, D., Sweeny, J., Williams, T., Freeman, J. and Shoesmith, E. (2007). Statistics for Business and Economics. Thomson Learning.

Anderson, J. (2003). Risk in rural development, challenges for managers and policy makers. *Agr. Sys.* 75(2): 161-19.

Bagamba, F., Ruerd, R. and Mariana, R. (2007). *Determinants of banana productivity and technical efficiency in Uganda*. In Smale, M., and Tushemereirwe, W.K. (Eds), An economic assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania (Ch.8, pp.109-128). Retrieved on 20th February 2012 from http://books.google.com/.

Bakhsh, K. and Hassan, S. (2006). *Relationship between Technical Efficiency and ManagementAbility, Evidence from Punjab, Pakistan*. University of Agriculture, Faisalabad, Pakistan.

Battese, G., Malik, S. and Gill, M. (1996). An investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. *Journal of Agricultural Economics* 47(1): 37-49.

Berry, W. and Feldman, S. (1985). *Multiple Regression in Practice*. Sage University Paper Series on Quantitative Applications in the Social Sciences, series no. 07-050. Newbury Park, Sage.

Bhasin, V. and Akpalu, W. (2001). *Impact of Micro-Finance Enterprises on the Efficiency of Micro-Enterprises in Cape Coast*. IFLIP Research Paper 01-5

Bravo-Ureta, B. and Pinheiro, A. (1997). Technical, Economic, and Allocative Efficiency in Pesant farming: Evidence from the Dominican Republic.

The Developing Economies, 35(1): 48–67. Retrieved on 20th February 2012 from http://www.ide.go.jp/English/Publish/Periodicals/De/pdf/97_01_03.pdf

Cobb, C. W. and Douglas, P. H. (1928). A Theory of Production. The American Economic Review, 18(1): 139-165. American Economic Association.

Coelli, T. and Battese, G. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics* 40:103-128.

COLEACP. (2011). *Crop Production Protocol: Passion Fruit*. PIP-COLEACP.

Croppenstedt, A. (2005). *Measuring Technical Efficiency of Wheat farmers in Egypt*, ESA Working Paper No. 05-06, Food and Agriculture Organization.

Dadzie, S. and Dasmani, I. (2010). Gender difference and farm level efficiency: Metafrontier production function approach, *Journal of Development and Agricultural Economics* 2(12): 441-451.

Dirou, J. (2004). *Passion fruit growing: what you need to know*. Retrieved on 15th January 2012 from http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/119691/passionfruit-growing.pdf

Farrell, M. (1957). Measurement of productive efficiency. *Journal of the Royal Statistical Society, Series A* 120(3): 253–90.

Feng, S. (2008). *Land rental, off-farm employment and technical efficiency of farm households in Jiangxi province, China*. China Centre for land policy research.

Fintrac. (2009). USAID-KHDP *Kenya Horticultural Development Program October 2003 – 2009.* Nairobi: USAID-Kenya.

Gachanja, S. and Ochieng, P. (2011). Effects of row spacing of purple passion fruit (*Passiflora edulis forma edulis Sims*) on fruit yield in Kenya.

Galanopoulos, K., Aggelopoulos, S., Kamenidou, I. and Mattas, K. (2005). *Assessing the effects of managementand production practices on the efficiency of commercial pig farming*. Retrieved on 05th May 2012 from www.elsevier.com/locate/agsy

Gaturuku, J. and Isutsa, D. (2011). Irrigation and Mulch Significantly Enhance Yield but not Quality of Purple Passion Fruits. *Journal of Agricultural and Biological Science* 6(11):47-53. Ipswich: Asian Research Publishing Network.

Gockowski, J. and Michel, P. (2004). The Adoption of Intensive Monocrop Horticulture In Southern Cameroon. *Agricultural Economics* 30(1): 195-202.

HCDA. (2011). *2010 Horticulture Validated Report*. Nairobi: HCDA.

HCDA. (2012). *2011 Horticultural Crops Production Report*. Nairobi: HCDA.

HDC. (2005). *Horticultural Update*. Nairobi: USAID-Kenya.

Igbekele, A. (2002). *Analysis of Policy Issues in Technical Efficiency of Small Scale Farmers Using the Stochastic Frontier Production Function: with Application to Nigerian Farmers.* Paper Prepared for Presentation at the International Farm Management Association Congress,Wageningen, Netherland.

Jeyanthi, H. and Kombairaju, S. (2005). Pesticide Use in Vegetable Crops: Frequency, Intensity and Determinant Factors. *Agricultural Economics*

Research Review pp 209-221. Retrieved on 1st September 2012 from http://ageconsearch.umn.edu/bitstream/58472/2/art-5.pdf

Johansson, H. (2007). *Technical, Allocative, and Economic Efficiency in Swedish Dairy Farms: The Data envelopment Analysis Versus the Stochastic Frontier Approach*. Copenhagen, Denmark.

Joy, P. (2010). *Passion fruit production technology*. Kerala Agricultural University. Vazhakulam.

Kachroo, J., Sharma, A. and Kachroo, D. (2010). Technical Efficiency of Dryland and Irrigated Wheat Based on Stochastic Model. *Agricultural Economics Research Review* 23: 383-390.

KENGAP. (2011). *The Passion Fruit Farming Handbook*. Nairobi: KENGAP Publishing Ltd.

Kenya Decides. (2012). *Map of Meru County*. Retrieved on 17th February 2012 from http://kenyadecides.co.ke/wp-content/uploads/2012/01/Meru.png

Kenya Open Data Project. (2012). *Kenya Open Data*. Retrieved on 15th February 2012 from https://www.opendata.go.ke/

Khai, H. and Yabe, M. (2011). Technical efficiency analysis of rice production in Vietnam. *J. ISSAAS 17(1):135-146*. Retrieved on 2rd April 2012 from http://www.issaas.org/journal/v17/01/journal-issaas-v17n1-15-khai_yabe.pdf

KHCP. (2011). *Kenya's Intra Africa Horticulture Trade*. Nairobi: USAID.

Kibaara, B. (2005). *Technical efficiency in Kenyan's maize production: An application of the stochastic frontier approach*. Colorado State University, MSc Thesis: Fort Collins, Colorado.

Kibe, J. (2009). *Horticulture in Kenya: Milestones*. Retrieved on 03rd March 2012 from http://www.actahort.org/books/911/911_28.htm

Kibet, N. (2011). *The Role of Incentives and Drivers in Crop Trade-Off: Evidence from Passion Fruit Uptake in Uasin-Gishu District, Kenya*. Unpublished MSc. thesis in Agricultural Economics of Egerton University, Kenya.

Kibet, N., Lagat, J. and Obare, G. (2011[a]). Identifying Efficient and Profitable Farm Enterprises in Uasin-Gishu County, in Kenya. *Asian Journal of Agricultural Sciences* 3(5): 378-384.

