ANALYSIS OF PRODUCTION, SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS AFFECTING TECHNICAL EFFICIENCY OF SMALLHOLDER BANANA PRODUCERS IN KIRINYAGA CENTRAL SUB-COUNTY, KENYA

JACKSON MKENYE MATIVA

A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Award of the Degree of Master of Science in Agribusiness Management of Chuka University

CHUKA UNIVERSITY

OCTOBER 2023

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for an award of diploma or conferment of degree in any other University.

Signature ..... Date 11/10/2023

Mativa Jackson Mkenye
NM24/45939/21

Recommendation

This thesis has been examined, passed and submitted with our approval as University supervisors.

Signature..... Date 11/10/2023

Dr. Carolyne A. Omukoko, PhD
Chuka University

Signature..... Date 11/10/2023

Dr. Jafford N. Rithaa, PhD
Chuka University

DEDICATION

I dedicate this thesis to my lovely Raheal Anyisa Mativa, my brother Nelson Olindo Mativa, my wife Claire Kabeyeka and my son Gamaliel Vulimu Mkenye.

ACKNOWLEDGEMENTS

I want to praise the Almighty God for making it possible for me to complete this study. Without the untiring and kind assistance of my supervisors, Dr. Carolyne A. Omukoko and Dr. Jafford N. Rithaa, I could not have completed this program. They have provided me with countless hours of support, patience, encouragement and counsel during my academic journey and I am sincerely grateful to them. I also want to express my gratitude to Professor Geofrey K. Gathungu for his assistance and support over the course of the project. I would like to express my gratitude to the staff members of the Department of Agricultural Economics, Agribusiness Management and Agricultural Extension and Education for their encouragement and assistance during the course of my study. I would also want to thank Mr. David Mwangi for all his helpful recommendations, guidance and assistance throughout the entire process. Finally, I want to sincerely thank my mother, my brother Nelson, my church family of Githurai P.A.G and my friends for all their prayers, encouragement and support. Through their support and compassion, they have served as a pillar of hope.

ABSTRACT

Banana provides food, nutrition security and income for most households and is fourth most popular food crop in the world after wheat, maize and rice. Despite its significance, full potential of banana production in Kenya remains unexploited by smallholder producers. This is as a result of low technical efficiency especially in utilization of farming inputs and producer specific factors like production, socio-economic and institutional factors among others. In Kirinyaga County, the actual banana production is at 4-18 tonnes per acre against the potential of 30-40 tonnes. Due to the limited supply of resources for production, attainment of highest possible levels of technical efficiency is key to achieving sufficiency in banana farming. This study aimed at analyzing the effects of production, socio-economic and institutional factors on technical efficiency of smallholder banana producers in Kirinyaga Central Sub-County, Kenya. The study used a cross-sectional research design and targeted a population of 24,440 smallholder banana producers. Multistage sampling technique was employed where purposive sampling and simple random sampling methods were used in some stages to sample respondents in the study area. A sample of 402 smallholder banana producers were selected. Using a questionnaire, primary data on production, socio-economic and institutional factors affecting technical efficiency of banana production was collected. The data was then analyzed using Stata version 17 and SPSS version 25. Descriptive statistics were used to describe the production, socio-economic and institutional factors of the smallholder banana producers. A stochastic frontier analysis approach was used to model the technical efficiency level using the Cobb-Douglas function. The stochastic production function of the Cobb Douglas function was estimated using the maximum likelihood estimation technique. The study showed that the level of banana production technical efficiency among the smallholder producers varied between 0.9% to 95.5% and average technical efficiency of 83.1%. According to the model parameters calculated, land set aside for production of banana, banana suckers and agrochemicals were significant production factors in banana cultivation at 5% significance level. The study found that agrochemicals and planting materials had positive effects on technical efficiency whereas land size had a negative impact on technical efficiency. This implied that increasing the amount of land set aside for banana production by an acre reduces the amount of banana harvested by 0.438 kgs while increasing the amount of planting materials and agrochemicals used by one unit increases banana production by 1.315 and 0.155 kgs, respectively. The study found that decision makers' age and size of the household had negative effects on banana production technical efficiency whereas education, experience, producer group membership and market access had positive effects. The study recommends people with high levels of education to venture into banana production. In addition, producer group formation and membership be encouraged for the benefit of increasing technical efficiencies. The inefficient producers are advised to increase their present output by enhancing technical efficiency as a result of the inefficient utilization of their resources throughout production.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AFA	Agriculture and Food Authority
ASTGS	Agricultural Sector Transformation and Growth Strategy
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GDP	Gross Domestic Product
GoK	Government of Kenya
KCIDP	Kirinyaga County Integrated Development Plan
KIPPRA	Kenya Institute for Public Policy Research and Analysis
KNBS	Kenya National Bureau of Statistics
KALRO	Kenya Agricultural and Livestock Research Organization
MLE	Maximum Likelihood Estimates
MoA	Ministry of Agriculture
SFA	Stochastic Frontier Analysis
SPSS	Statistical Package for Social Science
TE	Technical Efficiency
USAID	United States Agency for International Development

CHAPTER ONE
INTRODUCTION

1.1 Background to the Study

Banana (*Musa spp*) is a tropical crop produced in approximately 130 countries worldwide (Dhake *et al*., 2019). It is rated number four as a food crop in the world after wheat, maize and rice (Tumuhimbise and Talengera, 2018). In addition, banana production act as employment and income source to smallholder producers in high production areas. Ninety-eight percent of whole world banana come from undeveloped nations (Pillay *et al*., 2012) and is one of the most consumed food crop and helps to meet both food and nutritional security for smallholder producers. Banana is a high-value commercial crop and highly demanded (Bhatta *et al*., 2023). It has become the most consumed and exported food crop in the world and is grown on smallholder farms and large plantations around the world (Voora *et al*., 2023). Fifty percent of all domestic horticulture production is contributed by banana production (World Bank, 2020). More than 1000 varieties of banana exists in the world and Cavendish banana is the most popular type and merchandized (FAO, 2022).

More than 60% of the global banana production come from Brazil, China, Ecuador, India, Philippines and Indonesia (Vinayagamoorthi *et al*., 2019). Approximately 5.6 million hectares of land area is dedicated to banana production (FAOSTAT, 2017). The world's largest banana producer is India, accounting for around 15% of the total worldwide area and 29% of the global overall output (Dhake *et al*., 2019). India produces an average of 39 million tonnes of banana annually (Eutycus, 2019). Eighty percent of banana produced globally are locally consumed and 20% are exported (Vinayagamoorthi *et al*., 2019). It is among the most traded crop in the world (Voora *et al*., 2020) and in 2018 approximately 155 million tonnes were produced and traded (FAOSTAT, 2020). Several factors however affected banana trade in 2021 including banana production shortages and the continued spread of banana plant diseases (FAO, 2022).

In Africa, approximately 70 million people rely on banana to support their financial needs (Geberewold, 2019). Banana is the most significant food security crop for Central, Eastern and Western regions of Africa (Obaga, 2018). Approximately 2.3% of

all worldwide total banana harvested is produced in West Africa with Côte d'Ivoire, Liberia, Guinea and Mali producing the most (Olumba & Onunka, 2020). Eastern Africa on the other hand contributes around 20% of global banana production (FAO, 2020). The majority of Africa's banana are produced in Uganda and most of the grown banana are the cooking *Matooke* and the brewing *Mbidded* types (Arinaitwe *et al*., 2019).

In Kenya, banana production is mainly done on small scale and it helps in meeting the nation's food demands (Eutycus, 2019). Banana production is primarily rain-fed but in some regions of the country minimal irrigation is done (Karienye and Karimi, 2020). In addition, it has the potential to benefit the smallholder producers as well as other participants in the banana value chain. The common varieties grown include the cooking types: Uganda green, *Mutahato*, *Nusu Ng'ombe,* and *Gradi shisikame*, whereas among the dessert varieties include: apple banana (*Ndizi sukari*), *Bogoya*, *Bokoboko*, Chinese Cavendish, Gros Michel, giant Cavendish, *Kampala* and *Muraru* (Wahome *et al*., 2021). Banana constitutes one among the most significant basic crops, accounting for 14% of the country's overall crop value and 20% of the total food consumption (Kirimi *et al*., 2021).

The ripe banana is among the fruits that city dwellers consume most, whereas plantains are the second most popular across all socioeconomic levels (World Bank, 2020). Banana production is largely practiced in the Eastern, Western and Central areas (Omondi *et al*., 2020) and its output consumed locally (USAID, 2017). Meru, Kirinyaga, Muranga, Kisii, Tharaka Nithi, Kiambu, and Taita Taveta are the most productive counties [Agriculture and Food Authority (AFA, 2016)]. According to Horticulture Validated Report (2021), Meru County had an approximate production of 484,936 tonnes, Taita Taveta County 238,750 tonnes, Kirinyaga County 185,133 tonnes and Murang'a County 161,859 tonnes in the production year 2020. In Meru County, banana production is done for both food and commercial purposes and that majority (71.3%) of producers have average production, 16.3% have high production rates while 9.0% have low production rates (Kirimi *et al*., 2021). Banana producers in Meru harvests between 4.5 and 10 tonnes for every acre against the possible production range of 30 to 40 tonnes (Muchui *et al*., 2013).

In Kirinyaga County, the major fruits grown in order of importance are banana 34.85%, mango 20.13%, pineapple 15.52%, avocado 9.90%, water melon 5.67% and pawpaw 4.73%. Banana production in Kirinyaga County was estimated at 117,356 tonnes in 2017 and 152,409 tonnes in 2018, 99,316 tonnes in 2019 and 185,133 tonnes in 2020 (KNBS, 2018; Horticulture Validated Report, 2021). Banana farming is a popular choice among producers because of its adaptability for cultivation within the region, great market demand and relatively simple management of the crop (Mbaka *et al*., 2008). A study by Kairu (2020) found that Kirinyaga County has an actual production of 4-18 tonnes per acre against the potential of 30-40 tonnes per acre. Kairu (2020) further found that approximately 51% of producers indicated that their banana production remained the same in the year 2020. In addition, 70% of the respondents noted that their area under banana cultivation ranged between 0.1 to 0.3 acres indicating that small pieces of land were allocated for cultivation of banana.

Several factors have impacts on banana output which cut across socio-demographic factors, agronomic and management practices (Wahome *et al*., 2021) and among them are diseases, poor agronomic techniques, pests and a lack of access to sanitary and reasonably priced suckers. Additionally, pest and disease prevalence in the soils has an impact on soil fertility while increased soil temperature allows the spread of banana soil-borne illness, hence negatively influencing the production of banana. Lack of provision and accessibility to extension services and proper plantation management, marketing and climatic factors also affect banana production (Adhikari *et al*., 2022; Murongo *et al*., 2018). Karienye and Karimi, (2020) also noted that land use changes, fluctuating labour costs and soil water retention affects banana production.

Despite the challenges, banana production is an economic revenue source with a strong potential for revenue for the country thus an increase in its levels of production efficiency would lead to a society that is nourished, secure in its food supply and a positive influence on rural growth (MOA, 2017). Given that there is a huge demand for banana especially in towns (MOA, 2017; World Bank, 2020), a country's food supply would increase and producers would receive more money if production efficiency were to increase. An increase in banana output would result in more job prospects, more revenue and better food security. This is crucial to achieving Kenya

Vision 2030 of "attaining food security and economic growth" through the agricultural sector. The achievement of the Big Four Agenda by the national government of being a food secure country will be possible as well as the sustainable development goals of "no to poverty" and "pushing of hunger to zero". Comparing producer performance and locating the causes of low efficiencies in production is made easier with the use of technical efficiency measurements (Kassa and Demissie, 2019). To assess technical efficiency, it is crucial to consider a producer's performance and the variables that influence efficiency (Dessale, 2019). As a result of low efficiencies in production, there is need to investigate technical efficiencies in agricultural production especially among smallholder banana producers.

1.2 Statement of the Problem

Cultivation of banana has a substantial economic significance on the nation when it comes to food security, employment opportunities, income and revenue generation. Consequently, production is determined by good use of available inputs as well as application of new technology available. Production of banana in Kirinyaga County is low at 185,133 tonnes with an actual production of 4-18 tonnes per acre against the potential of 30-40 tonnes and this may be attributed to low technical efficiency in terms of resources utilization. Smallholder producers' levels of technical efficiency is affected by production, socio-economic and institutional factors which influences producers' decision in allocating and managing the available inputs efficiently. If technical efficiency is not achieved, then issues of unemployment, food insecurity and low income levels will increase among smallholder producers. There is limited information on how production, socio-economic and institutional factors affects the levels of technical efficiency in banana cultivation in most banana producing areas of Kenya especially in Kirinyaga County. It is to this extent that the study aims to look into the effects of production, socio-economic and institutional factors on smallholder banana producers' technical efficiency in Kirinyaga Central Sub County, Kenya.

1.3 Objectives of the Study

1.3.1 General Objective

To analyze the effects of production, socio-economic and institutional factors on banana production technical efficiency among smallholder producers in Kirinyaga Central Sub County, Kenya.

1.3.2 Specific Objectives

Among the specific objectives investigated were:

i. To determine the level of technical efficiency among smallholder banana producers in Kirinyaga Central Sub-County, Kenya.
ii. To analyze production factors affecting technical efficiency of the smallholder banana producers in Kirinyaga Central Sub-County, Kenya.
iii. To examine how socioeconomic factors affects technical efficiency of the smallholder banana producers in Kirinyaga Central Sub-County, Kenya.
iv. To determine the institutional factors affecting technical efficiency among the smallholder banana producers in Kirinyaga Central Sub-County, Kenya.

1.4 Research Questions

The investigation addressed the following research queries:

i. How technically efficient is the production of banana among smallholder banana producers?
ii. What are the production factors affecting technical efficiency of smallholder banana producers?
iii. To what extent does socioeconomic factors affect technical efficiency of smallholder banana producers?
iv. To what extent do institutional factors affect technical efficiency among smallholder banana producers?

1.5 Significance of the Study

The outcome of the study is a guide to those who make policies in formulating measures that have favourable effects on producers concerning technical efficiency. The results contributes to the creation of policies that would facilitate the achievement of the Agricultural Sector Transformation and Growth Strategy (ASTGS) goals of “increasing

agricultural output". The Big Four Agenda's component of food security will also be achieved when banana output is increased to its highest level. Through increased banana production and income earned by smallholder producers, the "no to poverty" and "pushing of hunger to zero" pillars in the sustainable development goals (SDGs) will be achieved. In addition, the study's results yielded valuable information on banana production technical efficiency and how it is affected by production, socioeconomic and institutional factors to the extension officers. The agricultural extension officers will be guided by the results in determining the most effective method of communicating and disseminating agricultural information to the producers in their pursuit to increase technical efficiency and encourage overall growth. The findings will also benefit both researchers and scholars since it will provide more detailed information on the production, socio-economic and institutional factors that affects technical efficiencies in production of banana. The smallholder banana producers from Kirinyaga County will benefit as they will have the ability to comprehend the production, socioeconomic as well as the institutional factors affecting technical efficiency and hence carry out successful farming.

1.6 Limitation of the Study

Availability of recorded data was a challenge as the banana producers had limited record of their production and therefore relied on recalling of information. A number of the respondents were unwilling to cooperate and give any information. This was fixed by finding other people who were ready to take part in the study survey and convincing them that the data collected from them was only intended for scholarly intent.

1.7 Scope of the Study

This study limited itself on smallholder banana producers within Kirinyaga Central Sub County which is the highest banana producing zone in Kirinyaga County. It focused on determining how technically efficient the smallholder banana producers in Kirinyaga were by establishing how land size, labour, planting materials, agrochemicals, age, gender, educational level, producers experience, household size, accessibility to credit, market accessibility, access to extension services and membership to groups factors affected technical efficiency.

1.8 Assumptions

The research made the assumption that the smallholder banana producers would cooperate and convey the information that is required to achieve the study's objectives. It was as well assumed that the findings would be representative and can be used to make inferences on the production, socio-economic as well as the institutional factors influencing technical efficiency in banana production. Existing level of technology for smallholder banana producers in Kirinyaga Central Sub County was assumed to be the same for all the producers.

1.9 Operational Definition of Terms

Inefficient	It is a situation whereby the real output of a producer falls short of the maximum possible output.
Institutional factors	They are structures set in society or the rules, norms and routines that guide producer's behavior. They include credit access, extension services, group membership and distance to market.
Production	is a measurement of how much output from agriculture is obtained from certain number of inputs.
Production factors	Are the inputs used in banana production and include land size, labour, planting materials and agrochemicals.
Production Frontier	Refers to the highest quantity of produce achieved from a particular input set with the available technology
Smallholder banana producer	is a producer who cultivates bananas on a plot of land that is not larger than two acres.
Socio-economic factors	These are the society and economic related factors that affect smallholder banana producers and they include age, gender, education, farming experience and household size that affects banana production technical efficiency.
Technical Efficiency	The capacity of a producer to produce a sufficient amount provided the resources and technologies at his or her disposal. It rates how well a producer integrates the available inputs to produce the greatest amount of produce.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Banana Production

One among the first cultivated agricultural crops in the world is the banana (Kamira *et al*., 2016). Globally, its production takes place in tropical nations with Brazil, China, Ecuador, India and the Philippines being the top producers (Shaibu *et al*., 2012). Development of the Banana subsector helps in the creation of employment opportunities, improves local economy and sustainable livelihood (Bhatta *et al*., 2023). Approximately 20% of global banana production was exported in the year 2021 and exporting countries earned foreign exchange revenues totaling to approximately 12,754,541 thousand USD (FAOSTAT, 2023). Banana is typically considered to be the fourth most popular food crop all over the world after wheat, maize and rice and is an important provider of employment for both on farm and off farm revenue generation within its main regions of cultivation. (Tumuhimbise and Talengera, 2018).