Kibet, N., Obare, G. and Lagat, J. (2011[b]). The Role of Extraneous Incentives and Drivers in Farm Enterprise Diversification: A Study of Passion-Fruit (Passiflora edulis) Uptake in Uasin-Gishu County, Kenya. *Asian Journal of Agricultural Science* 3(5): 358-365.

Kleemann, G., Chege, P. and Krain, E. (2010). *Growing Value: Achievements in Value Chain Promotion for Passion Fruit Value Chain in Kenya*. Nairobi: PSDA

Kumbhakar, S., Ghosh, S. and McGuckin, J. (1991). A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. *Journal of Business and Economic Statistics*, 9: 279–86.

Kuria, J., Ommeh, H., Kabuage, L., Mbogo, S. and Mutero, C. (2003). Technical Efficiency of rice producers in Mwea Irrigation Scheme. *African Crop Science Conference Proceedings*, 6: 668-673.

Li, Z and Liu, X. (2009). *The Effects of Rural Infrastructure Development on Agricultural Production Technical Efficiency: Evidence from the Data of Second National Agricultural Census of China*. International Association of Agricultural Economists Conference, Beijing, China.

Lima, A. (2002). *Crop Progress and weed control in plantations of passion fruit*. New York.

Mbaka, J., Waiganjo, M., Chege, B., Ndungu, B., Njuguna, J., Wanderi, S., Njoroge, J. and Arim, M. (2006). *A Survey of the Major Passion Fruit*

Diseases in Kenya. 10th KARI biennial scientific conference. Volume 1/Kenya. Retrieved on 11th January 2012 from www.kari.org/fileadmin/publications/.../AsurveyMajorPassion.pdf

Republic of Kenya. (2003). *Fruits and Vegetables Technical Handbook, 2nd edition*. Agricultural Information Centre-Nairobi-Kenya.

Mogues, T., Cohen, M., Birner, R., Lemma, M., Randriamamonjy, J., Tadesse, F. and Paulos, Z. (2009). *Agricultural Extension in Ethiopia through a Gender and Governance Lens.* IFPRI, Discussion Paper No. ESSP2 007. Addis Ababa Ethiopia.

Morton, J. (1987). *Passion fruits: Fruits of warmer climates*. Miami-Florida: Julia F Morton.

Msuya, E., Hisano, S. and Nariu, T. (2008). *Explaining Productivity Variation among Smallholder Maize Farmers in Tanzania.* XII World Congress of Rural Sociology of the International Rural Sociology Association. Goyang, Korea.

NAFIS. (2012).*Cultural Practices: Good Agricultural Practices*. Retrieved from http://www.nafis.go.ke/fruits/passion-fruit/cultural-practices/

Namu, L. (2007). *Status of Data Generation in Kenya on Minor Uses*. Global Minor Use Summit. Nairobi: KEPHIS.

Narayan, D., Chambers, R., Shah, M. and Petesch, P. (2000). Voices of The Poor Crying out for Change. Retrieved on 11th June 2012 from http://ruta.org:8180/xmlui/bitstream/handle/123456789/632/RN165.pdf

Nchare A. (2007). *Analysis of factors affecting the technical efficiency of Arabica Coffee Producers in Cameroon*. African Economic Research Consortium Research Paper 163.

Nelly-Kelly. (2010). Passion fruit. *Nellie Kelly Passion fruit Nurseries Pty Ltd*. Retrieved on 2nd September 2012 from http://www.nelliekelly.com.au/passionfruit.html

Ngowi, A., Mbise, T., Ijani, A., London, L. and Ajayi, O. (2007). Pesticides use by smallholder farmers in vegetable production in Northern Tanzania, *Crop Prot*. 26(11): 1617–1624. Retrieved on 17th October 2012 from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2410092/

Niringiye, A., Luvanda, E. and Shitundu, J. (2010). Firm Size and Technical Efficiency in East African Manufacturing Firms. *Current Research Journal of Economic Theory* 2(2): 69-75.

Njeru, J. (2010). Factors Influencing Technical Efficiencies among Selected Wheat Farmers in Uasin Gishu District, Kenya. *Journal of Economics and International Finance* 3(4): 211-216.

Nyagaka, D., Obare, G., Omiti, J. and Nguyo, W. (2010). Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya, *African Journal of Agricultural Research* 5(11): 1179-1186.

Nyanjong', J. and Lagat, J. (2012). *Analysis of efficiency in sugarcane production: the case of men and women headed households in SONY sugar out -grower zone, Rongo and Trans-Mara districts, Kenya.* Retrieved on 02nd September 2012 from http://mpra.ub.uni-muenchen.de/40796/

Ogunniyi, L. and Ajao, A. (2011). Investigation of Factors Influencing the Technical Efficiencies of Swine Farmers in Nigeria. *J. Hum Ecol* 35(3): 203-208.

Oladeebo, J. and Fajuyigbe, A. (2007). Technical Efficiency of Men and Women Upland Rice Farmers in Osun State, Nigeria, *Journal of Human Ecology* 22(2): 93-100. Retrieved on 05th September 2012 from http://www.krepublishers.com/02-Journals/JHE/JHE-22-0-000-000-2007-Web/JHE-22-2-000-000-2007-Abstract-PDF/JHE-22-2-093-07-1403-Oladeebo-J-O/JHE-22-2-093-07-1403-Oladeebo-J-O-Tt.pdf

Onumah, E., Hoerstgen-Schwark, G. and Brümmer, B. (2009). *Productivity of hired and family labour and determinants of technical inefficiency in Ghana's fish farms*. Georg August University Göttingen.

Otipa, M., Amata, R., Waiganjo, M, Mureithi, J., Wasilwa, A., Mamati, E., Miano, D., Kinoti, J., Kyamanywa, S., Erbaugh, M. and Miller, S. (2009). *Challenges Facing Passion Fruit Smallholder Pro-Poor Farmers in North Rift Region of Kenya*. 1st All Africa Horticulture Congress, Safari Park Hotel Nairobi, 31st August to 3rd September 2009, Nairobi, Kenya, p. 154.

Otipa, M., Amata, R., Waiganjo, M., Ateka, E., Mamati. G., Erbaugh, M. and Miller, S. (2008). *Incidences and severity of viruses in passion fruit production systems in Kenya.* 1st African Biotechnology Congress. Nairobi-Kenya.

Oyewo, I. (2011). *Technical efficiency of maize production in Oyo State*. African Economic Research Consortium Research Paper 206

Pande, R. (2010). *Does poor people's access to formal banking services raise their incomes?* Kennedy School of Economics. Retrieved on 08th September 2012 from http://www.dfid.gov.uk/r4d/Project/60807/Default.aspx

PSDA. (2011). *Fruits in Kenya Report*. Nairobi: PSDA.

Reifschneider, D. and Stevenson, R. (1991). Systematic departures from the frontier: A framework for the analysis of firm inefficiency. *International Economic Review,* 32: 715–23 *Rev. Bras. Frutic journal,* 24(3): 711-713.