Banana is a highly well-known and popular crop and is accessible all year round (Mohiuddin *et al*., 2020). In addition, its consumption level is greater than that of any other crop around the world. Banana serve as a primary source of nutrition for millions of Africans from various ethnic groupings (Ochola *et al*., 2015). More than 20 million tonnes of banana are harvested each year in Eastern and Southern Africa, making up to 26% of global production (Joachim *et al*., 2018). It is the most renowned crop and usually used as dessert and the cooking type as a staple food (Eutycus, 2019). Producers on both large and small scale depend heavily on banana industry for earnings and sustenance (AFA, 2016). There have been fluctuations in banana production quantities and land area allocated to its production in Kenya for the years 2017-2021 (Table 1). This may be due to some factors including pests and diseases, limited access to quality disease-free planting materials, inaccessibility to extension services and agrochemicals as well as changing climatic conditions. The production volume rose from 1,856,662 tonnes in 2020 to 1,985,254 tonnes in 2021 which represents a 6.5% increase that was attributed to good rains in the main producing areas.

Table 1: Kenya's banana production

Period	2017	2018	2019	2020	2021
Area (Ha)	77,576	72,748	76,912	72,123	71,681
Yield (Tonnes)	1,434,163	1,414,177	1,715,768	1,856,662	1,985,254

Source: FAOSTAT (2020)

In Kirinyaga County, banana production has brought about more transformation in the community and it is one of the top most produced food crop (KNBS, 2018). It provides potential for income generation as well as the achievement of food security amongst smallholder producers. In Mt. Kenya region it provides income that helps cater for medical needs, household's educational costs, food purchases along with residence advancement projects (Mbaka *et al*., 2008; USAID, 2013). The county government has promoted adoption of new technologies in banana value chain for example tissue culture banana all to ensure efficiency in production (County government of Kirinyaga, 2021). The County government distributed 4,000 banana seedlings to the smallholder producers for on farm planting (County government of Kirinyaga, 2019). The county is one of Kenya's largest producers of banana as shown in Table 2.

Table 2: Production of bananas in selected counties in year 2019-2020

County	2019 Area (Ha)	Quantity (tonnes)	2020 Area (Ha)	Quantity (tonnes)
Meru	13,031	371,391	14,012	484,936
Murang'a	6,366	156,133	7,338	161,859
Kirinyaga	3,547	99,316	4,312	185,133
Taita Taveta	5,405	142,692	4,909	238,750
Tharaka Nithi	3,419	72,074	4,283	54,980
Kiambu	2,451	64,873	2,140	60,921
Kisii	8,342	178,132	6,019	119,662

Source: Horticulture Validated Report (2021)

2.2 Technical Efficiency of Banana Production

Measuring technical efficiencies assists in measuring the performance of different producers (Kassa and Demissie, 2019). Technically efficient producers are able to produce as much as possible given the resources and technology they have at their disposal (Shettima *et al*., 2015). Measuring technical efficiency requires taking into account a producer's output and other factors that have an impact on production

(Dessale, 2019). In practice, productive farms are those that operate along the frontier while ineffective farms are those that are beneath the production function frontier (Tirra *et al*., 2019). Furthermore, farms nearer to the production frontier are technically more efficient unlike farms farther away from the production frontier (Katungwe *et al*., 2017). Enhancing performance helps producers raise output with no extra inputs or technological innovations and hence they become technically efficient (Saavedra *et al*., 2017).

The technical efficiency levels of banana production in Kenya is varied across counties for example in Meru County, it was found that technical efficiency ranges from 34.89% to 98.96% % and the average technical efficiency score was at 68.52% (Eutycus, 2019). In addition, results approximated that 31% of producers in Meru produce banana at technical efficiency score above 70%. Further, approximately 96% of producers produce banana at above 50% technical efficiency levels while 4% of the producers operate on technical efficiency of 50% and below. The findings stated that poor usage of farm inputs and producer-specific characteristics were the causes of the lower levels of technical efficiency. These possibly included insufficient and no access to agricultural trainings, inaccessibility to extension related services, water access for irrigation as well as possession of land.

Banana cultivation in Central Tamil Nadu was examined for technical efficiencies. The outcomes demonstrated that the efficiency levels of *Yelakki* banana variety was ranging between 50% and 99% alongside 78% mean technical efficiency and the *Nendran* variety had varying levels of efficiencies between 51% and 94% with an average of 83% (Vinayagamoorthi *et al*., 2019). Further, *Poovan* variety had technical efficiencies ranging about 80% to 99% and 84% as the average technical efficiency. The findings further established that *Rasthali* variety had technical efficiencies varying in between 87% and 99% and a 96% average level of technical efficiency. In Kisii and Nyamira counties, Kenya, Omondi *et al*. (2020) looked at the influence of collective action involvement on technical efficiency among smallholder banana growers. Technical efficiency was determined to be 87% on average while producers in producer groups exhibited better average efficiency of 89% against technical efficiency of 86% for those who did not participate.

2.3 Constraints to Crop Production Technical Efficiency

Technical efficiency is the term used to describe how effectively certain inputs are integrated to achieve a particular result (Gaviglio *et al*., 2021). It is how best the supplied inputs are combined by the producer to produce the highest level of output feasible. In order to do this, either the yield from a given set of resources must be maximized or the resources needed to create a given level of production must be minimized. The low production technical efficiencies in agriculture is due to producers' incapacity to properly exploit the technologies at their disposal (Kumar *et al*., 2018). Wanjiku (2015) stated that the amount of land suitable for production of agricultural crops had decreased as a result of the rapid population expansion, substantial soil degradation and exacerbated subdivision of land, which negatively impacts production efficiency. Additionally, producers have found it challenging to boost efficiency through the utilization of more resources because of higher poverty levels coupled with the unavailability of inputs for production (Simwaka *et al*., 2013). Incidences of unavailability of the farming inputs like quality saplings and poor agriculture cash flow are some of the problems facing banana farming practices (Bhatta *et al*., 2023).

It has been reported that pests and diseases are among major constraints affecting the production of banana and efficiency levels as 73% of respondents indicated that Embu was the most affected and identified them as major challenges (Wahome *et al*., 2021). In addition, lack of planting materials is another constraint facing smallholder banana producers. Access to agrochemicals (fungicides, herbicides and pesticides) was also a challenge. Additionally, financial constraints, shortage of assets and inadequate infrastructure affect smallholder producers (Mwangi and Kariuki, 2015). It is particularly challenging to group producers into organizations that either produce or market, even amongst those that are aware of the advantages of doing so, due to insufficient contemporary extension services available to smallholder producers (Shiferaw *et al*., 2011).

Muthee *et al*. (2019) found that banana production technical efficiency in many parts of Kenya is affected by limited assistance from the government, absence of effective avenues for marketing and processing, weak infrastructure, high costs of inputs and poorly organized producer associations. Karienye and Karimi (2020) also noted that

small land sizes, insufficient water for irrigation, shortage of management expertise about banana, diseases and pests and low output hinder producers from benefiting from banana production. Availability of land for production has reduced because of continued growth in population, extensive soil degradation and the continued division of land which lowers production efficiencies (Wanjiku, 2015). Smallholder banana producers are also constrained by fluctuations in prices resulting from high banana output and a shortage of ripe banana storage facilities (Obaga and Mwaura, 2018).

2.4 Effects of Production Factors on Crop Production Technical Efficiency

2.4.1 Land Size

In cultivation of crops, land is a key farming component and its size and output are closely related (Taiy *et al*., 2017). It may be assumed that producers with big tracts of land will produce more. It is also possible that crop production in small farms tend to be more efficient than in large farms (Muyanga & Jayne, 2019). Besides, other studies indicate large farms as being more efficient than small farms (Key, 2018). The smallholder producers in the Southern Ethiopia's Konso District were examined for their technical efficiency in production of sorghum and land was an important agricultural input that increased the yield of sorghum (Gemeyida *et al*., 2019). In Trans Nzoia County, Barasa *et al*. (2019) examined the technical efficiencies among smallholder irish potato growers and results indicated that land wasn't an important factor in irish potato production technical efficiency. The findings by Ugbabe *et al*. (2017) established that the size of land and soybean production technical efficiency were negatively correlated.

The size of land had a positive effect on technical efficiency signifying that producers having large tracks of land tend to be more technically productive compared to those having smaller landholdings (Tenaye, 2020). Upon the assessment of the technical efficiency among smallholder growers' production of potatoes in Ethiopia, it was reported that land dedicated to potato production had positive effects and that the technical efficiency of irish potato production was determined by land size (Dube *et al*., 2018). Tolno *et al*. (2016) examined the factors that influence how efficiently smallholder producers in Guinea produce potatoes and reported that land under potato production affected potato production technical efficiency levels among smallholder

producers. Omondi *et al*. (2020) established that the size of banana farms had a positive effect on technical efficiency levels for those individuals who took part in the collective action as well as those who did not. In addition, the findings were that technical efficiency levels showed positive relations with increase in banana land size.

Land size had a positive coefficient to technical efficiency and the findings showed that a bigger chili plantation had a lesser technical efficiency as opposed to a smaller one in Thailand (Krasachat, 2023). Mwangi *et al*. (2020) found that producers who have small areas for farming are more technically efficient than those having huge portions of land allocated for tomato production in Kirinyaga. As reported by Dessale (2019), land size under wheat production affects production technical efficiency levels positively in Ethiopia implying that those producers doing production on large areas are less efficient than those producing on small pieces. Eshete & Alamirew (2023) analyzed the factors that affect how efficiently smallholder producers produce bread wheat and found that size of land negatively affected technical efficiency in production. Naomi (2018) argued that producers with big tracts of land are more unlikely to grow snow peas since majority of producers prefer to concentrate their efforts on smaller and more manageable plots of land.

Land fragmentation is a major problem in the rural areas management of land and in addition an obstacle in modern technology adoption, maintenance and construction of rural infrastructure and agricultural modernization (Balogun & Akinyemi, 2017). Khatiwada & Yadav (2022) found that smallholder producers' producing ginger in a large pieces of land are less technically efficient than those doing the production in very small areas. Ateka *et al*. (2018) found that land size was negative to technical efficiency in tea production in Bomet and Nyamira Counties. Hong and Yabe (2015) on the other hand discovered that the size of the land had no significant impact on the technical efficacy of tea production in Vietnam. According to the reviewed studies, land is a crucial component in crop production, but it is still unknown to what extent land affects technical efficiency levels of banana production in Kirinyaga County.

2.4.2 Labour

Production of crops requires a lot of labour hence the importance of it can't be overlooked. It has been reported in Meru, Kenya that the coefficient for labour was negative and does not affect banana production technical efficiency (Eutycus, 2019). Ugbagbe *et al*. (2017) determined technical efficiencies among soybean producers in Nigeria and found labour to be significant to production technical efficiency. In another study Chimai (2011) established that the technical efficiencies in the production of sorghum was as a result of using hired labour. Further it was noted that if households have little or no access to hired labor because it is not available at critical times such as weeding or is unaffordable, the household may face labor shortages leading to low technical efficiency in production. Eshete & Alamirew (2023) found that labour positively affected bread wheat production technical efficiency in Ethiopia. However, Nguyen-Thi-Lan *et al*. (2023) reported that an increase in labour use decreases technical efficiency in tea production.

Ateka *et al*. (2018) found that the value of the coefficient of labour was positive, indicating that as more labour was used to produce tea per unit area the more the association with an increase in technical efficiencies. Hired labour had favorable as well as considerable impact on sorghum production technical efficiency within Machakos and Makindu Districts from the research by Chepng'etich (2013). This suggests that families that employed hired labor were more effective when compared to those that relied solely on family labor in the sorghum production operations. The earlier investigations show the significances of labour in the cultivation of crops but the impact of labour on banana production technical efficiency in Kirinyaga Central Sub County isn't well understood.

2.4.3 Agrochemicals

In order to replenish depleted nutrients in the soil, fertilizer is crucial. Abubakar & Sule (2019) analyzed technical efficiencies in maize production within Niger state and results showed that fertilizers were essential component in maize production technical efficiency. According to Ntabakirabose (2017) use of planting fertilizers both the organic manure as well as synthetic fertilizer had significant relationship with maize production technical efficiencies. Omondi *et al*. (2020) also found that use of inorganic

fertilizer and organic manure have substantial impact on banana production technical efficiencies in Kisii and Nyamira Counties. Lema *et al*. (2022) reported that use of fertilizers had positive impact in increasing barley production technical efficiency in Ethiopia.

Eutycus (2019) found that fertilizer application positively affected the production of banana and that raising the amount of fertilizer used would also raise banana production technical efficiencies of producers in Meru. Abdullahi (2012) also found that fertilizer use was an important factor in production technical efficiency of rice in Niger. In another study Gemeyida *et al*. (2019) results were that urea and Diammonium Phosphate are essential elements in raising the levels of sorghum production efficiencies in Southern Ethiopia. Kalule, (2013) found agro-chemical use in Uganda was associated with low technical efficiency and that households applying agro-chemicals were 4% more likely to increase technical efficiencies than those not using agro-chemicals at all.

Low yields in farming are significantly influenced by diseases hence necessitates the need to use fungicides and agrochemicals. Wahome *et al.* (2021) noted that pests and diseases affect banana production efficiencies in Embu. They noted that constrained access to agrochemicals (fungicides, herbicides and pesticides) affects technical efficiency in banana production. In addition, Ebiowe (2016) recognized that diseases and pests are the major problems and efficiency constraining variables in regions cultivating banana. According to Abubakar and Sule (2019) agro-chemicals are significant in maize production and positively affects technical efficiency in Rijau, Niger state. Yegon *et al* (2015) noted that use of agrochemicals was significant in soybean production technical efficiency in Bomet District, Kenya. In assessing technical efficiency among smallholder producers, Barasa *et al*. (2019) found that fungicides had no discernible impact on raising of Irish potato production efficiencies in Trans Nzoia County. The above reviewed literature showed how agrochemicals affected various crops production but its effects on banana production technical efficiency in Kirinyaga Central Sub County wasn’t known.

2.4.4 Planting Materials

Ntabakirabose (2017) found that improved seed use positively influenced maize production technical efficiency in Rwanda showing that as greater amounts of better seeds were used, the level of maize production technical efficiency also increased. Mwangi *et al*. (2020) found that the kind of seed that had been used in production of tomato in Kirinyaga was significant and positively affected production technical efficiencies. Tasila *et al*. (2019) as well noticed that using better seeds had an impact on technical efficiency on rice production in Northern Ghana. Mukhtar *et al*. (2018) found that planting improved pearl millet seeds positively influenced production technical efficiency in Kano State, Nigeria. Abdul and Isgin (2016) discovered an adverse relationship between improved seeds and cassava production technical efficiency in Ghana.

Chepng'etich *et al.* (2015) in their analysis revealed that utilization of improved varieties of seeds was positive to technical efficiency yet wasn't necessarily important. Ateka *et al*. (2018) while analyzing the extent of technical efficiency and the factors that affect it in Kenya's Bomet and Nyamira counties found that using improved tea seeds was statistically insignificant in production technical efficiency. Further, the scores of technical efficiencies of the surveyed households were not significantly influenced by the type of tea cultivated. Additionally, Kiprono (2013) discovered that the tea variety was not a significant factor in the technical efficiency variance in Kenya's tea production. Planting material therefore is a significant factor in crop production

2.5 Effects of Socio-economic Factors on Crop Production Technical Efficiency

2.5.1 Age of Decision Maker

Narcisse (2017) found that a producer's age had a negative influence on technical efficiency indirectly insinuating that older producers oppose adopting new technologies and lack the physical and mental capacity to engage in farming activities effectively. As reported by Yegon *et al*. (2015), technically, elderly producers are less productive than younger ones in soybean production and therefore age was a significant factor in soybean production in Bomet, Kenya. In another study, Nchare (2007) also found that elderly producers are technically more inefficient than more youthful arabica coffee producers in Cameroon. Karani, (2013) also found that age positively and significantly

influenced technical efficiency in purple passion fruit production in Kenya. Richman (2010) also found that age influenced technical efficiency in cocoa production negatively.

Ofori-Appiah *et al*. (2022) noted that elderly producers in Ghana are more productive than their younger counterparts, hence there existed an association amongst the aged and technical efficiency of pineapple producers. Ambetsa *et al.* (2020) reported that a producers' age negatively affected technical efficiencies in the production of sugarcane in Malava, Kenya. Getahun and Geta (2017) noted that producers get more knowledgeable as they age and became more technically efficient in barley production in Ethiopia. Eutycus (2019) also found that age of a producer was significant and related positively to banana production technical efficiency in Meru. In Ethiopia, the household heads' age exhibited a negative relationship with low technical efficiency, suggesting that elderly producers were more productive compared to youthful producers (Tenaye, 2020).

2.5.2 Gender of Household Head

Household head gender is an essential aspect that affects the production efficiency in agriculture. Families headed by men were less effective in producing soybeans compared to families with female heads in Bomet District (Yegon *et al*., 2015). On the other hand, Otitoju and Arene (2010) discovered that families with men heads have high technical efficiencies than households headed by women in soy bean production in Nigeria. This might be explained by the roles which the household women and men in the household play. Considering female may have additional role in taking care of household members. The output that they produce while farming may not be shown in the efficiency model (Doss, 2018). Besides, accessing resources like credit and land can be differing with gender and so household head with the resources may show high technical efficiency (Gebre *et al*., 2021).

The findings by Ateka *et al*. (2018) were that the value of the coefficient for the family head's gender proved important, indicating that the technical efficiencies were higher for farms belonging to households with male heads as opposed to those with female heads. In another study carried out by Hong & Yabe (2015), homes with men heads

tend to be more technically efficient compared to those households led by women. The technical efficiency of households headed by men exceeds that of female headed families in Nigeria (Oyetunde & Olagunju, 2019). It has also been reported that gender influenced technical efficiencies of irish potato cultivation in Molo and noted that men were more efficient compared to women (Kamau *et al*., 2020). Kalule, (2013) however found that the family head's gender had no significant effects on banana production technical efficiency in Uganda. It is unclear, however, how gender influences the technical efficiency of banana cultivation in Kirinyaga County.

2.5.3. Education Level

Improving the education levels of producers improves efficiency (Gaviglio *et al*., 2021). According to Paltasingh & Goyari (2018) there is a relationship between education and management skillson the farm and that they affect technical efficiency. Education especially that of the farm heads enables them to be quick to access information, capture new production techniques besides understanding the natural environment changeable trends and use the input elements suitably to promote producer's technical efficiency (Vu *et al*., 2019). Sapkota *et al*. (2017) found that home heads having greater years of education seemed technically more efficient compared to their counter parts and was significant in maize production in Nepal.

The findings of Narcisse (2017) were that a household head's efficiency is increased in maize production with a rise in educational years in Rwanda. Lema *et al*. (2022) found that higher educational levels of barley producers increase technical efficiency levels among smallholders in North Shewa, Ethiopia. According to Krasachat (2023) the Education variable displayed a negative correlation with Chili Production technical efficiency in Thailand signifying the greater educated the producers are, the lesser the technical efficiencies as the producers maintain their old production practices. The education level of coffee producers was negatively related to lower technical efficiencies in Southwest Ethiopia (Tamirat & Tadele, 2023). Mairabo *et al*. (2023) on the other side reported that in Nigeria, soybean producers' technical inefficiency or efficiency was unaffected by their schooling.

The findings of Yegon *et al*. (2015) showed that technical efficiencies in the production of soybean was improved with raising educational levels of producers in Bomet, Kenya. Nchare (2007) of Cameroon as well noted that education has significant influence on technical efficiency in Arabic coffee production. Kalule, (2013) found the variable of post-secondary education as a dummy implying that household heads who had achieved highest level of education above secondary school were 4% more likely to reduce technical inefficiency than those households whose head had not gone beyond secondary education. An investigation on resource usage efficiency among Nigerian sugarcane growers was conducted by Sulaiman *et al*. (2015) and it was reported that those producers with higher levels of education quickly picked up new advanced technology and used it to produce greater yields.

Mukami (2018) reported a negative connection between technical efficiency in cultivation of snow peas and formal education within Nyandarua. Tukara & Ashindo (2019), in their examination of the factors influencing the level of technical efficiency of sesame cultivation in Nigeria, discovered that education had a positive and significant impact on technical efficiency. The findings indicated that higher levels of education are not preferred for Sesame cultivation since they lower technical efficiency. It has been reported that since producers who have greater education are more willing to use modern technology along with advances, education possesses a favourable effect on technical efficiencies (Khatiwada & Yadav, 2022). There is still an information gap regarding how education affects the technical efficiency of bananas in Kirinyaga County.

2.5.4 Farming Experience

Ambetsa *et al*. (2020) noted that farming experience and technical efficiency are positively correlated and was significant in the production of sugarcane in Malava. Farming experience may be linked to improved competence in agricultural production operations and hence increased efficiency. Mulwa *et al*. (2014) and Mburu *et al*. (2014) also found that there exists a good correlation between experience in farming and production technical efficiency amongst small scale maize producers in both Nakuru and Western Kenya Districts. Mukami (2018) found that the more efficient producers have more years of experience growing snow peas than the less effective ones. Those

producers who have taken more years in peas production have mastered the art of effectively combining limited resources and the given state of technology and therefore raising production efficiency levels. Krasachat (2023) found that experience negatively affect technical efficiency levels. This is possibly attributed to the reason that most skilled producers would rather depend only upon their own expertise and might become hesitant to seek out the guidance provided by the extension providers.

It was noted by Sapkota *et al*. (2017) that experiences by producers positively and significantly influenced production of maize seeds in Palpa District, Nepal. The findings by Ntabakirabose (2017) showed that farming experience display a strong impact and positive influence on technical efficiency and that maize growers having greater number of years of expertise displayed greater degrees of technical efficiency. Due to the inconclusive nature of the studies mentioned above, it is necessary to investigate the impact in Kirinyaga County before passing judgment about the impact farming experience has on technical efficiency in banana production.

2.5.5 Household Size

Household size is associated with technical efficiency, thus increase or decrease in household size affects the farming technical efficiency through the effect it has on household's labor endowments (Bagamba *et al*., 2007). With a larger household it means that they are able to become more technically efficient as they are able to carry out actions within time and hence are able to attain high output with less or same labor input. In developing countries, the household size is linked to the availability of family labor (Chimai, 2011). Household size may also affect technical efficiency negatively (Miriti *et al*., 2021). It is possible that with a large farm size, the expenditure of the producer may increase and make the household to incur more expenses making it hard for the farm to invest in farming as more resources are used thus reducing the levels of production hence a negative effect on technical efficiency.

Tamirat & Tadele (2023) found that coffee producers with positive technical efficiency levels had significantly larger family sizes. Mwangi *et al*. (2020) found that technical efficiency in tomato production was significantly and positively influenced by household size and the findings implied that with an expanding family, smallholder

tomato producers' technical efficiency in Kirinyaga increased. Ayerh (2015) discovered that the size of the household had favourable effects with regards to technical efficiencies in tomato production in Ghana. On the contrary, Folorunso & Adenuga (2013) claimed that labour provided by family members is typically linked to inefficiencies hence expanding it in the farms lowers the technical efficiency levels. Additionally, Ayuko *et al.* (2023) reported that household size was negatively significant on the degree of technical efficiency amongst fodder producers in Kenya.

Eutycus (2019) reported that household size and technical efficiency are adversely correlated, with a rise in household's size being accompanied by decline in the technical efficiency. In another study Chepng'etich (2013) noted that the size of the household negatively affected technical efficiency indicating that sorghum producers became less technically efficient as family size increased. In Zambia's sorghum production, the size of the household had a detrimental effect on the technical efficiency levels (Chimai, 2011). Ullah *et al.* (2017) found that the household size variable had an adverse consequence on technical efficiencies meaning that smaller families don't seem to be as efficient as bigger ones. Based on these evaluations, it cannot be assumed that household size affects the levels of technical efficiencies among small scale banana growers; therefore, the study aims to further enhance our knowledge of its impact in Kirinyaga County.

2.6 Effects of Institutional Factors on Crop Production Technical Efficiency

2.6.1 Access to Credit

Credit access is a crucial source of funding that helps smallholder producers to make on-time purchases of agricultural inputs thereby enhancing farm technical efficiencies. It makes it possible for producers to adopt new technology and methods by managing their financial limitations (Ike and Inoni, 2006). Credit accessibility was discovered to have a negative coefficient by Oyetunde & Olagunju (2019), indicating that families with access to credit resources exhibit more technical efficiencies. It was reported in Zambia that maize producers' technical efficiency and accessibility to loans are negatively correlated (Ng'ombe and Kalinda, 2015). Sabroso & Tamayo (2022) found that access to credit had a negative coefficient and was negatively correlated with

technical efficiency revealing that credit accessibility influences efficiency levels negatively.

Ofori-Appiah *et al*. (2022) found that accessibility to credit does not influence smallholder pineapple producers' technical efficiency. Ayuko *et al*. (2023) found credit access to be positively significant to fodder production technical efficiency in Homabay, Kenya. Mairabo *et al*. (2023) noted that access to financial services positively affected technical efficiency in Nigeria implying that as loan accessibility increased, production efficiency of soybeans declines. Ntabakirabose (2017) found that accessibility to credit had positive influence on maize production technical efficiencies in Rwanda and that a household's technical efficiency in maize production increased by 4.5% for every unit increase in their access to credit. Eutycus (2019) reported that credit accessibility by smallholder banana producers increases technical efficiency. Further, it is possible that credit availability addresses the issue of lack of capital mostly amongst producers who face financial difficulties to purchase manures and pay hired laborers.

Accessibility to credit by a producer positively influenced efficiency in coffee production in Kiambu District, Kenya (Runo, 2009). Sapkota *et al*. (2017) concluded that credit accessibility had positive effect (2.67%) on maize seed production technical efficiency. Asfaw (2021) while analyzing technical efficiency among smallholder tomato producers, showed that tomato producers' technical efficiency is positively impacted by access to financing in Ethiopia. Tenaye (2020) reported that credit usage had a significant and positive impact on low technical efficiencies in Ethiopia indicating that those producers with access to credit are less efficient compared to non-borrower producers. Idiong (2007) and Olarinde (2011) established that credit access significantly influenced technical efficiency on swamp rice and maize production in Nigeria, respectively.

2.6.2 Access to Extension Services

The intermediary assistance between researchers and agriculturalists are extension services. The agricultural extension agents provide producers with research-based knowledge and assist them in putting best practices into effect on their farms (Kahan,

2007). Many obstacles still exist for agricultural extension programs in developing nations that make it difficult to provide smallholders with high-quality services and information (Babu *et al*. (2015). In addition, problems such as the widespread distribution of poor producers, the diversity of producers' information demands, and the low financial support for extension agencies have been highlighted. It is possible that technical efficiency will be affected by the availability or unavailability of extension services and according to Ofori-Appiah *et al*. (2022) frequent visits by extension people enhanced technical efficiencies in pineapple production in Ghana.

Mairabo *et al*. (2023) found that extension visit was positively significant with technical efficiency implying that increase in the number of extension contacts reduces efficiency in soybean production. Sapkota *et al*. (2017) noted that if producers had the accessibility to the extension programs, their technical efficiencies in maize seed cultivation would improve by 6.62% in Nepal. Ntabakirabose (2017) found that a higher degree of technical efficiency was demonstrated by maize producers who used extension services compared to those who did not. Naomi (2018) reported that technical efficiency and accessibility to extension services among snow pea growers are positively correlated. The level of technical efficiency in production of barley increases with accessibility to extension services (Lema *et al*., 2022). The findings of Kamau *et al*. (2020) established that technical efficiency of Irish potato production was positively impacted by extension services in Molo.

The coefficient of extension services demonstrated a favourable impact on the technical efficiency levels, indicating those growers who got additional technical education, trainings and guidance provided by outreach organizations frequently display greater levels of farming efficiency (Ullah *et al.*, 2017). According to Tenaye (2020) technical inefficiency was negatively impacted by access to extension services. This implied that those producers who received extension service from extension officers had higher levels of efficiencies. Accessibility to the extension services may have favourable or negative effects in agricultural production efficiency, although this is unclear in Kirinyaga County especially on banana.

2.6.3 Group Membership

Membership to a group may influence access to adequate inputs and facilities in banana production and therefore affect the smallholder producers' technical efficiencies (Nyamamba *et al*., 2020). Joining a producers' organization was found to be significant and favourably influenced fodder production in Homabay (Ayuko *et al*., 2023). Mukami (2018) established group membership and efficiency are positively correlated since group membership helps producers reduce inefficiency through increased bargaining power for their goods, large input purchases, and the advantages of economies of scale. It is possible that in a group, it is simpler to share current information. Karani (2013) found that affiliation to a producers group had a positively influenced technical efficiency in passion fruit production technical efficiency in Embu County. The findings were that there was a positive chance that a producer would boost technical production efficiency if they belonged to the purple passion fruit group.

Omondi *et al*. (2020) found that producers who took part in groups had greater average technical efficiency levels (89%) compared to those who did not participate in collective action activities (86%). Khatiwada & Yadav (2022) found that ginger producers who have association in groups are technically more efficient than those who are not members. According to Nyagaka *et al*. (2011) becoming a part of producer groups or community organizations offers a channel for the dissemination of knowledge as well as utilizing innovation through extension agents or even fellow members leading to gains in output hence improvements in production technical efficiencies. In Kirinyaga Central Sub County, the impact of membership to producer groups on technical efficiency in relation to smallholder banana producers is still not known.

2.6.4 Market Access

The more distant the producing location is from the market, the more difficult it is to operate the farm, which results in low production. Mamo *et al*. (2018) established that the distance of a farm from the market impacts its technical efficiency, which meant that farms that are closer to the market are handled more technically efficient than those that are far away. Also, in a study carried out on avocado producer's access to export markets, the findings showed that accessibility to market had influence on the producers' technical efficiencies (Amare *et al*., 2019). Producer access to export market

may impact the smallholders' efficiency as it affects the labour market, sales prices, farm output and earnings in the country as a whole. Karani (2013) found that there were negative effects of access to market on technical efficiency in Uasin Gishu and Embu Counties. According to the findings, purple passion fruit producers having limited access to market are less technically efficient; that is, the further away they are from the market, the more limited their access is.

Ntabakirabose (2017) found that the maize farms' technical efficiency in Rwanda was negatively impacted by the distance to the market. Wudineh & Endrias (2016) while assessing efficiency in the production of wheat and the factors that affect it in Ethiopia proved that most producers were not technically efficient and how far they are located from all-weather roads negatively affected production technical efficiencies. Bagamba *et al*. (2007) found the distance to the nearest market having unfavourable effects on the level of technical efficiency among Uganda's small-scale banana growers. They noticed that households engaged in banana farming were more technically efficient when they were close to the market than when they were farther away.

2.7 Theoretical Framework: Production Theory

The neoclassical theory of production by Robert Solow and Trevor Swan 1956 served as the foundation for this study's theoretical framework (Dimand & Spencer, 2009). The economic model determined the relationship between various factors and the output for banana production in Kirinyaga County using the production function model. Mitra and Yunus (2018) indicated that the production function model can be able to hold different input modeling and is efficient in management of correlation, heteroscedasticity and multicollinearity. Production is considered as the manner in which inputs are transformed into outputs and this may take different methods like changing in place or form (Mukami, 2018). Production as a concept classifies inputs as raw materials, capital, technology, land, labour and time (Nickolas, 2021). Output is considered as the end result of the production process which are the goods and services that are derived from the production process.

The production function is employed for describing the interaction among inputs and outputs and the two can be formulated in numerical manner. The production function

is able to illustrate this key concept of production theory. It is able to link input usage and output attainable level (Rekhi, 2022). Herein, technical efficiency was realized when a producer produced highest amount of yields from the given inputs and was also subjected to the existing level of technology (Mukami, 2018). The production function model was mathematically represented as:

$$Q = f(Ld, L, K, M, T, t) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (i)$$

Where Q = output, Ld =land and building, L=labour, *K*=capital, *M*=materials, *T*=technology and *t*=time.

The function would be as follows if the number of inputs were reduced to two: capital and labor:

$$Q = f(K, L) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (ii)$$

Where Q = output, *K*= capital and L= Labour. *K* and L need to increase in order for Q to rise, all other factors constant. The farm may enhance its productivity depending on the time frame either short or long term. It disclosed if the farm is technically efficient or inefficient by the level of production of output from the input employed in the course of production.

Most often, a production function is utilized to illustrate the technical connection among inputs and yields. The production frontier denotes maximum yields that may be achieved from various input mixtures (Coelli *et al*., 2005). The classical production frontier is shown as follows, supposing a single output:

$$y = f(x_i) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (iii)$$

Where y is the yields and $x_i = x_1, x_2, x_3, \ldots, x_n$ is a vector of inputs utilized in the production of banana. A production frontier provides a benchmark for measuring technical efficiency. The farms that operate along the frontier are considered to be efficient, but those who produce beneath the frontier are considered to be less efficient (Coelli *et al.*, 2005).

2.8 Empirical Review of Model

To measure technical efficiency in crop production among producers, either nonparametric or parametric approaches can be used. Econometric modeling of the production processes is a component of parametric techniques and on the distribution of the efficiency terms and the production function's functional form, various presumptions are made first. The technique entails defining as well as approximating a parametric production function that represents the greatest technology currently in existence (Coelli *et al*., 2002). Non-parametric techniques uses mathematical programming techniques to assess the relative technical efficiency of Decision-Making Units (DMUs).

Most frequently used nonparametric approach is Data Envelope Analysis (DEA), as it compares input and output combinations based on available data only (Ndirangu *et al*., 2017). It is founded on technical efficiency measures suggested by Farrell (1957) and Debreu (1951) "without any assumption to a functional relationship between outputs and inputs, empirical observations of outputs and inputs build a linear function. The linear programming DEA model maximizes output from an input unit, determining the best frontier. DEA approach assumes there are no outliers in the data, measurement error and random noise thus testing a hypothesis using DEA is impossible due to uncertainty in parameters estimation (Ndirangu *et al*., 2017; Adanguidi, 2021).

The widely utilized parametric approach is called the stochastic frontier approach (SFA). It involves production function estimation approximation with an already established function (Meeusen and Van, 1977; Aigner *et al*., 1977). The SFA function comprises three components: inefficiency error, measurement error and deterministic production function (Abdul & Isgin, 2016). Technical efficiency is then determined using maximum likelihood estimation method (Benedetti & Zucaro 2019). When compared to the ordinary least square method, the use of the SFA is more efficient as it uses a maximum likelihood estimation procedure (Weldegiorgis *et al*., 2018). They are also used in efficiency studies, especially if results are likely to be affected by factors beyond decision-making unit control thus it accounts for both measurement and inefficiency errors (Okunyama *et al*., 2017).

In Kirinyaga Central Sub County, banana production was likely to be affected by factors beyond producers' control, such as changes in climatic conditions and government policies. Therefore, SFA helped in capturing errors that could arise during the study. The two types of SFA most frequently employed are the Trans-log production and Cobb-Douglas. In this study, the Cobb-Douglas form of SFA was used based on its merited application while determining factors affecting technical efficiencies in the production of agricultural crops (Kamau *et al*., 2020; Mairabo *et al*., 2023; Ayuko *et al*., 2023; Omondi *et al*., 2020).

2.9 Conceptual Framework

The conceptual framework identifies both dependent and independent variables that will be investigated. The independent variables in the study were production, socio-economic and institutional while the dependent variable was technical efficiency and alongside are the intervening variables (Figure 1). Land size, labour, agrochemicals and planting materials which are the main production factors used in banana production may positively or negatively affect the level of banana production technical efficiency. Proper allocation of these characteristics may lead to improved technical efficiencies in banana production. It would therefore lead to increased output, producers' income levels and welfare.