Republic of Kenya. (2010[a]). *Agriculture Sector Development Strategy (ASDS) 2010-2020*. Nairobi: Government Printer.

Republic of Kenya. (2010[b]). *Economic Review of Agriculture 2010*. Nairobi: Government Printer.

Republic of Kenya. (2010[c]). *The Constitution of Kenya*. Nairobi: Government Printer. Retrieved on 03rd September 2012 from http://www.kenyaembassy.com/pdfs/The percent20Constitution percent20of percent20Kenya.pdf

Rheinlander, P., Fullerton,R. and Sale, P. (2009). *Sustainable Management of Passion fruit Diseases in New Zealand*. Retrieved on 03rd September 2012 from http://maxa.maf.govt.nz/sff/about-projects/search/06-094/technical-report.pdf

Richman, D. (2010). *What drives efficiency on the Ghanaian cocoa farm? Ghana Institute of Management and Public Administration, Ghana.*

Sebstad, J. and Snodgrass, D. (2008). *Impacts of the KBDS and KHDP projects on the tree fruit value chain of Kenya.* Micro Report no.129. Nairobi: USAID-Kenya

Shehu, J., Iyortyer, J., Mshelia, S. and Jongur, A. (2011). Determinants of Yam Production and Technical Efficiency among Yam Farmers in Benue State, Nigeria, *Journal of Social Science* 24(2): 143-148.

Sibiko, K. (2012). *Determinants of Common Bean Productivity and Efficiency: A Case of Smallholder Farmers in Eastern Uganda*. Unpublished MSc Thesis, Egerton University

Tchango, J., Bikoï, A., Achard, R., Escalant, J. and Ngalani, J. (1999). *Plantain: Postharvest Operations*. Regional Research Centre on Banana and Plantain, Cameroon (CRBP).

Teryomenko, H. (2008). *Farm Size and Determinants of Agricultural Productivity in Ukraine*. National University, Ukraine.

Theocharopoulos, A., Pappa, C., Papanagiotou, E. and Fotopoulos, C. (2009). Programming, efficiency and management of tobacco farms in Greece. *Journal of Development and Agricultural Economics* 1(9):212-221.

Tijani, A. (2006). Analysis of the technical efficiency of rice farms in Ijesha land of Osun state, Nigeria. *Journal of Agriculture Economics* 45(2): 126-135.

Ubokudom, E., Anselm, E. and Nsikan, B. (2010). *Technical efficiency and its determinants in garden egg (Solanum spp) production in Uyo Metropolis, Akwa Ibom State.*

Wangungu, C. (2012). *Etiology, Epidemiology and Management of Dieback Disease of Passion Fruit (Passiflora Spp) in Central and Eastern Regions, Kenya*. Unpublished MSc Thesis, Kenyatta University.

Wangungu, C., Maina, M., Mbaka, J., Kori, N. and Gathu, R. (2010). *Biotic constraints to passion fruit production in central and eastern provinces of Kenya.* Second RUFORUM Biennial Meeting. Entebbe, Uganda. Retrieved on 03rd January 2012 from http://kenyatta.academia.edu/MainaMwangi/Papers/545041/Biotic_constraints_to_passion_fruit_production_in_central_and_eastern_provinces_of_Kenya

Watts, M. (2010). Pesticides: Sowing Poison, Growing Hunger, Reaping Sorrow, 2nd Edition. Penang: Pesticide Action Network Asia and the Pacific. Retrieved on 08th September 2012 from http://www.pananz.net/resources/Div_Loaded_Files/Documents/Sowing_Poison/sowingpoisongrowinghunger_2ndedition.pdf

Zaeske, A. (2012). *Aggregate Technical Efficiency and Water Use in U.S. Agriculture. Centre for Environmental and Resource Economics*, SLU and Umea University, Sweden.

APPENDICES

Appendix 1: Questionnaire

PURPLE PASSION FRUIT QUESTIONNAIRE

The purpose of this study is to do an evaluation of production efficiency of the small scale purple passion fruit farmers. The information availed will assist in making necessary policy recommendations based on the findings. The information needed is for the period January-December, 2011. All information provided will be treated as confidential.

A. Details of the respondent

Date________________________________

Enumerator______________________

County -----------------District_____________________

Division_____________________

Location ____________________________ Sub-location______________________

Farmer (Orchard owner) _________________________ Gender: 1=Male 2=Female

Age category 1=18- 35; 2=36 – 50; 3=above 50 --------------------------------

Highest academic level: none; primary; secondary; tertiary

Group name ---------------------------- Household size____________

Total farm acreage owned_____________ Acreage under passion/

B. General farm information (management practices and field observation)

Purple Passion fruit production

1. No. of plants---------------/acreage---------------------
   Spacing.......................
2. Age of the orchard(s)..
3. Farming experience (passion)…………..years
4. Do you intercrop passion fruit with other crops? (1=yes; 2=No).
5. Sources of planting materials (seed or seedlings)

[own seed / seedlings] [Local nursery] [Research institution] [Others...specify]

C. Passion fruit nutrition

a. Fertilizer applied at planting?
b. Do you top dress?
c. Do you foliar feed?
d. Top dressing or foliar fertilizer applied?

D. Field observation

Assessment of general agronomic and farm management practises (researcher to observe and assess this on a 1 - 5 scale; 1=poor; 5 = Excellent).

Practice	Tick if done	Score
Training of vines and pruning		
Weeding (indicate manual/herbicides)		

Removal of infected plants/parts		
Manure application		
Watering		
Other practices (specify)		

E. Information on inputs utilised

a. What is the number of purple passion seedlings bought and the cost of each? No------ cost(kshs)-----

b. What is the labour used in the passion fruits enterprise in the last one year? (man days)

Activity	Labor type (f=family and h=hired)	Quantity (hours, days, months)	Cost (Kshs)
Totals			

Activity: Clearing of land, ploughing, planting, trellising, watering, weeding, spraying, pruning, harvesting, transportation (from farm and to market), grading, packing and others specify.

c. Average cost of each man day? ----------

d. What are the amounts of fertilizers used and their respective costs?

Type/name	Amount (kg) or L	Cost per kg(kshs)	Total cost (kshs)
1			
2			
3			
4			
		TOTAL	

e. What are the amounts of pesticides used and their costs?

Type	Amount bought (kg/litres)	Cost per kg/litre (kshs)	Frequency of spraying	Number of pumps	size of pump
1					
2					
3					
4					

5 TOTAL					

f. Did you receive any extension advice on the purple passion enterprise? 1=yes 0=no

g. How many times have you received extension advice………………times last season

h. Did you borrow any money for purple passion fruit farming? 1=yes 0=no

i. If yes, what amount did you use on purple passion fruit enterprise? ____________Kshs

j. Are you a member of any farmers' association which deals with purple passion fruit? 1=yes 0=no

k. If yes in 7 above, what services do you get from the association?