Maximum banana production depends not only on the production factors but also on how producers combines the available resources. Socioeconomic factors considered in the study were age of the decision maker in banana production, household head gender, years of experience in banana farming, education level and household size. These factors affect the levels of technical efficiency crop production (Eutycus, 2019; Vinayagamoorthi *et al*., 2019). Institutional factors included variables such as accessibility to credit and credit use, extension service availability, distance to banana market and membership to banana producers' groups. Group membership provides producers with new ideas for promoting efficient resource use. Credit access provides smallholder producers with capital to cater for production costs which includes payments to hired labourers and purchase of production inputs. Access to extension services assists producers in adopting improved farming methods and thus more output, which fetches high market prices. Banana market access lowers transaction costs

incurred by the producers which in return motivates more producers to engage in production as a result of high returns.

The intervening variables included in this study were government policies and climatic factors. Certain clauses and policies set by government may affect banana production technical efficiency. Climatic factors such as drought and rainfall affects producers' technical efficiency level as they exogenously affect the day-to-day producers' farming operations. A producer is deemed to be technically efficient if he/she produces maximum output from minimum inputs. Attainment of highest levels of technical efficiency in banana production by a producer increases their income and achieves food security for the economy as a whole.

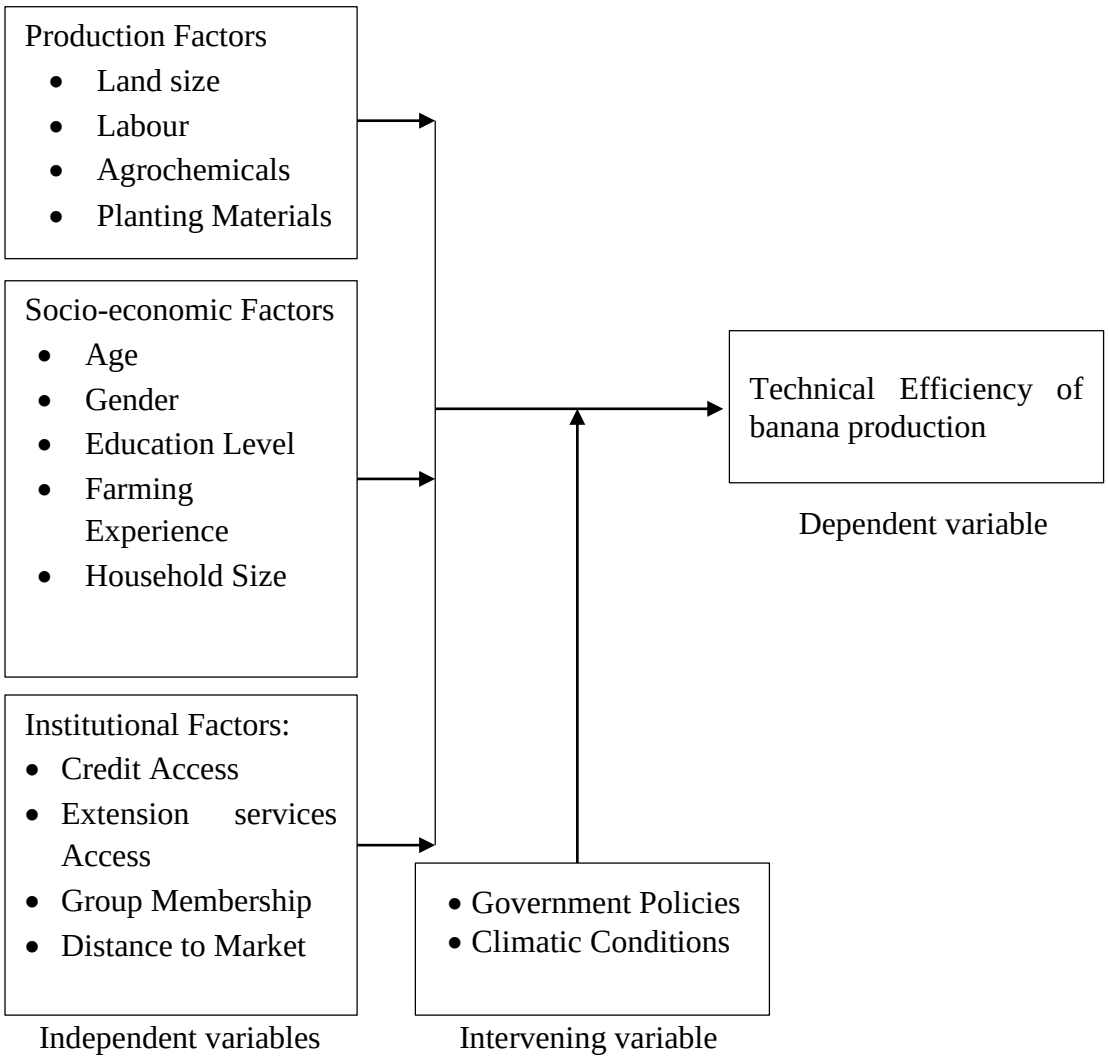

Figure 1 Conceptual Framework

CHAPTER THREE
METHODOLOGY

3.1 Study Area

The study was carried out between November and December 2022 in Kirinyaga Central Sub County, Kirinyaga County within Mt. Kenya region (Figure 2). Kirinyaga County is bordered to the North and West by Nyeri County, to the West by Murang'a County and to the East and South by Embu County (County Government of Kirinyaga, 2020). The County covers a total surface area of approximately 1,478.1 kilometer squared. Kirinyaga Central Sub County is amongst the five sub counties in Kirinyaga County. The Sub County's overall land area is approximately 173.6 square kilometers and a population of 122,740 (County Government of Kirinyaga, 2020). The Sub County is organized into four wards: Mutira, Kanyekiini, Kerugoya and Inoi. The study area experiences bimodal rainfall, having prolonged precipitation through March until May and short rainfall throughout October into December, with amounts varying from 1,212 mm to 2,146 mm (GoK, 2018). The range of temperatures is 8.1 °C to 30.3 °C on average. Agricultural production is the major source of earning for most of the producers (70%) who are smallholders (MOA, 2011). In addition, 87% of the county's population relies on agriculture for their primary source of earnings making it the most significant activity. Agriculture accounts for approximately 72% of the incomes received by households and banana is among the major crops grown (County government of Kirinyaga, 2019).

3.2 Research Design

This study used a cross sectional research design. The design made it possible to collect quantitative data on inputs as well as outputs in one period in the production year 2022. The design also permitted the use of both quantitative and qualitative data analysis techniques. This design in addition helped in the description of production, socioeconomic and institutional factors affecting smallholder banana producers in Kirinyaga Central Sub County.

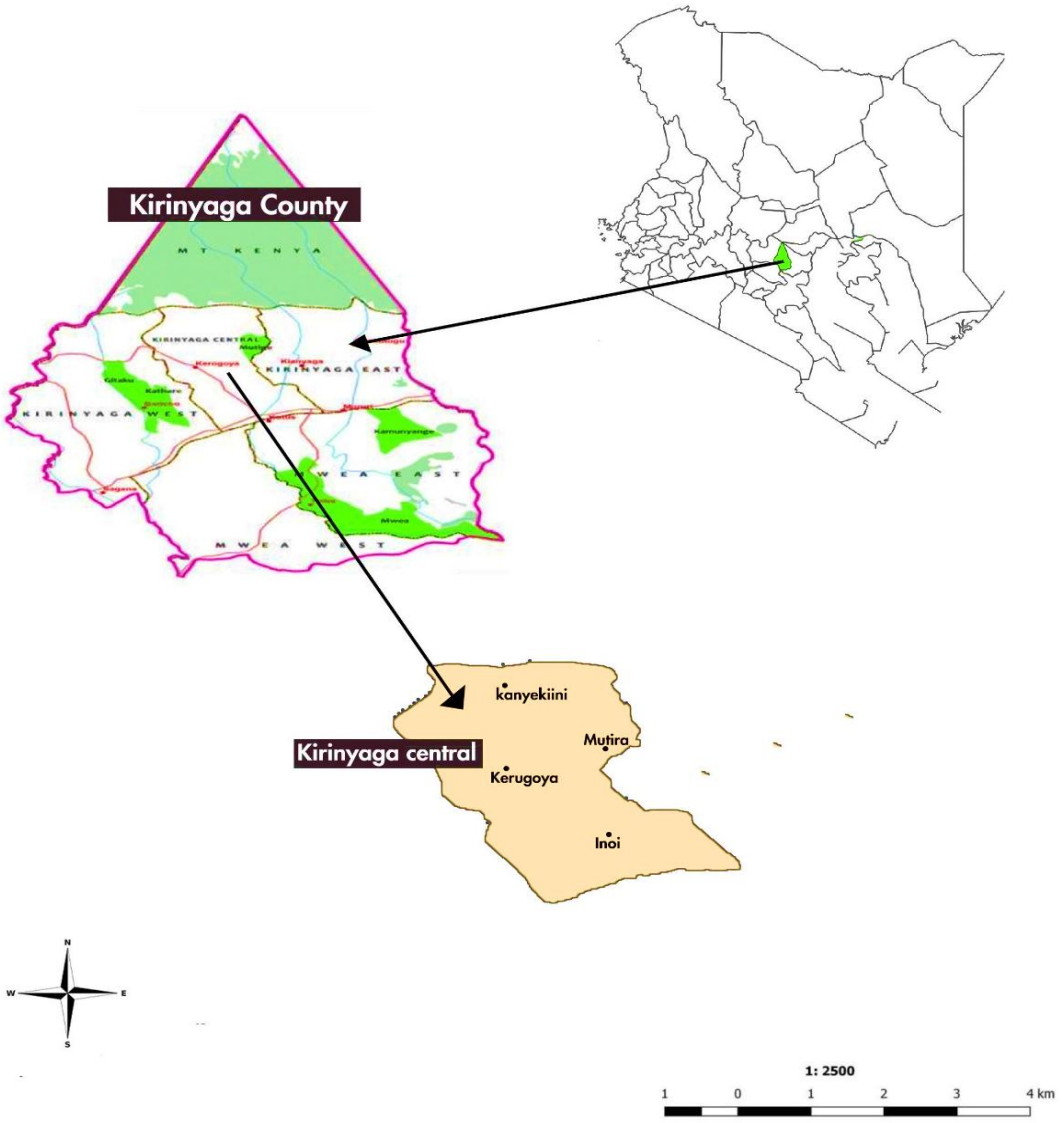

Figure 2: Map of the Study Area

Source: Geocurrent (2016)

3.3 Target Population

This study concentrated on smallholder banana producers in Kirinyaga Central Sub County of Kirinyaga County. According to unpublished Ministry of Agriculture Kirinyaga Central Sub County (2022) data, an estimated total smallholder banana producers are 24,440 and they formed the target population.

3.4 Sample Size

Sample size of the smallholder banana producers was drawn from the 24,440 households. Smallholder banana producer research sample size was computed as in Daniel and Cross (2013) and was presented in equation (*iv*)

$$n = \frac{[N\, z^2 p(1-p)]}{[(N-1)d^2 + z^2 p(1-p)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

given that *n* is the sample size and *N* is the size of the entire population., *z* is equal to 1.96 which is the tabulated *Z* value for 95% confidence level, *p* is the approximate percentage of population included (50%) and *d* equals to the error limit (5%)

$$n = \frac{[24{,}440\text{x}\ 1.96^2\text{x}0.5(1-0.5)]}{[(24{,}440-1)0.05^2 + 1.96^2\text{x}0.5(1-0.5)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (v)$$ = 402 smallholder banana producers

3.5 Sampling Procedure

In order to choose the producers who would make up the sample, the study used a multistage sampling technique. During the first stage, Kirinyaga Central Sub County was purposively selected from the five Sub-Counties and then four wards were randomly selected. In the second stage, villages from the selected wards were identified randomly. Lastly, a list of smallholder banana producers from the selected villages was generated with the support of the local administrative leaders and the ministry of agriculture extension officers to aid in the random selection of the producers to be interviewed. The samples were allocated to each ward based on proportionate random sampling, as illustrated in Table 3.

Table 3: Sample size for each of the ward

Ward	Population of smallholder banana producers	Sample size
Mutira	7,810	128
Kerugoya	4,436	73
Kanyekiini	6,520	107
Inoi	5,674	94
Total	24,440	402

Source: Ministry of Agriculture Kirinyaga Central Sub County (unpublished reports, 2022)

3.6 Research Instrument

To achieve the goals of this study, information was collected using questionnaires (Appendix 2) completed by smallholder banana producers within the area of study. Part A of the questionnaire covered smallholder banana producers' Socio-economic information, part B the information on production factors and part C the institutional factors. The information on banana production was mainly for the production year 2022. The respondent was either the heads of households or the person who makes decisions for the family.

3.7 Pre-test

The pretesting of the questionnaire was carried out in October 2022 in Mwea constituency, Nyangati Ward that possesses comparable qualities with the study area. A sum of 40 smallholder producers that represented 10% of the overall sample size were utilized. During this stage, examination of content reliability and validity was done to confirm if the questionnaire contained every necessary information.

3.7.1 Validity

To find pertinent questions to be included in the questionnaire, an exhaustive literature review was conducted. The questionnaire utilized in this study was validated with assistance from the academic supervisors and subject matter experts in banana production who included the Ministry of Agriculture extension officers.

3.7.2 Reliability

A reliability test was performed using the results from pilot study and with the guidance of supervisors. The Cronbach Alpha test was utilized to conduct a reliability investigation. The Alpha value was $\alpha = 0.757$ (Table 4). George and Mallery (2003) provided the following rule of thumb: if $\alpha > 0.9$ – excellent, $\alpha > 0.8$ – good, $\alpha > 0.7$ – acceptable, $\alpha = 0.6$ – questionable, $\alpha = 0.5$ – poor and $\alpha < 0.5$ unacceptable. Therefore, since the alpha coefficient (0.757) was greater than 0.7, the instrument was reliable for use in the study.

Table 4: Results of the reliability analysis using the Cronbach Alpha

Variable	Value
Average interim covariance	0.027
Number of items in the scale	19
Scale reliability coefficient	0.757

3.8 Data Collection

The study made use of first-hand information that was gathered from smallholder banana producers using structured questionnaires that were given to the respondents selected using simple random sampling (Appendix 2). Data was collected on inputs such as land, labour, agrochemicals and planting materials. In addition, information on socio-economic factors influencing producers' production included age of producer, gender, experience in banana production, level of education and household size was collected. Institutional information included data on group membership, extension services, market access and access to credit.

3.9 Data Analysis

Data analysis was performed after collection of data and coding. The data was then examined using Statistical Packages for Social Sciences (SPSS) version 25 and Stata version 17 was used as a computerized data analysis package for detailed analysis of the study variables. SPSS carried out frequency analysis and descriptive statistics. The maximum likelihood estimation technique was used to estimate the stochastic production function based on the Cobb Douglas functional form. The projected efficiency ratings were further modelled against the chosen production, socio-economic and institutional factors using Stochastic model to find out the factors that affects technical efficiency. Descriptive statistics, such as standard deviations, frequencies, percentages and means were utilized to present and summarize data collected from smallholder banana producers who participated in the interviews.

3.9.1 To Determine the level of Technical Efficiency and Production Factors influencing Smallholder Banana Producers Technical Efficiency in Kirinyaga Central Sub-County, Kenya

In the context of the Cobb-Douglas production function, this study employed the stochastic frontier model in identifying the level of technical efficiency and production

variables. The stochastic frontier model was defined in accordance with the models of Battese (1992) and Coelli (1995) as below:

$$Y_i = f(X_i; \beta) \exp(V_i - U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .. (vi)$$

where i = 1, 2… 402 producerr, Y_i is banana yield of the i^th^ producer, $f(X_i\ ;\ \beta)$ is an appropriate Cobb Douglas production function, X_i is a vector of the quantities of farm inputs used in banana production, β is a vector of parameters to be estimated, V_i captures measurement errors while U_i represents the technical inefficiency model. Under the assumption that $(X_i\ ;\ \beta)$ utilizes the log linear Cobb-Douglas form equation, then equation (vi) can be expressed as;

$$lnY_i = \beta_0 + \beta_i lnX_i + V_i - U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (vii)$$

where lnY_i represents natural logarithms of banana output for 402 smallholder banana producers, β_0 is a constant which represents the intercept of production function, β_i is a vector of parameters to be estimated, V_i is the random error that has a mean of zero and is related to uncontrolled variables like measurement error and climatic conditions that are beyond of the control of producers, U_i is the inefficiency which is sometimes called the one-sided error term. The following was the specification of the Cobb Douglas production function for the banana producers in the study area:

$$lnY_i = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + V_i - U_i \ldots\ldots\ldots\ldots (viii)$$

where, ln = is the natural logarithm, Y_i is the output of banana by the i^th^ producer, β_0 is a constant which represents the intercept of production function, $\beta_1 \ldots \beta_4$ are unknown scalar parameters to be estimated, X_1 is labour used (Man-days), X_2 is manure quantity (wheelbarrow), X_3 is land size under banana production (acre), X_4 is planting materials (suckers), Y_1= total Quantity of banana (kg), βi= Parameter to be estimated, V_1= are random variables which are assumed to be independent of U identical and normally distributed with zero mean and constant variance N (0, δ_v^2), U_i= it represents production technical inefficiency.

Technical efficiency of the banana producers is defined to be the ratio of observed output (Y_i) to the corresponding frontier output (Y_i *) using the existing technology and so the technical efficiency of the producers is denoted by;

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{exp(\beta X_i + V_i - \cup_i)}{\exp(\beta X_i + V_i)} = \exp(-\cup_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ix)$$

where, TE_i= Technical Efficiency, Y_i=observed banana production level, Y_i * = predicted level of banana production. The producers' level of technical efficiency is expressed as a value ranging from zero to one (Battese & Coelli, 1995). A producer who has a value of one is considered to be technically efficient and zero totally inefficient producer. The likely expectations of the effects of production factors was as shown in Table 5.