1=financial advise

2=monetary credit

3=crop management (good farming practices)

4=identifying and control of pests and diseases

5=marketing of produce

6=inputs (seedlings, fertilizer, pesticides, propping materials etc)

7=other, specify_______________________________

l. Do have knowledge on the following?

a. Knowledge of pests, diseases and control?

b. Knowledge of recommended inputs amounts?

c. Knowledge of irrigation systems?

m. Do you use irrigation on the enterprise? 1=yes 2=no

n. If yes, what method do you use? 1=sprinkle 2=manual

F. Information on market and returns realised

a. What is your produce main market? 1=Export 2=Local

b. What is the distance of the main (the one that the farmer mostly sells the produce)…………..KM; {0 KM IF FRUITS ARE SOLD ON THE FARM}

c. Do you have any influence over the selling price (bargaining power)? 1=yes; 0=no (price taker)

d. What is the amount of your off-purple passion enterprise income?--------------(kshs)

e. What is the average selling price per kg of the fresh purple passion fruits? …………

f. What is the amount of output (consumed and sold) for the last one year? ....

THANK YOU FOR YOUR PATIENCE. BE BLESSED.

Appendix 2: Passion fruit varieties

*A and B represents yellow and purple passion fruit varieties respectively.

Appendix 3: Summary of technical efficiency literature.

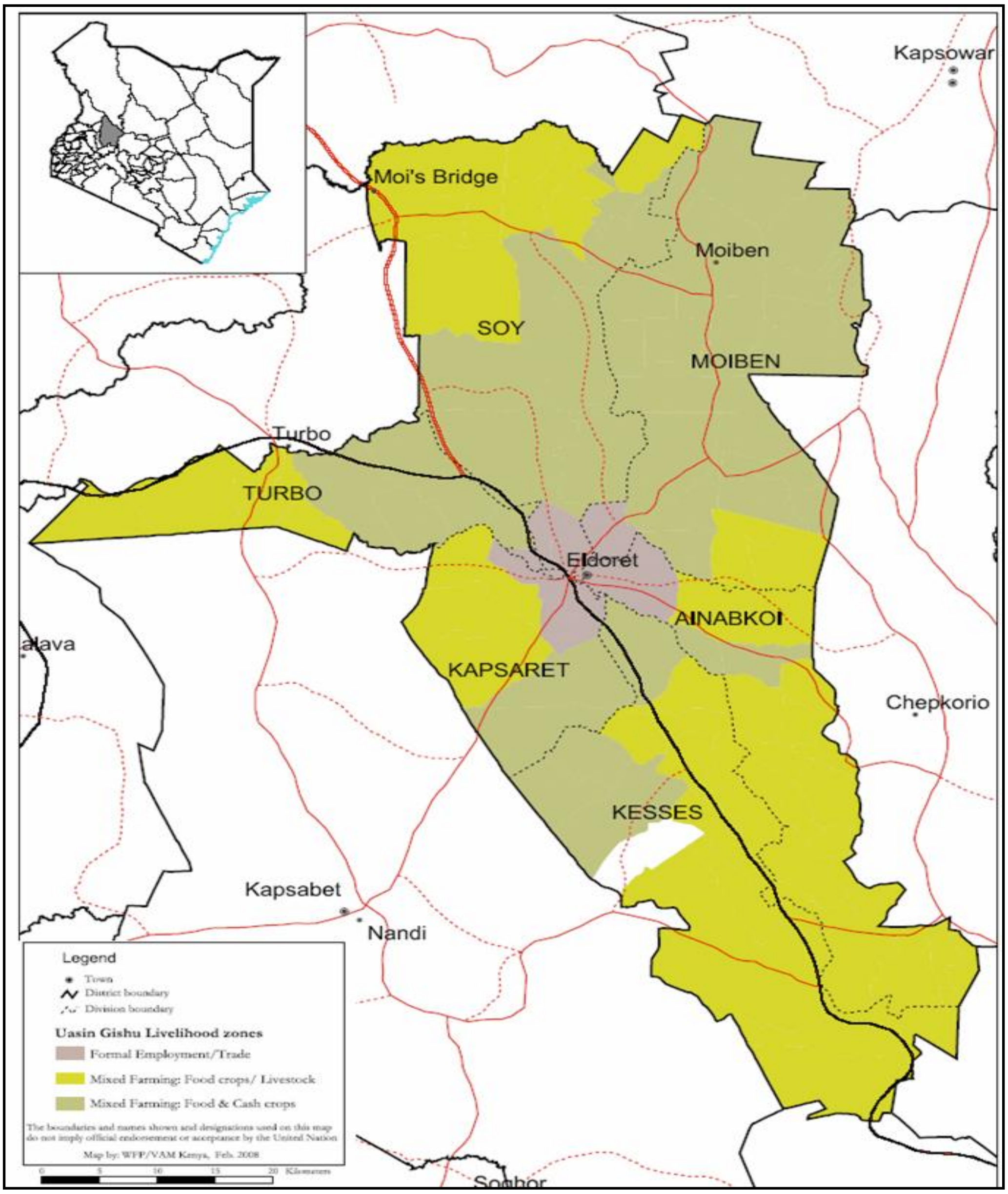
Authors and year	**Study title**	**Objectives**	**Analytical method**	**Main findings**	
				Mean TE (percent)	**variables influencing TE**
Nchare, 2007	Analysis of factors affecting the technical efficiency of Arabica Coffee Producers in Cameroon	1.Estimate the level of technical efficiency of Arabica coffee producers, 2.Identify and analyze the variables affecting their technical performance	Translog stochastic frontier production function, MLE	90	Age (-), educational level (+) and experience of the farmer (-), membership in a mutual aid group (-), family size (-), the contact of the coffee plantation with extension workers (+), access to credit (+), the use of the Java variety (-), and the mono-cropping system (-)
Teryomenk o, 2008	Farm size and determinants Of agricultural Productivity in Ukraine	To investigate the relationship between farm size and productivity for Ukrainian farmers; To determine level of technical efficiency among the Ukrainian farmers	DEA and stochastic frontier production model	DEA: 90 stochastic frontier production model: 76	Not identified
Richman, 2010	What drives efficiency on the Ghanaian cocoa	1.Level of technical efficiency; 2.Determinants of	stochastic frontier model	44	household size (-), age (-), education (-), gender (-), fertilizer intensity (-) and

	farm?	technical efficiency			quality of farm maintenance (-)
Niringiye *et al.*, 2010	Firm Size and Technical Efficiency in East African Manufacturing Firms	To establish the relationship between firm size and technical efficiency in East African manufacturing firms	DEA, two-step approach	Not calculated	Firm size (-)
Kachroo et al., 2010	Technical Efficiency of Dryland and Irrigated Wheat Based on Stochastic Model	To examine the technical efficiency of wheat under dry and irrigated conditions; To identify the factors influencing technical efficiency in wheat production under dryland and irrigated conditions	stochastic frontier production model	Dry land: 84; Irrigated: 88	Dry land: farm size (-), female workers (-), education (-), proportion of children (+) Irrigated: education (-), proportion of children (-), farm-size (-), male workers (+) and female Workers (+)
Oyewo, 2011	Technical efficiency of maize production in Oyo state	1.Examine the determinants of technical efficiency of maize producing-farmers in the study area, 2.Determine the technical efficiency of maize production	stochastic frontier production model	88	Level of education (-), Years of farming (-), Family size (+)

		in the study and 3. Determine the level of production in the study.			
Ogunniyi and Ajao, 2011	Investigation of Factors Influencing the Technical Efficiencies of Swine Farmers in Nigeria	1. To estimate the technical efficiency of the swine farmers 2. To investigate the influence which some basic farmer specific and input variables have on technical inefficiency of production of the swine farmers	Cobb Douglas Stochastic frontier production function	82	Age (-), education (-), farmer's experience (+)
Kibet *et al*, 2011 [a]	Identifying Efficient and Profitable Farm Enterprises in Uasin-Gishu County, in Kenya	To determine level of technical efficiency and profitability of various farm enterprises; To compare Technical Efficiency (TE) and Gross Margins (GM) of different farm enterprises within Uasin-Gishu County	DEA and Gross margin analysis	Maize: 66 Wheat: 75 Dairy: 43	Not part of the study

+…….positively influences TE, -………negatively influences TE

Appendix 4: Maps of study areas.

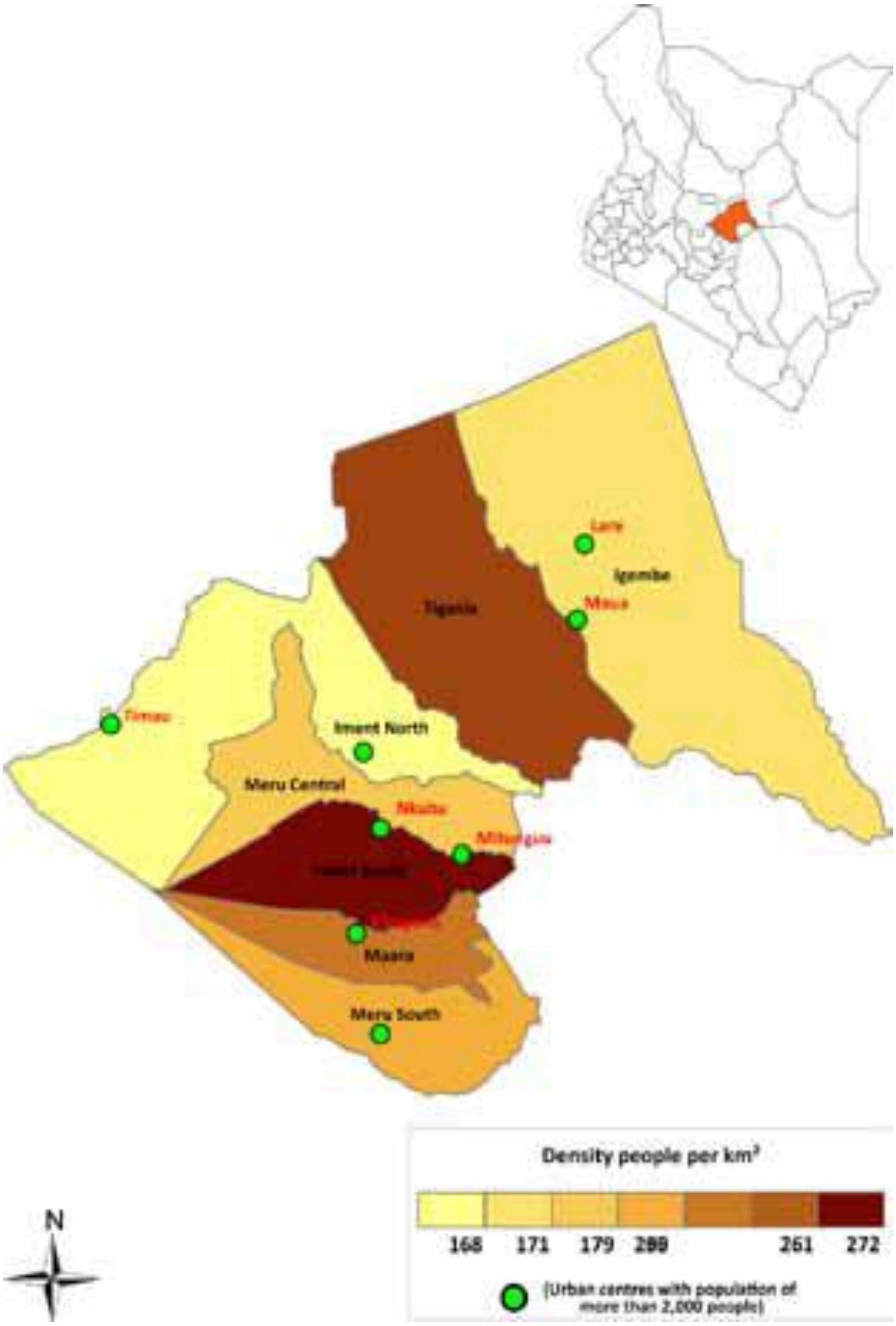


Map of Uasin Gishu County

Source: Kibet (2011)

Map of Embu County

Source: Kenya Open Data (2012)



Map of Meru County

Source: Kenya Open Data (2012)

Appendix 5: Validation tests.

Heteroscedasticity test (Hettest) results

Variable	**chi^2**	**p-value**
Number of seedlings (number)	123.71	0.00
Farm size under passion fruit (ha)	100.65	0.00
Fertilizer (kg)	52.14	0.00
Manure (kg)	109.43	0.00
Pesticide (kg)	156.10	0.00
Hired labour (person-days)	0.53	0.47
Family labour (person-days)	196.69	0.00
Gender (male or female)	9.75	0.00
Age (years)	1.41	0.23
Education (0=none, 1=primary, 2=secondary and 3=tertiary)	3.57	0.06
Farming experience (years)	6.15	0.01
House hold size (persons)	10.96	0.00
Orchard age (years)	0.18	0.67
Seedling source (1=own, 2=local and 3=research institution)	0.16	0.69
Extension frequency (times)	0.00	0.98
Farmer group (1=yes and 0=no)	3.94	0.05
Market access (km)	0.05	0.83
Irrigation (0=none, 1=sprinkle, 2=drip and 3=manual)	11.92	0.00
Credit used (kshs)	3.12	0.08
Non-passion fruit income (kshs)	0.41	0.52
County (1=Embu, 2=Meru and 3=Uasin Gishu)	16.29	0.00
Simultaneous	306.58	0.00