Table 5: Description of the production factors and their expected signs

Variable Production Factors	Variable Description	Measurement	Expected Sign
Land	Land size allocated for banana farming	Acres	+/-
Labour	Amount of man hours	Hours	+
Planting Materials	Banana seed used	Suckers	+
Agrochemicals	Quantity of fertilizer and fungicides used in the farm	Kgs	+

3.9.2 Socio-Economic and Institutional Factors Affecting Technical Efficiency for the Smallholder Banana Producers in Kirinyaga Central Sub-County, Kenya

The study employed the Stochastic frontier model in investigating the impact of socio-economic and institutional variables on technical efficiency in banana production. The model was utilized to conduct a regression analysis using the efficiency scores as the dependent variable and socio-economic and institutional variables as the independent variables. The connection between socio-economic variables, institutional variables and technical efficiency were analyzed using stochastic frontier model and was applied as below:

$$Y_i^* = X_i'\beta + \cup_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (x)$$

$$Y_i = Y_i^* \; if \; Y_i^* < 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xi)$$

Where: $U_i \sim$ N $(0,\sigma^2)$ and β are vectors of explanatory variables and unknown parameters respectively. Y_i * is a latent variable and Y_i is a technical efficiency score and U_i is the error term.

The stochastic frontier model used in the analysis was as in equation (*xii*) below:

$$TE_i = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_4 + \cdots + \delta_9 X_9 + \omega \ldots\ldots\ldots\ldots (xii)$$

where, TE_i= technical efficiency, δ_0 is the intercept of the function while δ_1, δ_2 , … δ_9 are unknown scalar parameters to be assessed and X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, are age, gender, education, farming experience, household size, credit access, access to extension services, group membership and access to market. The ω is the error term which is presumed to be normally distributed. The likely expectations of the effects of socioeconomic and institutional factors was as shown in Table 6 and Table 7, respectively.

Table 6: Description of the socioeconomic factors and their expected signs

Variable Socioeconomic Factors	Variable Description	Measurement	Expected Sign
Age	Age of Respondent	Year	+/-
Gender	Gender of Respondent	Dummy 1=Male,0=Otherwise	+
Farming Experience	Banana farming experience	Years	+
Education Level	Education level of respondent	Years	+
Household Size	Persons per household	Person	+

Table 7: Description of the institutional factors and their expected signs

Variable Institutional Factors	Variable Description	Measurement	Expected Sign
Access to Credit	Credit	Dummy 1=Yes,0=Otherwise	+
Access to Extension	Extension Service	Dummy 1=Yes,0=Otherwise	+
Group Association/ Membership	Producer group	Dummy 1=Yes,0=Otherwise	+
Access to Market	Distance to Market	Kilometers	+

3.10 Ethical Considerations

High standards of integrity were upheld throughout the study to guarantee the privacy and confidentiality of the data provided by respondents. Respondents were provided with an introduction to the study letter (Appendix 1) explaining aim of the research as well as its goals. Conscious approval was sought from producers. For individuals who were willing to engage in the survey, the study made sure that the responses of the respondents were anonymous and confidential. The study's conduct met the institutional ethical standards of Chuka University (Appendix 4). The National Commission for Science, Technology, and Innovation also awarded an authorization for research for the purpose of allowing the collection of data and information for this study (Appendix 3). Research authorization letters were also acquired from Kirinyaga County Commissioner and County Director of Education (Appendix 5 and Appendix 6, respectively)

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Response Rate

The response from this study revealed that the sampled smallholder banana producers accepted to be interviewed, therefore, the response rate was 100% (Table 8). This response rate was attained by using face to face interview. This is acceptable and is consistent with Booker *et al*. (2021) who noted that a response rate of 80% or more is considered excellent.

Table 8: Response rate of the respondents

Ward	Sample Size	Achieved Sample Size	Percent
Mutira	128	95	23.63
Kerugoya	73	104	25.87
Kanyekiini	107	112	27.86
Inoi	94	91	22.64
Total	402	402	100.00

4.2 Characterization of Banana Production Factors

4.2.1 Land Size and Ownership

The average total land owned by producers was 2 acres varying in size from 0.24 acres at the lowest to 7 acres at the largest. According to the findings of this study, the average size of land under banana production was about 0.4 acres with some smallholder producers having farms as small as 0.1 acres and others as large as 5 acres (Table 9). During this study, it was observed that banana production faced competition from other alternative farming activities. In addition, due to small land size available producers may have to use land in a technically efficient manner. The findings by this study are consistent to those reported by Omondi *et al*. (2020), that a large proportion of producers cultivated banana in plots between 0.03 acres and 0.79 acres.

Table 9: Land size among sampled banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Total land Area	402	2.003	1.183	0.24	7
Land Size under banana production	402	0.429	0.253	0.1	5

The findings on land ownership system showed that 96.27% of the respondents are landowners with title deeds, whereas just 3.73% own land without title deeds (Table 10). The kinds of improvements a producer adopts on a land is determined by the land ownership structure, which is a crucial factor in agricultural production. It is possible that producers who own the land they work on will put additional resources into the operation thereby increasing output. This study's findings are in agreement with those by Eutycus (2019) who found that 88% of banana producers in Meru possessed the parcels of land where the bananas were grown and 12% did not. Kamau *et al*. (2020) also established that majority of irish potato producers in Molo (48.33%) owned land with title deeds. The findings of this study contradict Kristof (2022) who established that majority of the maize growers in Kavango East Region, Namibia did not own the land they farmed on.

Table 10: Land ownership among smallholder banana producers

Land Title Deed	Frequency	Percent
Yes	387	96.27
No	15	3.73
Total	402	100

4.2.2 Labour

Labour related the number of individuals who worked on the farm throughout entire year that bananas were produced and was measured in man days. This study's findings indicated that the average total amount of labour was 10 man days every year ranging from 7 to 14 man days. Some producers depended on family labour which averaged at 6 man-days ranging from 1 to 12 man-days while others supplemented family labour with paid labour. Average hired labour was 4 man days with a lowest of 2 and up to of 10 man days (Table 11). The findings of this study contradicted those of Eutycus (2019) who found the average labour used in banana production was 108.8 man days per year in Meru. This study's findings coincide with Kamau *et al*. (2020) who found average labour of 7 man-days used in irish potato production. The study results show that family labour is the most used type of labour while hired labour is the least used. The findings are in agreement with those of Omache (2016) who found that hired labour was the least used in Kiambu, Kenya.

Table 11: Labour input of the sampled banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Family labour	402	6.493	2.867	1	12
Hired Labour	402	3.833	2.155	2	10
Total Labour	402	10.336	2.128	7	14

4.2.3 Agrochemicals

The study aimed to determine the use of agrochemicals during banana production. According to the findings, majority of banana producers (99.5%) used manure during planting, 7.21% used planting fertilizer and 0.25% used top dressing fertilizer. The average amount for manure used in banana production was 200.68 wheelbarrows and it ranged from five to 4,600 wheelbarrows (Table 12). Agrochemical application directly increases the fertility of the land which in return is expected to increase banana yields of the producers. Muthee e*t al*. (2019) established that only 15% of the producers in Embu applied manure and other fertilizers to their banana plantations and this affected production. Debebe & Dagne (2018) in their examination of the socio-economic factors influencing banana production in Ethiopia found that majority of producers (70.77%) growing banana were not applying fertilizer in their banana farms. Omondi *et al*. (2020) reported that fertilizer was not used by the majority of producers to produce banana in Kisii and Migori counties and that the average amount of organic fertilizer utilized by those that used fertilizer was 118.27 kg compared to 1.17 kg of inorganic fertilizer per acre.

Table 12: Agrochemical used by respondents in the study area

Agrochemicals Used	Response	Percent of responses	Percent of cases
Manure	402	93.02	99.5
Planting fertilizer	29	6.74	7.21
Top dressing	1	0.23	0.25
Total	432	100.00	106.97

4.2.4 Planting Materials

The study's objective was to establish the varieties of banana suckers grown by smallholder banana producers in Kirinyaga Central Sub County. The findings were that a majority (68.41%) of banana producers use local banana variety while 31.59% use the improved variety (Table 13). It was observed that producers used the local suckers

from their own farms and some borrowed from their neighbours. Use of improved suckers was anticipated to have a favourable upsurge on production and technical efficiencies among banana producers. The findings of this study agree with those of Muthee *et al*. (2019) who found that averagely smallholder producers in Embu County planted 38% improved banana variety suckers and 62% local variety suckers implying that majority used the local banana variety. Additionally, Omondi *et al*. (2020) found that majority (99%) of banana producers in Migori and Kisii counties use local variety banana suckers as planting materials. Contrary to this study's findings, in Ethiopia 84% of banana producers planted improved banana varieties (Gebre *et al*., 2020).

This study established that 23.38% of producers used certified banana suckers while 76.62% used uncertified suckers. This study's outcome concede the findings of Kamau *et al*. (2020) who reported that uncertified Irish potato seed was utilized by 70.56% of potato growers whilst certified seed was utilized by 16.11% of producers and noted that unavailability of certified seeds and high price were among the reasons why most producers chose to use the uncertified seeds.

Table 13: Banana variety and suckers used by respondents in the study area

Banana	Characteristic	Frequency	Percent
Banana Variety	Local	275	68.41
	Improved	127	31.59
	Total	402	100
Certified Suckers	No	308	76.62
	Yes	94	23.38
	Total	402	100

The mean number of banana suckers grown by the smallholder producers in the study area were 196 per acre ranging from 10 to 2300 suckers (Table 14). Number of banana suckers planted by a producer is significant since it greatly affects the total yields produced. Even if there is a sufficient supply of other inputs, output will be low if the correct quantity and quality of suckers are not used. This study's findings are not in agreement with Sharma *et al*. (2021) who established that the average number of banana suckers planted in Nepal was 2,034 per hectare.

Table 14: Number of banana suckers planted by smallholder producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Banana Suckers	402	195.898	49.424	10	2300

4.3 Characterization of Socioeconomic Factors of Respondents

4.3.1 Age of Decision Maker, Household Size and Farming Experience

This study purposed to investigate the impact of the age of the family decision maker, household size and farming experience on banana production. The findings demonstrated that the mean age of smallholder banana producers was 54 years old ranging from 24 to 85 years (Table 15). The findings showed that most of the banana producers surveyed were in the age range of 47 and 61years indicating that the study area has many of the middle aged producers participating in banana production. This imply that the bulk of producers are in their prime of life, economically energetic and fruitful age bracket and can therefore carry out successful farming. It is possible that decision makers' age in production of banana is a major determinant in embracing of innovation in the banana sector.

The findings of this study concur with those of Sharma *et al*. (2021) who reported that the typical household heads' age among banana producers in Nepal was approximately 51.84 years and was ranging from 22 to 82 years. The results of this study are contrary to those of Eutycus (2019) who found that majority of banana producers in Meru were middle aged and ranged between 31-40 years. There have been claims that age serves an important role regarding the supply of manpower that is needed in carrying out farming activities (Kamau, 2019). The findings of this study also corresponds to the findings of Nguyen-Thi-Lan *et al*. (2023) and Tamirat & Tadele, (2023) who reported that the household head's mean age was 52 and 56.21 years, respectively. Looking at the results of this study, age plays an essential part on the availability of labour for carrying out farming activities and is among the most essential socio-economic determinant that affects a producer's decision-making as production is being done.

The study established mean household size as four people with a least family having one person and 12 people maximum (Table 15). The results imply that there could be availability of family labour amongst smallholder banana producers in Kirinyaga

Central Sub County. The number of people in a family may determine the availability of workers eligible for manual work to perform farm activities mostly during banana planting, distribution of manure, weeding and harvesting. As a result, total number of inhabitants staying in a producer's home might have an impact on the amount of agricultural production through the availability of manpower and also helps to cut off labour costs. In addition, producer's household size may demand more food and therefore might motivate more production. Debebe & Dagne (2018) in their examination of socioeconomic factors influencing the production of banana in Ethiopia and found that the minimum size of household was one and maximum of 12 people while the average family size was 7.

The findings study concurs with those reported by Sapkota *et al*. (2017) and Tiruneh & Geta (2016) which established that smallholder households contained an average of four people. The outcomes of the study contradict those presented by Mairabo *et al*. (2023) and Saliu *et al*. (2017) which established the average household size to be 9 persons. Findings of this study varied closely with those of Tamirat & Tadele (2023) study on the factors that affect efficiencies in coffee cultivation in Ethiopia who discovered the average household size for coffee producers in Ethiopia was five people. Further, Sharma *et al*. (2021) found that the mean household size among banana producers in Nepal was six people.

Banana growing experience is the total duration a smallholder producer has been involved in active banana cultivation. The findings of this study were that on average, smallholder banana producers had 12 years of experience in banana production with 3 years as the least, and 33 years at the most (Table 15). Experienced producers may offer accurate information and possess in-depth knowledge of banana growing and this would translate to higher technical efficiencies and productivity. There is a possibility that experience is crucial in increasing output because it is normal to expect that the more time one spends working in a given occupation, the better they get at performing tasks. Eutycus (2019) found that on average banana producers in Meru County had experience of 10 years. Contrary to the outcomes of this research, Vinayagamoorthi *et al*. (2019) while examining the experience of the farm households found that most

producers (54%) were having 20 years of farming experience demonstrating that the producers had a wealth of knowledge in banana growing in Tamil Nadu, India.

Table 15: Age, household size and experience of sampled smallholder banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Age of decision maker	402	53.940	6.971	24	85
Household size	402	4.167	1.188	1	12
Banana Experience	402	12.420	4.015	3	32

4.3.2 Gender of Decision Maker

This study established that most decision makers among the banana producers were men (86.57%), whereas only 13.43% were female (Table 16). This implies that most smallholder banana producers' households are controlled by males and therefore banana production decisions are made by males. This may indicate that more men than women are actively engaged in the cultivation of banana reflecting gender inequality among smallholder banana producers in Kirinyaga. During cultivation of bananas, a producer's gender may be important, especially when family labour is the primary source of labour. It's possible that male producers put in more labour than female producers do. It has been reported that if provided an equal amount of time to finish an agricultural task, female producers seem likely to spend longer or would likely require more man-days than male producers (Doss, 2018). As a result, men producers are essential in supplying labor input and lowering the cost of hiring labour.

When identifying the underlying reasons of smallholder producers' low efficiencies, the producers' gender is a crucial consideration. There is a possibility that men are typically more muscular over female producers, allowing them to manage farming duties easier compared to female producers, which can make female producers less effective than male producers. At the same time, in comparison to their female counterparts, men possess greater accessibility to resources as well as expertise needed to grow crops more effectively. Findings from this study are in line with Bhatta *et al*. (2023) who found that majority of banana producers in Chitwan District, Nepal were males. In addition, majority of banana producers in Kisii, Nyamira and Embu counties

were male (Wahome *et al*., 2021). The findings of this study contradict Eutycus (2019) who noted that majority (56%) of small scale banana producers in Meru County were females. Likewise, the results agree with those of Khatiwada & Yadav (2022) who noted that ginger production in Nepal is dominated by men. Ntabakirabose (2017) established that most maize producers in Rwanda were men. In addition, the outcomes of this study is also in agreement with results of Bhatta *et al*. (2023) who reported that most banana producers in Nepal were male headed.

Table 16: Gender of decision maker among the sampled banana producers

Gender of Decision Maker	Frequency	Percent
Male	348	86.57
Female	54	13.43
Total	402	100

4.3.3 Education Level of Respondents

The education level was determined through calculating the total number of years spent in school by the smallholder banana producers. The study findings indicated that 2.49% of the producers had no education at all, 2.99% having not completed primary education, 16.42% have attained primary education, 13.93% did not complete secondary education, 55.97% have secondary education, 8.21% having attained college education or University level of education (Table 17). The sampled banana producers had a mean education level of 10 years of formal education, from 0 up to 18 years range insinuating that some producers had low levels of education (Table 18). The highest possible level of schooling a producer has attained may influence their decision making in the process of production as it impacts the producer's capacity to receive and make use of the production data offered and to adopt new and advanced technologies. This is in return expected to increase technical efficiencies in production as producers can make the most of the resources at their disposal to increase yield. According to the outcomes of this study, the mean educational level among respondents is high school. These findings agree with those by Mairabo *et al*. (2023) who noted that majority of soybean growers in Nigeria had secondary education as their highest educational level.

In accordance with this study's findings most of the producers had some formal educational backgrounds providing them with the fundamentals of farming techniques so that they can easily implement creative farming methods on their farms and seek out additional information from other sources. This study found that greater than 50% of those surveyed were literate at the very least having completed secondary level of education. This imply that there may be potential for increased in banana production since majority are educated. During the study the majority of producers were found to be using certified suckers were educated clearly proving the importance of education. In their evaluation of potato growers' technical efficiency in the Mezam Division, Cameroon, Atamja & Yoo (2022) found that 10 years on average were spent in school. In Rwanda, it has been reported that majority of maize producers (89.5%) never went to school (Narcise, 2017).

Table 17: Education level of respondents in the study area

Highest Level of Education	Frequency	Percent
No formal education	10	2.49
Incomplete Primary Education	12	2.99
Complete Primary Education	66	16.42
Incomplete Secondary Education	56	13.93
Complete Secondary Education	225	55.97
University/College	33	8.21
Total	402	100

Table 18: Years of education among smallholder banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Years of Education	402	10.892	2.748	0	18

4.4 Characterization of Institutional Factors Affecting Technical Efficiency

4.4.1 Access to Credit

This study sought to identify the need for credit among smallholder producers since it is essential in financing the various farming activities that are carried out by producers. The findings showed that 42.79% of the producers lacked the ability to obtain financing, compared to 57.21% of those who had access to credit in Kirinyaga Central Sub County (Table 19). This imply that majority of the smallholder banana producers in Kirinyaga had accessibility to credit. Credit availability may enable producers to make prompt

acquisitions of the inputs they are unable to furnish by themselves. It aids in the improvement of household efficiency by removing financial restraints that can make it difficult for households to make timely purchases of inputs, tools, and farm management decisions. The findings of this study contradict Eutycus (2019) who analyzed small-scale banana farming technical efficiency in Meru, Kenya and reported that the majority of producers lacked access to financing. The findings coincide with those of Tamirat and Tadele, (2023) who found that a total of 56.12% of coffee producers have access to credit in Southwest Ethiopia. Moreover, Debebe and Dagne (2018) reported that majority of the banana producers in Ethiopia (64.28%) had no access to credit.