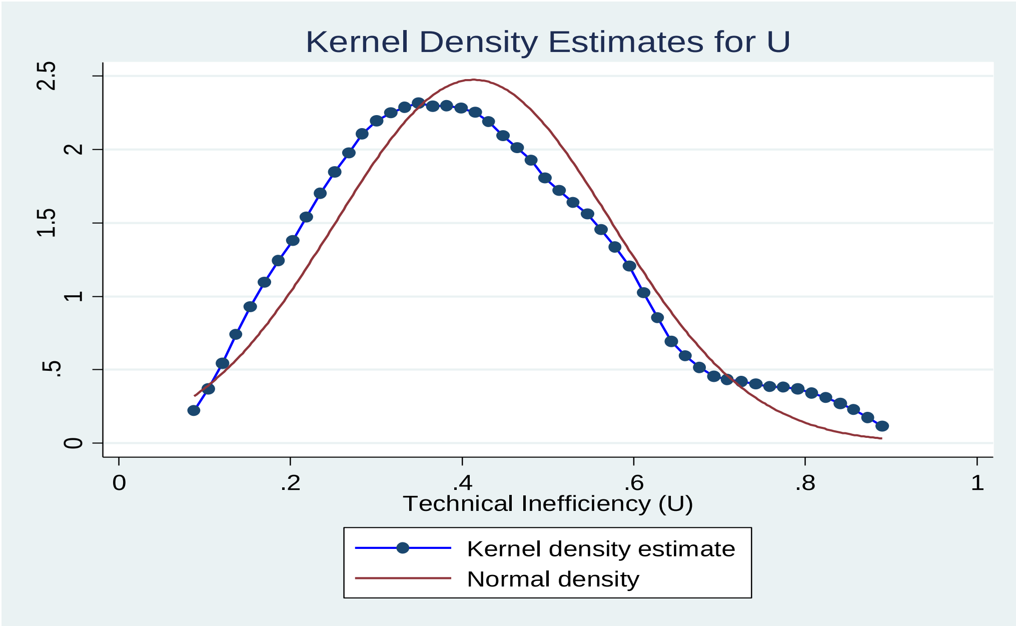
df=21

Correction of heteroscedasticity

Variable	chi^2	p-value
Number of seedlings (number)	0.72	0.40
Farm size under passion fruit (ha)	1.72	0.19
Fertilizer (kg)	0.01	0.93
Manure (kg)	0.03	0.86
Pesticide (kg)	1.34	0.25
Hired labour (person-days)	0.71	0.40
Family labour (person-days)	0.22	0.64
Gender (male or female)	1.20	0.27
Age (years)	0.00	0.98
Education (0=none, 1=primary, 2=secondary and 3=tertiary)	0.74	0.39
Farming experience (years)	0.14	0.71
House hold size (persons)	0.59	0.44
Orchard age (years)	3.75	0.05
Seedling source (1=own, 2=local and 3=research institution)	0.49	0.48
Extension frequency (times)	0.11	0.74
Farmer group (1=yes and 0=no)	0.68	0.41
Market access (km)	0.05	0.83
Irrigation (0=none, 1=sprinkle, 2=drip and 3=manual)	0.36	0.55
Credit used (kshs)	2.53	0.11
Non-passion fruit income (kshs)	2.98	0.09
County (1=Embu, 2=Meru and 3=Uasin Gishu)	2.54	0.11
Simultaneous	26.26	0.20

df=21

Normality test



Appendix 6: Separation of means of production, socioeconomic and institutional characteristics by County.

Variable	(I) County	(J) County	Mean Difference (I-J)	Std. Error	P-value	95 percent Confidence Interval	
						Lower Bound	Upper Bound
output	1	2	-1294.89022*	1326.49297	.031	-3921.2540	1331.4735
		3	-1519.26326*	1346.60634	.061	-4185.4501	1146.9236
	2	1	1294.89022*	1326.49297	.031	-1331.4735	3921.2540
		3	-224.37303	1042.13919	.830	-2287.7361	1838.9900
	3	1	1519.26326*	1346.60634	.061	-1146.9236	4185.4501
		2	224.37303	1042.13919	.830	-1838.9900	2287.7361
seedlings number	1	2	-147.16209	135.42973	.279	-415.3035	120.9793
		3	-191.70455	137.48323	.166	-463.9118	80.5027
	2	1	147.16209	135.42973	.279	-120.9793	415.3035
		3	-44.54245	106.39832	.676	-255.2037	166.1188

	3	1	191.70455	137.48323	.166	-80.5027	463.9118
		2	44.54245	106.39832	.676	-166.1188	255.2037
farm size under passion fruit	1	2	-.07644	.13109	.561	-.3360	.1831
		3	-.19683	.13307	.142	-.4603	.0666
	2	1	.07644	.13109	.561	-.1831	.3360
		3	-.12039	.10299	.245	-.3243	.0835
	3	1	.19683	.13307	.142	-.0666	.4603
		2	.12039	.10299	.245	-.0835	.3243
hired labour	1	2	2.81904	17.63890	.873	-32.1048	37.7428
		3	-15.55871	17.90636	.387	-51.0121	19.8946
	2	1	-2.81904	17.63890	.873	-37.7428	32.1048
		3	-18.37775	13.85774	.187	-45.8151	9.0596
	3	1	15.55871	17.90636	.387	-19.8946	51.0121
		2	18.37775	13.85774	.187	-9.0596	45.8151
family labour	1	2	-12.85806	18.71814	.493	-49.9187	24.2026
		3	-48.22220*	19.00196	.012	-85.8448	-10.5996
	2	1	12.85806	18.71814	.493	-24.2026	49.9187
		3	-35.36414*	14.70563	.018	-64.4803	-6.2480
	3	1	48.22220*	19.00196	.012	10.5996	85.8448
		2	35.36414*	14.70563	.018	6.2480	64.4803
fertilizer	1	2	-12.17003	20.89440	.561	-53.5395	29.1994
		3	-53.50786*	21.21122	.013	-95.5046	-11.5111
	2	1	12.17003	20.89440	.561	-29.1994	53.5395
		3	-41.33783*	16.41537	.013	-73.8391	-8.8365
	3	1	53.50786*	21.21122	.013	11.5111	95.5046
		2	41.33783*	16.41537	.013	8.8365	73.8391
manure	1	2	-891.31218	1002.03263	.376	-2875.2671	1092.6427
		3	-2864.39394*	1017.22628	.006	-4878.4312	-850.3567
	2	1	891.31218	1002.03263	.376	-1092.6427	2875.2671
		3	-1973.08176*	787.23182	.014	-3531.7460	-414.4175
	3	1	2864.39394*	1017.22628	.006	850.3567	4878.4312

		2	1973.08176*	787.23182	.014	414.4175	3531.7460
pesticides	1	2	1.58772	3.44375	.646	-5.2307	8.4061
		3	-4.29382	3.49597	.222	-11.2156	2.6280
	2	1	-1.58772	3.44375	.646	-8.4061	5.2307
		3	-5.88153*	2.70553	.032	-11.2383	-.5248
	3	1	4.29382	3.49597	.222	-2.6280	11.2156
		2	5.88153*	2.70553	.032	.5248	11.2383
age	1	2	.246	.199	.217	-.15	.64
		3	.394	.202	.053	.00	.79
	2	1	-.246	.199	.217	-.64	.15
		3	.148	.156	.345	-.16	.46
	3	1	-.394	.202	.053	-.79	.01
		2	-.148	.156	.345	-.46	.16
farming experience	1	2	.30086	.60208	.618	-.8912	1.4929
		3	-1.48314*	.61121	.017	-2.6933	-.2730
	2	1	-.30086	.60208	.618	-1.4929	.8912
		3	-1.78400*	.47302	.000	-2.7205	-.8475
	3	1	1.48314*	.61121	.017	.2730	2.6933
		2	1.78400*	.47302	.000	.8475	2.7205
household size	1	2	.17153	.57026	.764	-.9576	1.3006
		3	-.44129	.57891	.447	-1.5875	.7049
	2	1	-.17153	.57026	.764	-1.3006	.9576
		3	-.61281	.44802	.174	-1.4999	.2742
	3	1	.44129	.57891	.447	-.7049	1.5875
		2	.61281	.44802	.174	-.2742	1.4999
orchard age	1	2	-.01947	.18748	.917	-.3907	.3517
		3	-.05909	.19032	.757	-.4359	.3177
	2	1	.01947	.18748	.917	-.3517	.3907
		3	-.03962	.14729	.788	-.3313	.2520
	3	1	.05909	.19032	.757	-.3177	.4359
		2	.03962	.14729	.788	-.2520	.3313
extension	1	2	.25386	.65862	.701	-1.0502	1.5579

frequency		3	.98106	.66861	.145	-.3427	2.3049
	2	1	-.25386	.65862	.701	-1.5579	1.0502
		3	.72720	.51744	.162	-.2973	1.7517
	3	1	-.98106	.66861	.145	-2.3049	.3427
		2	-.72720	.51744	.162	-1.7517	.2973
market access	1	2	1.89151	.92731	.044	.0555	3.7275
		3	4.83333*	.94137	.000	2.9695	6.6972
	2	1	-1.89151	.92731	.044	-3.7275	-.0555
		3	2.94182*	.72853	.000	1.4994	4.3843
	3	1	-4.83333*	.94137	.000	-6.6972	-2.9695
		2	-2.94182*	.72853	.000	-4.3843	-1.4994
credit amount	1	2	-5263.89365*	4516.33791	.046	-14205.9284	3678.1411
		3	32.76515	4584.81834	.994	-9044.8561	9110.3864
	2	1	5263.89365*	4516.33791	.046	-3678.1411	14205.9284
		3	5296.65881*	3548.19276	.038	-1728.5159	12321.8335
	3	1	-32.76515	4584.81834	.994	-9110.3864	9044.8561
		2	-5296.65881*	3548.19276	.038	-12321.8335	1728.5159
non-passion fruit income	1	2	41494.16810	30716.04753	.179	-19321.4683	102309.8045
		3	22467.04545	31181.78949	.473	-39270.7276	84204.8186
	2	1	-41494.16810	30716.04753	.179	-102309.8045	19321.4683
		3	-19027.12264	24131.59944	.432	-66806.0101	28751.7648
	3	1	-22467.04545	31181.78949	.473	-84204.8186	39270.7276
		2	19027.12264	24131.59944	.432	-28751.7648	66806.0101

*. The mean difference is significant at the 0.05 level.

Appendix 7: Separation of means of orchard management practices.

Variable	(I) Region	(J) Region	Mean Difference	Std. Error	P-value	95 percent Confidence Interval	
						Lower Bound	Upper Bound
TVP	1	2	-1.88165*	0.24151	0	-2.3598	-1.4035
		3	-.59470*	0.24518	0.017	-1.0801	-0.1093
	2	1	1.88165*	0.24151	0	1.4035	2.3598
		3	1.28695*	0.18974	0	0.9113	1.6626
	3	1	.59470*	0.24518	0.017	0.1093	1.0801
		2	-1.28695*	0.18974	0	-1.6626	-0.9113
Weeding	1	2	-1.26158*	0.29127	0	-1.8383	-0.6849
		3	-.65152*	0.29568	0.029	-1.2369	-0.0661
	2	1	1.26158*	0.29127	0	0.6849	1.8383
		3	.61006*	0.22883	0.009	0.157	1.0631
	3	1	.65152*	0.29568	0.029	0.0661	1.2369
		2	-.61006*	0.22883	0.009	-1.0631	-0.157
Disease management	1	2	-0.43739	0.38114	0.253	-1.192	0.3172
		3	-0.42992	0.38691	0.269	-1.196	0.3361
	2	1	0.43739	0.38114	0.253	-0.3172	1.192
		3	0.00747	0.29943	0.98	-0.5854	0.6003
	3	1	0.42992	0.38691	0.269	-0.3361	1.196
		2	-0.00747	0.29943	0.98	-0.6003	0.5854
Manure/fertilizer	1	2	-.84134*	0.29667	0.005	-1.4287	-0.254
		3	-1.41288*	0.30116	0	-2.0092	-0.8166
	2	1	.84134*	0.29667	0.005	0.254	1.4287
		3	-.57154*	0.23307	0.016	-1.033	-0.1101
Watering	1	2	-1.89280*	0.32657	0	-2.539	-1.246
		3	-.6950*	0.3315	0.038	-1.351	-0.038
	2	1	1.89280*	0.32657	0	1.2462	2.5394
		3	1.19772*	0.25657	0	0.6897	1.7057
	3	1	.69508*	0.33153	0.038	0.0387	1.3515
		2	-1.1977*	0.2565	0	-1.705	-0.689

Appendix 8: Individual technical efficiencies of purple passion fruit farmers in Embu, Meru and Uasin Gishu Counties.

Farmer	T E	Farmer	TE	Farmer	TE	Farmer	TE
1	0.51	32	0.75	63	0.70	94	0.69
2	0.64	33	0.73	64	0.76	95	0.44
3	0.60	34	0.51	65	0.78	96	0.66
4	0.63	35	0.83	66	0.66	97	0.40
5	0.51	36	0.55	67	0.54	98	0.37
6	0.61	37	0.45	68	0.60	99	0.59
7	0.67	38	0.79	69	0.67	100	0.56
8	0.44	39	0.81	70	0.68	101	0.48
9	0.35	40	0.80	71	0.58	102	0.60
10	0.24	41	0.61	72	0.18	103	0.48
11	0.63	42	0.86	73	0.68	104	0.63
12	0.48	43	0.49	74	0.77	105	0.38
13	0.46	44	0.65	75	0.23	106	0.63
14	0.48	45	0.79	76	0.71	107	0.63
15	0.57	46	0.76	77	0.46	108	0.45
16	0.46	47	0.81	78	0.63	109	0.24
17	0.44	48	0.66	79	0.62	110	0.81
18	0.31	49	0.82	80	0.59	111	0.47
19	0.37	50	0.50	81	0.68	112	0.40
20	0.43	51	0.78	82	0.50	113	0.37
21	0.23	52	0.60	83	0.70	114	0.50
22	0.29	53	0.51	84	0.61	115	0.17
23	0.59	54	0.77	85	0.81	116	0.67
24	0.72	55	0.75	86	0.66	117	0.85
25	0.73	56	0.58	87	0.79	118	0.75
26	0.79	57	0.81	88	0.61	119	0.51
27	0.56	58	0.66	89	0.18	120	0.48
28	0.63	59	0.47	90	0.56	121	0.73
29	0.44	60	0.64	91	0.78	122	0.42
30	0.55	61	0.57	92	0.68	123	0.64
31	0.68	62	0.75	93	0.66		

Farmer number 1-22 (Embu County); 23-75 (Meru County) and 76-123 (Uasin Gishu County)

Appendix 9: Marginal effects after the frontier.