Among the smallholder banana producers having credit available to them, this study established that 9.75% of the respondents used it in banana production for purchase of manure, fertilizer and payment of hired labour while 90.43% used in other areas of need (Table 19). Majority of smallholder banana producers did not use credit acquired in banana production which can be mistaken that producers do not require credit in banana production. Tenaye (2020) found that only 34% of the producers who had accessed loans used it for production purposes while majority of producers with credit (66%) shift credit usage away from production and transfer it to consumption. During data collection, this study established that banana producers within the county had many loan sources available to them including banks, neighbors, family, producer groups and cooperatives among other sources of financing.

Table 19: Access to credit by smallholder banana producers

Access to Credit	Characteristic	Frequency	Percent
Credit Accessed	No	172	42.79
	Yes	230	57.21
	Total	402	100
Credit used in banana Production	Yes	22	9.57
	No	208	90.43
	Total	230	100

4.4.2 Group Membership

The study's findings demonstrated that out of the banana growers examined only 5.72% were members in a producer's organization. The majority (94.28%) among the

surveyed smallholder banana producers did not belong to a group of banana producers in the research region (Table 20). It is possible that the platform provided by producers' associations or groups allows access to information on marketing and the availability of new technology. The groups provide a platform that allow smallholder producers to better organize the sale of their harvested products and sale in large quantities. There is likelihood that where high number of respondents are not involved in group/cooperative activities results in low bargaining powers for producers and also lack of banana market information. Producers belonging in groups may be in a position to receive various agricultural trainings and other financial support. Further, famers in groups probably benefit from different projects and programs that may come up from government or NGOs. The findings of this study coincide those of Onuwa *et al*. (2022) who concluded that most (80%) of the cowpea producers in Nigeria do not belong to cooperatives.

As the study was carried out, it was established that producers access to agricultural information, advanced technology and new production methods were limited as they were not members to producer groups. Most of the banana growers in the research area missed the opportunities that come from information exchanges and shared experiences that is available among group members. Miassi *et al*. (2023) analyzed the production of rice in West Africa by examining technical efficiency and constraints in its production and found that 30.7% of the sample belonged to a producer group while 43.4% did not belong to any of these groups. This study's findings are in agreement as those of Kamau *et al*. (2020) where most irish potato cultivators in Nakuru belonged to producers' organizations. On the contrary, Khatiwada and Yadav (2022) reported that 88% of ginger producers in Nepal are members of local producer's associations.

Lower producer engagement in groups might be a result of producers' perception that joining would provide less benefits than not doing so. In light of this study's findings, it's probable that the choice to join a producer organization is influenced by the anticipated benefit of group membership. Producers are therefore more likely to join when the advantages of doing so are viewed as being greater than the disadvantages of not doing so. During the study, it was observed that producers joined association groups so they could have access to extension services, inputs, and markets for their products as well as for financial, social, and other reasons. In order for them to benefit from some

of the group advantages, it is necessary to encourage the non-members in the study area to join a group.

Table 20: Access to producer organizations by respondents in the study area

Group Membership	Frequency	Percent
Yes	23	5.72
No	379	94.28
Total	402	100

4.4.3 Access to Extension Services

This study sought to find out the effects of accessibility to extension services on banana production technical efficiency in Kirinyaga Central Sub County. The findings show that 85.75% of banana producers failed to receive extension services while only 14.43% accessed the services (Table 21). Extension services and training ensures that producers get the information and abilities to help them carry out good agricultural practices and efficient use of available resources. Producers who have access to extension visits and trainings probably stand a chance of profiting from new knowledge, more crop production methods, new farming methods, and a desire to adopt modern inputs, all of which could increase their technical efficiency.

During the study it was observed that extension services were very weak due to unavailability of enough extension officers. There was a high ratio of extension providers to producers whereby most producers are not reached. The results of this investigation concur with those of Eutycus (2019) who established that 69% of the banana cultivators in Meru were not able to access extension services, while only 31% accessed extension services. Adeoye (2020) analyzed factors influencing Nigeria's ability to produce vegetables efficiently and found that a large portion of producers had the ability to use extension services implying that tomato crop yield rises with a rise in extension contact. Debebe & Dagne (2018) stated that most of banana producers in Ethiopia (65.58%) had no access to extension services. Rukwe & Zubairu (2019) noted that access to extension services remains a challenge in agricultural production activities as over 80% of smallholder producers do not have access in Nigeria. It was discovered during the study that banana growers in Kirinyaga Central Sub County had a variety of options for obtaining extension services, including government extension agents, producer groups, private providers, other producers, NGOs, and agricultural

offices. It was also observed that the producers took advantage of one or the other of the sources in order to advance their technical efficiencies and output

Table 21: Access to extension services by respondents in the study area

Access to Extension Services	Frequency	Percent
No	344	85.57
Yes	58	14.43
Total	402	100

4.4.4 Distance to Market

This study sought to identify producer accessibility to market which assists producers to sale their produce on time. The study observed that the distance to closest banana market was 12 kilometers on average, ranging from one to 24 kilometers (Table 22). Long distances translate to huge transportation and carrying costs which in return affects producers' incomes and production. The outcomes of this study are in agreement with Katungwe *et al*. (2020) study which established average distance to be 9 kilometers from producer homestead to the nearest tea factory. In addition, the tomato producers were located 9.72 kilometers on average from the markets (Mwangi *et al*., 2020). This study's outcomes oppose those by Sharma *et al*. (2021) who established average distance to the nearest market by banana producers in Nepal was 5.09 kilometers. Debebe and Dagne (2018) on the other hand reported that the nearest banana market was 5.428 kilometers away from producers place.

Table 22: Summary statistics of distance to the market by smallholder banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Distance to Market	402	12.248	4.833	1	24

4.5 Technical Efficiency of Smallholder Banana Producers

The goal of this study was also to ascertain levels of smallholder banana producers' technical efficiency. The findings on the Cobb-Douglas stochastic frontier function showed that smallholder banana producers mean technical efficiency was 83.1%, ranging from 0.9% to 95.5% (Table 23). Therefore, smallholder banana producers in Kirinyaga Central Sub County had varied levels of technical efficiencies. These findings suggest that given the prevailing input level, smallholder banana producers can

still increase current production by 16.9% perhaps through productive management of their orchards. The inefficient producers had technical efficiency score of 0.9%, therefore the producers could increase their existing output by enhancing technical efficiencies because they are utilizing their resources ineffectively as production is being done. The findings on the technical efficiency level suggests that banana production technical efficiency varied amongst smallholder banana producers in Kirinyaga Central Sub County and that differences in efficiencies may be contributed by inefficiencies in production.

Decreasing levels of technical efficiencies could be linked to both inefficient input use and producer-specific characteristics, such as decision-makers age, producers' experience, market distance, lack of participation in producer organizations, inaccessibility to credit and extension services. The findings of this study contradict those of Van Hung *et al*. (2022) who found that banana producers' technical efficiency varied in Viet Nam and ranged between 89.68% to 97.81% with an average technical efficiency of 95.92%. The findings of this study coincide with those of Asfaw (2021) who found that tomato producers in Ethiopia had an average technical efficiency of 80.9%. Mairabo *et al*. (2023) found that soybean producers in Nigeria had an average technical efficiency level of 89% indicating that a typical soybean grower in Nigeria could raise yield by up to 11% using the same input combination.

Table 23: Technical efficiency of the sampled banana producers

Variable	Observation	Mean	Standard Deviation	Minimum	Maximum
Technical Efficiency	402	0.831	0.128	0.009	0.955

4.6 Influence of Production Factors on Banana Production Technical Efficiency

The study sought to analyze influence of production factors on technical efficiency. It applied a Cobb-Douglas stochastic frontier encompassing four production variables to test for the level and factors affecting technical efficiency level among the smallholder banana producers in Kirinyaga Central Sub County. The inputs utilized included; the area of land under banana production (acres), amount of manure applied (wheelbarrows), the quantity of planting materials (suckers) and family as well as paid labour used during banana production (man days). The findings of this study showed

that land size, planting materials and agrochemicals significantly affected banana cultivation at 5% level of significance (Table 24). The corresponding coefficients for banana plants used along with agrochemical factors were found positive while that on land was negative.

Measurements of land were based on the amount of area utilized for banana production. The findings of this study indicated that a rise in the amount of land given to banana farming reduces production by 0.438%. This imply that banana production would decrease if producers increase the land allocated to its production. This finding could imply that it's simpler managing smaller pieces of land under banana for optimum production unlike comparatively bigger land pieces. In addition, family labour may be used in smaller farms while larger farms may require additional costs of engaging hired labourers. It is possible that as the size of banana orchards increase management becomes difficult and therefore producers tend to keep just small pieces. The negative effect between technical efficiency and farm size may be attributed to the worry by producers that increasing land size their costs of production will also increase.

The outcomes of this study are in agreement with those of Eshete & Alamirew (2023) who established a detrimental impact of land area in bread wheat production technical efficiency in Ethiopia. Omondi *et al*. (2020) found that banana producers who did not participate in groups in Nyamira and Kisii counties had decreased production technical efficiencies with increase in land size. Contrary to this study's findings, land size under maize cultivation was significantly and positively affecting maize production technical efficiency in Rwanda (Narcisse, 2017). Debebe & Dagne (2018) also established that land size under banana cultivation had a positive coefficient but was not significant to banana production technical efficiency implying that land size has no effect on banana production.

During the study it was observed that planting materials (banana suckers) were a necessary input in production. The variable showed a positive relationship at 1.315. The outcomes implied that increasing the amount of planting materials used will lead to increased banana output by a factor of 1.315 (Table 24). The findings imply that use of correct number of suckers on a farm may results in achieving maximum production.

Based on this study finding, use of more banana suckers would lead increased production since many plants will be harvested. Thus, a producer who plants more banana suckers receives higher banana output. Vinayagamoorthi *et al*. (2019) had similar findings to this study and reported that banana suckers were a factor among smallholder banana producers in Tamil Nadu, India and affected technical efficiency positively.

Banana sucker had noteworthy effect on banana production in Bangladesh where it was reported that a 1% rise in quantity of sucker would raise the banana yields up to 0.29% (Mohiuddin *et al*., 2020). Seed had substantial as well as positive impact on maize production technical efficiency among producers in Rwanda indicating that increasing seed rate with 1% raises technical efficiency with 4.1%. (Narcisse, 2017). Tenaye (2020) examined technical efficiency levels among small scale agricultural producers in Ethiopia and the results established that seeds used influenced the technical efficiencies of production in agriculture. Mukami (2018) examined welfare effects along with technical efficiencies among small-scale producers' production of snow peas in Kenya. The findings established a positive connection among the quantity of yields obtained and type of seed utilized.

Table 24: Stochastic frontier model parameter estimates

Variable	Coefficient	SE	Z	P-Value	95% Confidence interval	
Loglandsize	-0.438	0.047	-9.26	0.000	-0.531	-0.346
Logfamily_labour	-0.003	0.028	-0.12	0.904	-0.058	0.051
Loghired_labour	0.052	0.046	1.12	0.263	-0.039	0.142
Logplantingmaterials	1.315	0.054	24.43	0.000	1.210	1.421
Logagrochemicals	0.155	0.031	4.96	0.000	0.094	0.216
Constant	0.585	0.261	2.24	0.025	0.074	1.097
Log likelihood	-35.945					
Total observations	402					
Prob> chi2	0.000					

This study's findings showed that the correlation coefficient for agrochemical was essential as well as positive implying that using more manure would significantly increase production. The findings indicated that an increase with a unit in the usage of manure increases yields in banana up to 0.155 kgs (Table 24). These findings might imply that manure is a key input in banana production. Agrochemical use especially

manure was discovered to be statistically significant and to have a positive relationship with banana yield, meaning that increasing the amount of manure use causes a rise in levels of technical efficiency in Viet Nam (Van Hung *et al*., 2022). Manure variable was significant and had positive influence to banana production where it was observed that 1% increase manure usage increased banana production technical efficiency by 5.92%. (Vinayagamoorthi *et al*., 2019). Khatiwada & Yadav (2022) found consistent results that agrochemical had substantial impact in ginger cultivation technical efficiency.

The findings of this study showed hired labour (man-days) was not significant but produced a positive effects on banana production technical efficiency within the area of study. This implies that hired labour was a key input in banana production. Chepng'etich (2013) found hired labour had similar positive results on sorghum production in Machakos and Makindu. Family labour on the other hand negatively influenced banana production in Kirinyaga Central Sub County but the influence wasn't significant at any given level. Contrary to this study findings, Gebre *et al*. (2021) reported that family labour had significant as well as positive impact on cultivation of maize in Ethiopia.

4.7 Effects of Socio-economic and Institutional Factors on Smallholder Banana Production Technical Efficiency

In the second step of the Cobb-Douglas stochastic frontier model, this study investigated the socio-economic and institutional factors that affected smallholder banana production technical efficiency. It was assumed by the study that factors classified as socio-economic and institutional might have an effect on banana production technical efficiency within the area of study. Finding of the variables influencing technical efficiency during production of banana aids in the development of interventions and strategies that can boost the present level of production. A negative sign on the parameter coefficient denotes a rise in technical efficiency levels as independent variable rises. A rise in independent factor will result in reduction of technical efficiency while technical inefficiencies rises, according to a positive value for the parameter's coefficient. As a result, every adverse coefficient enhanced or raised the producers' technical efficiencies, and the other way around. Age of decision maker,

education years of the head, size of the household, banana farming experience, group membership as well as market distance tested significant at 5% significance level.

Age of decision maker variable proved significant at a 5% significance level but had a negative influence on technical efficiency levels. These findings indicate that increasing producers' age might result in 1.46 decline in banana yield technical efficiency. The findings show that the technical efficiency of older producer is typically less compared to that belonging to younger producer. The elderly producers are assumed to be more reluctant to take risks associated with production unlike the young people. It is also possible that older individuals lack physical strength and do not easily accept new farming techniques. Conversely, producers who are younger appear to be enthusiastic, creative, energetic, and risk-takers and therefore are more likely change the agriculture sector than the older people. They may seek and obtain extension services which helps them to manage the different farming situations earlier. Younger producers may increase their degree of technical efficiency by investing in innovative and advanced technologies in agriculture, effectively increasing total production. As a result, younger producers have much higher technical efficiencies.

The findings of this study on the age of decision-maker stand consistent with the results of Onuwa *et al*. (2022) which established age had unfavourable effects on cowpea production technical efficiency in Nigeria. Kristof (2022) noted that there was a negative sign in the producer's age coefficient (-0.002) implying that age and technical efficiency were positively correlated in Namibia. Abubakar and Sule (2019) analyzed the technical level of efficiency in production of maize in Niger State, Nigeria and reported that the inefficiency model was adversely impacted by producers' age, which may have suggested that as producers aged, their technical inefficiency also increased. Findings of this study differed from that of Sabroso and Tamayo (2022) whose work made a technical efficiency estimate in production of coffee in the Philippines, and discovered that producers' age is positively related to technical efficiency.

The findings of this study showed that household size had negative effects on smallholder banana production technical efficiency levels. The findings showed that as household size increases, banana production technical efficiency reduces to the extent

of 2.217. During the study it was established that majority of household heads were educated and therefore sent their children to school who then are not involved in active farming and this may lead to decrease in technical efficiency levels. It was established that children participated in production during weekends and on holidays. The study's outcomes coincide with those of Ayuko *et al*. (2023), which highlighted that a rise in family size reduces the level of technological efficiency in fodder productivity in Homabay County, Kenya. Tenaye (2020) found that there existed good correlation between technical inefficiency and size of household showing that bigger families are more technically inefficient. The findings of this study differed those of Rukwe & Zubairu (2019) who reported that the households' size variable had detrimental coefficient with technical efficiency signifying that a rise in household size raises technical efficiency in production of sesame.

The findings of this study disclosed that education variable had positive effects on level of technical efficiency. The findings indicated that increasing smallholder banana producers' education level by a unit would increase banana production technical efficiency by 1.325 units, *ceteris puribus*. It is possible that education access improves the management and technical abilities of producers and raises the household's capacity to make use of new and current technology and achieve better levels of efficiency. Education is supposed to help producers allocate inputs efficiently and also in better management of banana orchards. The outcomes of this research agree with those presented by Dessale (2019) who noted that education had positive effects on wheat production technical efficiency in Ethiopia implying that technical efficiency level of less educated producers was low compared to those who are more educated. Van Hung *et al*. (2022) as well reported education variable had a good and significant impact on banana production technical efficiency in Viet Nam. In addition, Kristof (2022) found that a strong connection existed between the producers' technical farm efficiency and their level of education.

Muzeza *et al*. (2023) determined that education had a negative coefficient, meaning that A1 maize producers with greater education had higher technical efficiencies than the less educated producers. Technical inefficiencies are assumed to decrease as education level increases since it improves producers' abilities to acquire technical knowledge

and apply it in production. Contrary to outcomes of this study, Mairabo *et al*. (2023) pointed out that the technical efficiency of soybean growers is unaffected by education in Nigeria. Eshete and Alamirew (2023) observed that education variable was negative and insignificant to bread wheat production technical efficiency. Tamirat and Tadele (2023) also found that the technical inefficiency had a negative relationship with the education level of coffee producers meaning that producers' level of education didn't affect their levels of technical efficiencies.

The outcomes of this investigation depict that banana farming experience factor was significant at 5% level of significance and produced positive impact on the level of technical efficiency. The findings showed that a year's worth of additional farming experience increases smallholder banana production technical efficiency by 1.712 kgs. This could be because more work experience leads to more job knowledge and improves how smallholder banana producers perform tasks on their orchards. This studys findings contradicted those of Eutycus (2019) who found that experience in banana cultivation negatively influenced technical efficiency in Meru. This study's outcomes are in line with those of Muzeza *et al*. (2023) which established a negative coefficient on the experience variable, implying that the more knowledgeable A1 smallholder maize producer was more technically efficient. Similarly, Mairabo *et al*. (2023) established experience of producers influenced technical efficiency of soybean production positively.