Y predict=3.0206

Variable	**ME/ Elasticities**	**SE**	**z**	**p>|z|**	**lnx**
Number of seedlings	0.86	0.22	3.93	0.00	2.44
Farm size under passion fruit	-0.12	0.18	-0.68	0.50	0.55
Fertilizer	0.19	0.10	1.90	0.06	1.29
Manure	0.01	0.05	0.22	0.82	2.90
Pesticide	-0.02	0.16	-0.15	0.88	0.48
Hired labour	0.00	0.01	0.68	0.50	1.73
Family labour	-0.04	0.11	-0.32	0.75	1.49

Appendix 10: Overall Stochastic Frontier Production Function Results.

Variable	**coefficient**	**standard error**	**z**
Output			
Seedling number	0.80**	0.37	2.14
Farm size under passion fruit	-1.15***	0.45	-2.57
Fertilizer	0.14	0.11	1.25
Manure	0.88***	0.28	3.17
Pesticide	-0.07	0.19	-0.36
Hired labour	0.37**	0.17	2.22
Family labour	-0.03	0.14	-0.22
_cons	-2.84**	1.30	-2.19
lnsig2v _cons	-1.85***	0.58	-3.19
lnsig2μ_cons	-0.59	0.43	-1.37
Variance parameters			
sigma_v	0.31**	0.04	
sigma_μ	0.75**	0.25	
$sigma^2$	0.65**	0.20	
Lambda (λ)	2.42**	0.35	
Mean technical efficiency (overall)	58.66 %		

Appendix 11: Inefficiency Model Results.

Variable	Coefficient	Std. Error	z
Technical inefficiency (μ)			
County	-2.19**	1.02	-2.15
Gender	2.24	1.65	1.35
Age	0.74	0.73	1.01
Education	-1.04*	0.56	-1.86
Farming experience	4.30**	1.84	2.33
House hold size	0.84	1.37	0.61
Orchard age	-16.70**	8.03	-2.08
Seedling source	-1.62	1.04	-1.55
Extension frequency	-0.85*	0.51	-1.67
Farmer group	1.80	1.25	1.43
Market access	-1.75*	1.75	-1.00
Irrigation	-0.15	0.51	-0.29
Credit used	-0.22**	0.07	-2.92
Non-passion fruit income	-2.39**	0.92	-2.59
_cons	-0.16**	5.66	-0.03

Appendix 12: Stochastic Frontier Production Function for Individual Counties Results.

	Embu County			Meru County			Uasin Gishu County		
Variable	**Coeff**	**SE**	**z**	**Coeff**	**S E**	**z**	**Coeff**	**SE**	**z**
Output									
Seedling number	1.59***	0.51	3.13	1.18***	0.27	4.34	1.02**	0.42	2.45
Farm size under passion fruit	-1.89**	0.75	-2.53	-0.37	0.28	-1.33	-0.26	0.20	-1.32
Fertilizer	-0.28	0.15	-1.80	0.37***	0.12	3.18	-0.21	0.17	-1.20
Manure	0.11***	0.03	3.79	-0.01	0.05	-0.24	0.71***	0.27	2.66
Pesticide	0.10**	0.05	2.09	0.16	0.25	0.64	-0.23	0.21	-1.08
Hired labour	0.20	0.13	1.51	-0.01	0.01	-1.57	-0.06	0.10	-0.59
Family labour	0.29***	0.10	2.99	-0.28*	0.15	-1.84	0.01	0.14	0.05
_cons	-0.10	0.70	-0.14	0.77	0.61	1.25	-1.38*	0.81	-1.70
lnsig2v_cons	-7.90**	0.85	-9.30	-2.77***	0.76	-3.63	-2.84***	0.51	-5.53
lnsig2u_cons	-7.62	132.17	-0.06	-0.21	0.33	-0.64	-0.60	1.00	-0.60
Variance Parameters									
sigma_v {σ_v}	0.02**	0.07		0.25**	0.10		0.24**	0.06	
sigma_u {σ_μ}	0.43	1.47		0.90**	0.15		0.74**	0.37	
sigma2 {σ^2}	0.19**	0.07		0.88**	0.24		0.61	0.40	
lambda	21.50	1.49		3.60**	0.22		3.08**	0.56	
Mean technical efficiency (County)		46.94%			65.24%			56.76%	

Appendix 13: Inefficiency Model Results for the Counties.

	Embu County			Meru County			Uasin Gishu County		
Variable	**Coefficient**	**Std. Error**	**z**	**Coefficient**	**Std. Error**	**z**	**Coefficient**	**Std. Error**	**z**
Technical inefficiency (μ)									
Gender	-13.52	33.56	-0.40	2.32**	1.01	2.30	-1.45*	0.83	-1.75
Age	-48.33**	21.54	-2.24	0.27	0.35	0.77	0.15	0.63	0.24
Education	-18.15***	5.80	-3.13	0.43	0.43	0.99	-0.05	0.53	-0.09
Farming experience	-99.60***	30.28	-3.29	-0.30	0.64	-0.46	-1.56	1.81	-0.86
House hold size	-57.00	124.18	-0.46	0.92	1.06	0.87	0.16	2.06	0.08
Orchard age	37.86	107.14	0.35	-0.96	1.51	-0.64	-6.40**	3.18	-2.01
Seedling source	-29.11**	12.52	-2.33	0.58	0.48	1.20	-1.21**	0.57	-2.12
Extension frequency	1.46	4.10	0.36	-0.18*	0.11	-1.65	-0.57	0.53	-1.08
Farmer group	-55.75*	33.60	-1.66	-0.39	0.63	-0.62	0.26	0.80	0.33
Market access	83.58***	25.77	3.24	0.13	0.61	0.21	3.86**	1.93	2.00
Irrigation	24.88	26.59	0.94	0.15	0.35	0.41	-0.07	0.50	-0.13
Credit used	-5.08	14.31	-0.36	-0.46***	0.16	-2.79	-0.26	0.24	-1.09
Non-passion fruit income	-79.79**	13.06	-6.11	-0.52**	0.23	-2.27	-1.46	1.61	-0.90
_cons	0.92	1.57	0.59	-2.70	3.08	-0.88	12.75**	7.91	1.61