Table 25: Maximum likelihood estimates of the inefficiency model

Variable	Coefficient	SE	Z	P-Value	95% Confidence interval	
Age decision maker	1.460	0.503	2.90	0.004	0.474	2.446
Gender of HH	4.487	4.754	0.94	0.345	-4.830	13.804
Household size	2.217	1.148	1.93	0.053	-0.033	4.466
Education level	-1.325	0.689	-1.92	0.045	-2.676	0.026
Farming experience	-1.712	0.670	-2.55	0.011	-3.025	-0.398
Group membership	-27.923	14.150	-1.97	0.048	-55.656	-0.190
Credit access	-4.887	3.647	-1.34	0.180	-12.036	2.261
Extension access	-1.762	5.202	-0.34	0.735	-11.957	8.434
Market distance	-1.583	0.619	-2.56	0.010	-2.796	-0.371
Constant	-58.101	24.436	-2.38	0.017	-105.995	-10.207

The study's findings show that group membership variable was negative implying that membership to producer group affected technical efficiency positively. This study's

outcomes demonstrate that belonging to producer's organization boosts the technical efficiency of banana production by a factor 27.92. It is possible that participation by smallholder producers in group organizations and cooperatives has a substantial impact on raising production technical efficiency levels. This could imply that producers who belong to these groups are more productive than those who do not. Membership ensures sharing of valuable information among members, collective selling of producer produce, access to current market information and bargaining power to be able to get good prices for the products. These findings are in line with Ofori-Appiah (2022), who claimed that group participation possessed favourable influence on the technical efficiency of pineapple production in Ghana.

In Nepal, the coefficient of cooperative participation was discovered to be negative, meaning that ginger the technical efficiency of producers who belong to such groups is higher than that of nonmember producers (Khatiwada & Yadav, 2022). Therefore, there is need for development of initiatives to entice producers to join and take part in banana cooperatives or other producer associations or groups within the region of study. Adeoye (2020) analyzed characteristics of vegetable production efficiency in Nigeria and found membership to producer cooperative significantly and positively influenced technical efficiency indicating that an increase in pepper production efficiency resulted from membership in a cooperative society. Membership to the producer organization was discovered to be positively significant to fodder production in Homabay, Kenya implying that producers who are part of the producer group have a 4.3% increase in technical efficiency (Ayuko *et al*., 2023)

The findings of this study shows that proximity to the market affects smallholder banana producers' technical efficiency positively (Table 25). According to the findings, an increase of one unit in the distance to the closest market will translate to a rise in technical efficiency of banana production with a factor of 1.583, *ceteris paribus*. Possible reason for this is that producers perceive that they get better higher prices from urban areas unlike selling produce at farm gate. For smallholder producers, the distance to the nearest market is a crucial standard measure of the viability of the market for both inputs and outputs and access to market information. Outcomes of this study

contradict those presented by Martey *et al*. (2019), where it was discovered that distance to market as having adverse impacts on technical efficiencies in maize production.

The findings of this study on market distance contradict those of Endalew *et al*. (2022) which reported the distance to market significantly and adversely impacted teff production technical efficiency. Distance to the market was important and showed detrimental correlation with tomato production technical efficiency in Asaita district, Ethiopia, indicating that the most effective producer is one who is close to nearest marketplace as opposed to one who lives a long way off (Asfaw, 2021). How far the farm is from the nearest market had positive coefficient but showed insignificant effects to banana production technical efficiency in Ethiopia (Debebe and Dagne, 2018). This study found household heads' gender, credit accessibility and access of extension services having no important influence on the level technical efficiency of smallholder banana producers. They are statistically insignificant indicating no relationship between gender, credit access and accessibility to extension service variables and technical efficiency in banana production within the area of study.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Findings

The goal of this study was to analyze effects of production, socio-economic as well as institutional factors on technical efficiency of smallholder banana producers in Kirinyaga Central Sub County, Kenya. The study used a cross sectional research approach during collection of primary data. Cross sectional research design was employed. The study sought information from 402 smallholder banana producers located by use of a multistage sampling method. A questionnaire was employed to collect data in the study region. In a two-step process, data was analyzed using a Cobb-Douglas production function under the stochastic frontier technique.

The study purposed to estimate the level of technical efficiency amongst smallholder banana producers. Banana production technical efficiency levels amongst smallholder producers ranged from 0.9% to 95.5%, with a mean technical efficiency of 83.1%. The technical efficiency level results indicate that smallholder producers in Kirinyaga Central Sub County produced banana with varying levels of technical efficiency, and that production inefficiencies may have contributed to these variations. The findings suggest that given the prevailing input level smallholder banana producers can still increase current production by 16.9%. Banana producers might boost their present yield by improving technical efficiency since inefficient cultivators had a technical efficiency rating of 0.9%. This is because inefficient producers are using their resources inefficiently during the production process.

The study also examined the production factors that influenced the level of technical efficiency among the smallholder banana producers in Kirinyaga Central Sub-County, Kenya. Four production factors (land size, labour, agrochemicals and planting materials) were considered in the stochastic frontier model. The research established that land size, manure as well as planting materials had a positive effect on technical efficiency of banana production at 5% significance level (p-value= 0.000<0.05, p-value =0.000<0.05 and p-value=0.000<0.05 for land, planting materials and manure, respectively). In line with study's findings, land used for banana production showed

negative effects on technical efficiency while banana suckers and manure had positive effects.

The findings further indicated that a rise in land area set aside for production of banana by a unit, reduces banana quantity harvested by 0.438 units, keeping every other factor the same. Additionally, it was found that increasing the number of planting materials by one unit would result in a rise in banana production with 1.315 units, all other factors kept constant. The findings showed that raising the amount of manure application with a unit, there would be a rise by 0.155 units in banana production, *ceteris paribus*. It was noted that both hired and family labour had no significant impact on banana production technical efficiency but hired labour affected production positively.

Thirdly, the study sought to examine the influence of socioeconomic variables on banana production technical efficiency among smallholder producers in Kirinyaga Central Sub County. The study findings from a model of inefficiency showed that age of decision maker, years of education, household size and producers' experience influenced banana production technical efficiency. The study found that age of decision maker negatively and significantly affected banana production technical efficiency. Age of decision maker had a positive sign showing that older producers were less efficient. The study found that education level had a negative sign indicating that more educated banana households' heads had higher technical efficiencies. Producers experience years in banana production had a negative sign indicating the greater experienced banana producer was, the more the technical efficiency level. Household size variable had a positive sign showing that producers with many people were less efficient. The findings on the gender of household head variable showed that it was unessential in determining banana production technical efficiency.

Lastly, the study purposed to assess the influence of institutional factors of smallholder banana producers' technical efficiency. The findings indicated that market distance and membership to producer organization affected technical efficiency. Membership to producer organization had a negative sign indicating that producers in group organizations have higher levels of efficiencies compared to those who are nonmembers. The proximity to the closest market was having a negative sign indicating

that the more the producer was far away to the market the more efficient the producer is. The findings on credit access and access to extension services variables showed that they were inconsequential in finding banana production technical efficiency.

5.2 Conclusion

The study aimed at determining effect of production, socio-economic as well as institutional factors on smallholder banana producers' technical efficiency in Kirinyaga Central Sub County. Banana production and technical efficiency can be increased by increasing number of banana suckers planted, increasing manure usage and maintaining land size allocated to banana production. This study further found that banana production technical efficiency was influenced by age of decision maker, experience of the producer, education level attained, size of households, distance traveled to nearest banana market and membership to producer group.

It was found that an increase in banana producers' experience, education level, distance to market, and membership in producer groups would increase banana production technical efficiency, while the increase in age of decision maker and household size decreases banana production technical efficiency. The study established that smallholder banana producers had varied technical efficiencies ranging from 0.9% to 95.5%. Further, the study noted that smallholder banana producers produced banana at 83.1% technical efficiency level thus they had the potential of increasing their production level by 16.9% given the available resources in the Sub County.

5.3 Recommendations

The following recommendations were given in light of the findings of this study:

i. To improve banana production technical efficiency smallholder producers ought to be motivated to increase agrochemical usage as well as more banana suckers.
ii. There is need for people with high levels of education to venture into banana production since smallholder banana producers with high levels of education had high levels of production technical efficiencies.
iii. Banana producers ought to be urged to form and join banana groups or other producer groups in order to take advantage of opportunities that result from

knowledge sharing and shared experiences, receive various agricultural trainings, and receive other financial support that will ultimately result in technical efficiencies.

iv. Make extension services more accessible to smallholder banana producers so that they have access to the most recent, pertinent, and crucial knowledge about banana farming. There is also a need for deploying a greater number of extension officers to rural regions to help producers in need of extension services.

v. To reduce the distance covered by smallholder producers in marketing their banana produce, the county government and field stakeholders should ensure the establishment of banana markets and institutions in banana growing areas.

5.4 Suggestion for Further Research

The study suggests that future studies to:

i. Investigate effects of marketing factors on banana production technical efficiency among smallholder producers.

ii. Due to the limitations of the study's scope, this study primarily addressed the technical efficiency of banana production, leaving out allocative and economic efficiency. More research is needed to determine the allocative and economic efficiency of banana production in Kenya.

REFERENCES

Abdul, M. M., & Isgin, T. (2016). Technical Efficiency of Cassava Production in the Savannah Zone of Northern Ghana: Stochastic Frontier Analysis. *Journal of Biology, Agriculture and Healthcare* (20):62-72.

Abubakar, S., & Sule, A. (2019). Technical efficiency of maize production in Rijau Local government area of Niger state, Nigeria. *Journal of Agriculture and Veterinary Science*, 12, 63-71.

Adeoye, I. B. (2020). Factors Affecting Efficiency of Vegetable Production in Nigeria: A Review. *Agricultural Economics, 1*, 1-14.

Adhikari, A., Paudel, B., & Pokhrel, A. (2022). Banana Production Status and Its Role on Income Generation and Livelihood Improvement in Chitwan, Nepal. *International Journal of Applied Sciences and Biotechnology*, *10*(2), 93-98.

Aghion, P., Angeletos, G. M., Banerjee, A., & Manova, K. (2005). Volatility and Growth: Credit Constraints and Productivity-Enhancing Investment (No. w11349). *National Bureau of Economic Research.*

Agriculture and Food Authority (AFA). (2016). Horticultural Validated Report 2015-2016.

Ajewole, O. C., & Folayan, J. A. (2008). Stochastic Frontier Analysis of Technical Efficiency in Dry Season Leaf Vegetable Production among Smallholders in Ekiti State. *Nigeria. Agricultural Journal*, *3*(4), 252-257.

Amare, M., Mariara, J., Oostendorp, R., & Pradhan, M. (2019). The Impact of Smallholder Farmers' Participation in Avocado Export Markets on the Labor Market, Farm Yields, Sales Prices and Incomes in Kenya. *Land Use Policy*, Volume 88, 2019, 104168, ISSN 0264-8377. https://doi.org/10.1016/j.landusepol.2019.104168.

Ambetsa, F. L., Mwangi, S. C., & Ndirangu, S. N. (2020). Technical Efficiency and Its Determinants in Sugarcane Production among Smallholder Sugarcane Farmers in Malava Sub-County, Kenya. *African Journal of Agricultural Research*, *15*(3), 351-360.

Anyaegbunam, H.N., Nto, P.O., Okoye, B.C. & Madu, T.U. (2012). Analysis of Determinants of Farm Size Productivity among small-holder Cassava Farmers in South East agro ecological zone, Nigeria. *American Journal of Experimental Agriculture* 2(1):74-80.

Arinaitwe, I. K., Teo, C. H., Kayat, F., Tumuhimbise, R., Uwimana, B., Kubiriba, J., & Othman, R. Y. (2019). Evaluation of Banana Germplasm and Genetic Analysis of an F1 Population for Resistance to Fusarium oxysporum f.sp. cubense race 1. *Euphytica*, *215*(10), 1-11.

Asfaw, D. M. (2021). Analysis of Technical Efficiency of Smallholder Tomato Producers in Asaita District, Afar National Regional State, Ethiopia. *PloS one*, *16*(9), e0257366.

Atamja, L., & Yoo, S. (2022). Analysis of the Technical Efficiency of Potato Farmers in Mezam Division of the Northwest Region of Cameroon. *Journal of Agricultural, Life and Environmental Sciences*, *34*(2), 118-133.

Ateka, J. M., Onono, P. A., & Etyang, M. (2018). Technical Efficiency and Its PDeterminants in Smallholder Tea production: evidence from Nyamira and Bomet counties in Kenya.

Athukorala, W. (2017). Identifying the Role of Agricultural Extension Services in Improving Technical Efficiency in the Paddy Farming Sector in Sri Lanka. *Sri Lanka Journal of Economic Research.* DO - 10.4038/sljer.v5i1.58

Ayerh, F. (2015). Technical Efficiency of Tomato Farmers in the Ashanti Region of Ghana (*Doctoral dissertation, University of Ghana*).

Ayiera, K. N. (2020). Banana Production and Its Implications on Food Security in Imenti South Sub-County, Kenya. *Journal of Arts and Humanities*, *9*(9), 17-30.

Ayuko, M. S., Lagat, J. K., & Huaser, M. (2023). The Level and Determinats of Technical Efficiency in Fodder Production in Homa Bay County, Kenya. *Open Access Library Journal*, *10*(1), 1-15.

Ayuko, M. S., Lagat, J. K., & Huaser, M. (2023). The Level and Determinats of Technical Efficiency in Fodder Production in Homa Bay County, Kenya. *Open Access Library Journal*, *10*(1), 1-15.

Babu, S. C., Huang, J., Venkatesh, P., & Zhang, Y. (2015). A Comparative Analysis of Agricultural Research and Extension Reforms in China and India. *China Agricultural Economic Review*.

Bagamba, F., Ruben, R., & Rufino, M.C. (2007). Determinants of Banana Productivity and Technical Efficiency in Uganda.

Balogun, O. L., & Akinyemi, B. E. (2017). Land Fragmentation Effects on Technical Efficiency of Cassava Farmers in South-West Geopolitical Zone, Nigeria. *Cogent Social Sciences*, 3:1, 1387983.https://doi.org/10.1080/23311886.2017.1387983

Barasa, A.W., Odwori, P.O., Barasa, J., & Ochieng, S. (2019). Technical Efficiency and Its Determinants on Irish Potato Farming Among Smallholder Farmers in Trans-Nzoia County, Kenya. *International journal of research and innovation in social science*, 235-238.

Battese, G.E., & Coelli, T. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics*, 20 (2), 325-332

Bhattarai, D., Singh, S. B., Baral, D., Sah, R. B., Budhathoki, S. S., & Pokharel, P. K. (2016). Work-related injuries among farmers: a cross-sectional study from rural Nepal. *Journal of occupational medicine and toxicology*, *11*(1), 1-7.

Bhatta, S., Pant, P., Kapri, R., & Mishra, B. P. (2023). Production Efficiency of Banana Cultivation in Chitwan District, Nepal. *Cogent Food & Agriculture*, *9*(1), 2212461.

Booker, Q. S., Austin, J. D., & Balasubramanian, B. A. (2021). Survey Strategies to Increase Participant Response Rates in Primary Care Research Studies. Family Practice, 38(5), 699–702. https://doi.org/10.10 93/fampra/cmab070

Bucheli, M. (2005). *Bananas and Business*. New York University Press.

Chepng'etich, E. (2013). Analysis of Technical Efficiency of Smallholder Sorghum Producers in Machakos and Makindu Districts in Kenya (Doctoral dissertation, Kenyatta University).

Chepng'etich, E., Nyamwaro, S. O., Bett, E. K., & Kizito, K. (2015). Factors that Influence Technical Efficiency of Sorghum Production: A Case of Small Holder Sorghum Producers in Lower Eastern Kenya. *Advances in Agriculture*, *2015*.

Chimai, B. C. (2011). Determinants of Technical Efficiency in Smallholder Sorghum Farming in Zambia (Doctoral Dissertation, *the Ohio State University*).

Choudrie, J., & Dwivedi, Y. K. (2005). Investigating Broadband Diffusion in the Household: Towards Content Validity And Pre-Test Of The Survey Instrument.

Coelli, J., Rao, P., Christopher, J., Donnell, O., & Battese, E. (1995). An Introduction to Efficiency and Productivity Analysis, 2nd Edition. *Springer Science and Business Media*, New York, USA.

County Government of Kirinyaga. (2019). Retrieved on April, 2022 from Http://Www.Devolution.Go.Ke/Wp-Content/Uploads/2020/02/Kirinyaga-CIDP-2018-2022.Pdf

County Government of Kirinyaga. (2020). Retrieved on August, 2022 from Http://Kirinyaga.Go.Ke/Wp-Content/Uploads/2021/06/Annual-Development-Plans-2021-22.Pdf

County Government of Kirinyaga. (2021). County Fiscal Strategy Paper. Retrieved On September, 2023 from Http://Kirinyaga.Go.Ke/Wp-Content/Uploads/2021/06/County-Fiscal-Strategy-Paper-2021.Pdf

Daniel, W.W. & Cross, C.L. (2013). Biostatistics: A Foundation for Analysis in the Health Sciences. 10th Edition. New York: John Wiley & Sons.Pp 190. Retrieved on November, 2021 from Http://Docshare02.Docshare. Tips/Files/22448/2 24486444.Pdf

Debebe, A. D., & Dagne, D. (2018). Analysis of Socio-Economic Factors Affecting Banana Production: Evidences from Lowlands of Uba Debretsehay Woreda, Gamo Gofa Zone, SNNPRS. *Journal of Economics and Sustainable Development, 9*(9), 1-7.

Dessale, M. (2019). Analysis of Technical Efficiency of Small Holder Wheat-Growing Farmers of Jamma District, Ethiopia. *Agriculture and Food Security* 8(1):1.

Dhake, K., Jain, S. K., & Lakhawat, S. S. (2019). Value Addition In Green Banana For Rural Employment Generation. *Food Engineering, 59*(1), 1-11.

Dimand, R. W., & Spencer, B. J. (2009). Trevor Swan and the Neoclassical Growth Model. *History of Political Economy*, *41*(Suppl_1), 107-126.

Domaingue, R., Lewicki, S., This, P., Bakry, F., Horry, J. P., Braconnier, S., & Trouche, G. (2017). Evolution and Challenges of Varietal Improvement Strategies. In *Sustainable Development and Tropical Agri-Chains* (Pp. 141-152). Springer, Dordrecht.

Doss, C, R. (2018). Women and Agricultural Productivity: Reframing the Issues. *Dev Policy Rev*, 36:35–50. Https://Doi.Org/10.1111/Dpr.12243

Dube, A.K., Ozkan, B., Ayele, A., Idahe, D., & Aliye, A. (2018). Technical Efficiency and Profitability of Potato Production by Smallholder Farmers: The Case of Dinsho District, Bale Zone of Ethiopia. *Journal ff Development and Agricultural Economics*, 10(7), 225-235.

Ebiowe, P. (2016). Empirical Review of Problems and Prospects of Banana (Musa Sapientum) and Plantain (Musa Parradisiaca) Production Enterprises. *Global Journal of Biology, Agriculture and Health Sciences, 2*(4), 181-186.

Efficiency and Supply of Tea. Research Paper No. 19, *Africa Technology Policy Studies*, Nairobi, Kenya.

Endalew, B., Anteneh, A., & Tasie, K. (2022). Technical Efficiency of Teff Production among Smallholder Farmers: Beta Regression Approach. *The European Journal of Development Research*, 34(2), 1076-1096.

Eshete, Y., & Alamirew, B. (2023). Determinants of Technical Efficiency of Smallholder Farmers' Bread Wheat Production and Implications of Seed Recycling: A Stochastic Frontier Approach. *F1000Research*, *12*, 502.

Eutycus, K. M. (2019). Technical Efficiency of Small Scale Banana Farming in Meru County, Kenya. *Doctoral Dissertation*, Kenyatta University

Food and Agriculture Organization Statistics. (2020). Accessed on April, 2022 from: Http://Www.Fao.Org/Faostat/En/-Data/QC.

Food and Agriculture Organization Statistics. (2023). Retrieved on September, 2023 from: Http://Www.Fao.Org/Faostat/En/-Data/QC.

Food and Agriculture Organization Statistics. (2023). Bananas: Production, Trade and Farmer's Price Data. Retrieved September, 2023 from: Http://Www.Fao.Org/Faostat/ En/#Data.

Farrell, M.J. (1957). The Measurement of Productive Efficiency. *Journal of Royal Statistical Scientific Series*, 120,253–90.

Folorunso, S.T., Adenuga, K.M. (2013). An Analysis of Technical Efficiency of Ginger Crop Production in Jaba Local Government Area, Kaduna State, Nigeria. *Advances in Applied Science Research* 4(5):85-90.

Fonsah, E. G. (2003). Integrated Quality-Control Management Strategies in Banana Production, Packaging and Marketing. *Journal of Food Distribution Research*, *34*(856-2016-56263), 99-106.

Food and Agriculture Organization (FAO). (2009). Retrieved February 26, 2022, From World Bank Annual Production Of Banana. Http://Faostat.Fao.Org/Site/567/Default.Aspx.

Food and Agriculture Organization (FAO). (2017). Https://Www.Fao.Org/Economic/Est/Estcommodities/Oilcrops/Bananas/Bananafacts/En/

Food and Agriculture Organization (FAO). (2020). Medium-Term Outlook: Prospects for Global Production and Trade in Bananas and Tropical Fruits 2019 to 2028. Rome, February 2020.

Food and Agriculture Organization (FAO). (2022). Retrieved on September 2023 from: Https://Www.Fao.Org/3/Cb9411en/Cb9411en.Pdf

Food and Agriculture Organization (FAO). (2022). Https://Www.Fao.Org/Markets-And-Trade/Commodities/Bananas/En/

Gaviglio, A., Filippini, R., Madau, F. A., Marescotti, M. E., & Demartini, E. (2021). Technical Efficiency and Productivity of Farms: A Periurban Case Study Analysis. *Agricultural and Food Economics*, *9*(1), 1-18.

Geberewold, A. Z. (2019). Review on Impact of Banana Bacterial Wilt (Xhantomonas Campestris Pv. Musacerum) in East and Central Africa. *Cogent Food & Agriculture*, *5*(1), 1586075.

Gebre, G. G., Isoda, H., Rahut, D. B., Amekawa, Y., & Nomura, H. (2021). Gender Differences in Agricultural Productivity: Evidence from Maize Farm Households in Southern Ethiopia. *Geojournal*, *86*, 843-864.

Gebre, G. G., Rik, E., & Kijne, A. (2020). Analysis of Banana Value Chain in Ethiopia: Approaches to Sustainable Value Chain Development. *Cogent Food & Agriculture*, *6*(1), 1742516.

Gemeyida, K., Haji, J., & Tegegne, B. (2019). Sources of Technical Inefficiency of Smallholder Farmers in Sorghum Production in Konso District, Southern Ethiopia. *International Journal of Agriculture Education And Extension*, 5(1), 180-196.

Geocurrents, 2016: The Geography Kirinyaga Counties Map available at Https://Www.Geocurrents.Info/Gc-Maps/Geocurrents-Maps-By-Country/Geocurrents-Maps-Of-Kenya.

George, D., & Mallery, P. (2003). SPSS for Windows Step By Step: A Simple Guide and Reference. 11.0 Update (4th Ed.). Boston, Massachusetts, USA: Allyn & Bacon.

Getahun, W. & Geta, E. (2017). Technical Efficiency of Smallholder Barley Farmerss: The Case of Welmera District, Central Oromia, Ethiopia. *African Journal of Agricultural Research* 12(22):1897-1905.

Government of Kenya (Gok) (2018). Kirinyaga County Government. County Integrated Development Plan 2018-2022.

Greene, W. H. (2003). Econometric Analysis, 5th Ed. Pearson Education Inc., Upper Saddle.

Haile, K., Haji, J., & Tegegne, B. (2018). Technical Efficiency of Sorghum Production: The Case of Smallholder Farmers in Konso District, Southern Ethiopia Agric. *Development*, *3*, 1-15.

Hong, N. B., & Yabe, M. (2015). Resource Use Efficiency of Tea Production in Vietnam: Using Translog SFA Model. *International Journal of Biology*, 7, 160.

Horticultural Crop Directorate (2016). Validation Report 2016-2017. Retrieved From Http://Horticulture.Agricultureauthority.Go.Ke

Horticulture Validated Report (2021). Retrieved From Https://Horticulture.Agricultureauthority.Go.Ke/Index.Php/Statistics/Reports

Horticulture Validated Report (2019). Retrieve At Http://Www.Horticulture.Agricultureauthority.Go.Ke/Index.Php/Statistics/Reports?Download=127:Validated-Report-2017-2018

Ibitoye, S.J., Shaibu, U.M., Omole, B. (2015). Analysis of Resource Use Efficiency in Tomato (Solanumlycopersicum) Production in Kogi State, Nigeria. *Asian Journal of Agricultural Extension, Economics and Sociology* Pp. 220-229.

Ike, P.C., & Inoni, O. (2006). Determinants of Yam Production and Economic Efficiency among Smallholder Farmers in South Eastern Nigeria. *Journal of Central European Agriculture* 44(6):102 -119.

Joachim, V., Spieth, P., & Heidenreich, S. (2018). Active Innovation Resistance: An Empirical Study on Functional and Psychological Barriers to Innovation Adoption in Different Contexts. *Industrial Marketing Management*, *71*, 95-107.

Kahan, D. G. (2007). Farm Management Extension Services: A Review of Global Experience.

Kairu, E. K. (2020). The Influence of Agricultural Innovative Strategies on Banana Productivity among Smallholder Farmers in Kirinyaga County, Kenya (*Doctoral Dissertation, Strathmore University*).

Kalule, S. W. (2013). Credit Use and Technical Efficiency among Smallholder Banana Producers in Sheema District Uganda. *International Journal of Accounting and Financial Management Research (LJAFMR)*, *3*(4), 41-52.

Kamau, P. N. (2019). Technical, Economic and Allocative Efficiency among Maize and Rice Farmers under Different Land-Use Systems in East African Wetlands (No. 672-2019-2284).

Kamau, P. N., Gathungu, G. K., & Mwirigi, R. N. (2020). Technical Efficiency of Irish Potato (Solanum Tuberosum L.) Production in Molo Sub County, Kenya. *Asian Journal of Advances in Agricultural Research*, *13*(3), 1-9.

Kamira M, Ntamwira J, Sivirihauma C, Ocimati W, Asten P, Vutseme L, Blomme G (2016). Agronomic Performance of Local and Introduced Plantains, Dessert, Cooking and Beer Bananas (Musa Spp.) Across Different Altitude and Soil Conditions in Eastern Democratic Republic Of Congo. *African Journal of Agricultural Research* 11(43):4314-4332.

Karani, C. G. (2013). Assessment of Purple Passion Fruit Orchard Management and Farmerss' Technical Efficiency in Embu, Meru and Uasin-Gishu Counties, Kenya. *Journal of Economics and Sustainable Development*, *4*

Karienye, D., & Kamiri, H. (2020). Trends of Banana Production among Smallholders' Farmers Due to Rainfall and Temperature Variations in Mount Kenya Region, Kenya. *Budapest International Research in Exact Sciences (Birex-Journal) Vol*, *2*(2), 213-227.

Kassa, M. D., Demissie, W. M., & Batu, M. M. (2019). Smallholders' Technical Efficiency of Teff Production in Ethiopia. *African Journal of Agricultural Research*, *14*(33), 1641-1648.

Kasyoka, M. R., Mwangi, M., Kori, N., Mbaka, J., & Gitonga, N. (2011). Banana Distribution and Their Seed Systems in Central and Eastern Kenya. *African Crop Science Conference Proceedings*, 10, 457–459.

Katungwe, F., Elepu, G., & Dzanja, J. (2017). Technical Effi Ciency of Smallholder Tea Production in South-Eastern Malawi: A Stochastic Frontier Approach.

Kenya Institute for Public Policy Research and Analysis (KIPPA). (2017), Kenya Economic Report 2017, Sustaining Kenya's Economic Development by Deepening and Expanding Economic Integration in the Region. Kenya Institute for Public Policy Research and Analysis (KIPPA). Nairobi, Kenya

Kenya National Bureau of Statistics (KNBS). (2018). Economic Survey 2018. KNBS, Nairobi, Kenya. Retrieved on July, 2022 from: Http://Www.Knbs.Or.Ke

Kenya National Bureau of Statistics (KNBS). (2018). Validated Report 2016-2017. Retrieved on June, 2022 From: Http://Kilimodata .Developlocal. Org/ Dataset/ 3534b0b9-E49e-4c72-A90a-E423844a83a2/Resource/C7758a80-9102-481e-A6c2-Fa983081221d/Download/Horticulture-Validated-Data-2016-2017.Pdf

Khatiwada, D., & Yadav, P. (2022). Technical Efficiency of Ginger Production in Ilam District of Nepal: A Stochastic Production Frontier Approach. *Advances in Agriculture*, *2022*.

Kibaara, B.W. (2005). Technical Efficiency in Kenyan's Maize Production: An Application of The Stochastic Frontier Approach. *Msc. Thesis. Colorado State University, Colorado*.

Kimenyi, E., (2008). Kenyan Extension Services. A Paper Presented At The JICA Training Program On Rural Development By Songa Mbele Community Development Initiative Approach. Nairobi.

Kiprono, P. K. (2013). Economic Efficiency of Resource Use among Smallholder Tea Producers in Selected Counties of Kenya. *Unpublished Phd Thesis, Moi University*.

Kirimi, F. K., Onyari, C. N., Njeru, L. K., & Mogaka, H. R. (2021). Effect of On-Farm Testing on Adoption of Banana Production Technologies among Smallholder Farmers in Meru Region, Kenya. *Journal of Agribusiness in Developing and Emerging Economies*.

Knoema. (2021). Kenya - Bananas Production Quantity. Retrieved From Https://Knoema.Com/Atlas/Kenya/Topics/Agriculture/Crops-Production-Quantity-Tonnes/Bananas-Production

Krasachat, W. (2023). The Effect of Good Agricultural Practices on the Technical Efficiency of Chili Production in Thailand. *Sustainability*, *15*(1), 866.

Kristof, S. K. T. (2022). Analysis of Factors Influencing the Technical Efficiency of Maize Small-Scale Farmerss of Kavango East Region. *Doctoral Dissertation*, Namibia University of Science and Technology.

Lema, T. Z., Masresha, S. E., Neway, M. M., & Demeke, E. M. (2022). Analysis of the Technical Efficiency of Barley Production in North Shewa Zone of Amhara Regional State, Ethiopia. *Cogent Economics & Finance*, *10*(1), 2043509.

Mairabo, A., Jibrin, S., Audu, H., Salihu, M. Y., & Elisha, Y. (2023). Technical Efficiency of Soybean Production in Niger State, Nigeria. *Fudma Journal of Sciences*, *7*(1), 201-206.

Mamo, T., Getahun, W., Chebil, A., Tesfaye, A., Debele, T., Assefa, S., & Solomon, T. (2018). Technical Efficiency and Yield Gap of Smallholder Wheat Producers in Ethiopia: A Stochastic Frontier Analysis. *African Journal of Agricultural Research*, *13*(28), 1407-1418.

Martey, E., Wiredu, A. N., Etwire, P. M., & Kuwornu, J. K. (2019). The Impact of Credit on the Technical Efficiency of Maize-Producing Households in Northern Ghana. *Agricultural Finance Review*, *79*(3), 304-322.

Masuku, M. B., Raufu, M. O., & Malinga, N. G. (2014). The Impact of Credit on Technical Efficiency among Vegetable Farmers in Swaziland. *Sustainable Agriculture Research*, *4*(526-2016-37875).

Matere, J. S. (2009). Socio-Economic Factors Influencing Smallholder Banana Farmers' Participation in Banana Farmers' Association Marketing Channel in Murang'a South District. *Master of Science Thesis, University Of Nairobi*.

Mbaka, J. N., Mwangi, M. And Mwangi, M. N. (2008). Banana Farming as a Business: The Role of Tissue Cultured Planting Materials in Kenya. *Journal of Applied Biosciences,* 9(1): 354 – 361

Mburu, S., Ackello-Ogutu, C., & Mulwa, R. (2014). Analysis of Economic Efficiency and Farm Size: A Case Study of Wheat Farmers in Nakuru District, Kenya. *Economics Research International*, *2014*.

Miassi, Y. E., Akdemir, Ş., Dossa, K. F., & Omotayo, A. O. (2023). Technical Efficiency and Constraints Related to Rice Production in West Africa: The Case Of Benin Republic. *Cogent Food & Agriculture*, *9*(1), 2191881.

Ministry Of Agriculture (Moa). (2011). Ministry Of Agriculture, Livestock and Fisheries Strategic Plan 2013-2017. Kenya Vision 2030.Towards an Innovative, Commercially Oriented and Modern Agriculture. Nairobi, Kenya.

Ministry Of Agriculture (Moa). (2017). Rural Development Crop Division Annual Report, Nairobi, Kenya.

Ministry Of Agriculture (Moa). (2017). Horticultural Crops Production nd Consumption Annual Report. Nairobi, Kenya.

Miriti, P., Otieno, D. J., Chimoita, E., Bikketi, E., Njuguna, E., & Ojiewo, C. O. (2021). Technical Efficiency and Technology Gaps of Sorghum Plots in Uganda: A Gendered Stochastic Metafrontier Analysis. *Heliyon*, 7(1), E05845. Https://Doi.Org/10.1016/J.Heliyon.2020.E05845

Mitra, S., & Yunus, M. (2018). Determinants of Tomato Farmers Efficiency in Mymensingh District of Bangladesh: Data Envelopment Analysis Approach. *J Bangladesh Agril Univ*, *16*(1), 93-97.

Mohiuddin, M., Hasan, M. R., & Miah, M. M. (2020). Profitability Analysis of Cultivation of Banana Cultivars Sabri and Sagar in Some Areas of Narsingdi District. *Bangladesh Journal of Agricultural Research*, *45*(2), 175-183.

Moser, C. A. & Kalton, G. 1989. Survey Methods in Social Investigation, Aldershot, Gower.

Muchui, M. N., Gatambia, E. K., Kamau, M. W., Thuranira, D. M., Miruka, M., Wasilwa, L., & Gitau, C. (2013). Enhancing Small Scale Banana Production through the Farmer Field School in Eastern Kenya.

Mukami, N. N. (2018). Analysis of Technical Efficiency and Welfare Effects of Snow Peas Production by Small Scale Farmers in Nyandarua County Kenya (*Doctoral Dissertation, Egerton University*).

Mukhtar, U., Mohamed, Z., Shamsuddin, M. N., Sharifuddin, J., & Iliyasu, A. (2018). Application of Data Envelopment Analysis for Technical Efficiency of Smallholder Pearl Millet Farmers in Kano State, Nigeria. *Bulgarian Journal of Agricultural Science, 24*(2), 213-222.

Mulwa, R., Emrouznejad, A., & Muhammad, L. (2009). Economic Efficiency of Smallholder Maize Producers in Western Kenya: A DEA Meta-Frontier Analysis. *International Journal of Operational Research, 4*(3), 250-267.

Murongo, M., Wangai, K. J., Mwine, T. J., & Ayuke, O. F. (2018). Farmer-Based Dynamics in Tissue Culture Banana Technology Adoption: A Socio-Economic Perspective among Small Holder Farmers in Uganda. *African Journal of Agricultural Research* 13 (50), Pp. 2836- 2854.

Muthee, A. I., Gichimu, B. M., & Nthakanio, P. N. (2019). Analysis of Banana Production Practices and Constraints in Embu County, Kenya. *Asian Journal of Agriculture and Rural Development, 9*(1), 123-132.

Muthoni, J., Shimelis, H., & Melis, R. (2013). Potato Production in Kenya; Farming Systems and Production Constraints. *Journal of Agricultural Science*, 5, 5.

Muyanga, M., & Jayne, T.S. (2019). Revisiting The Farm Size-Productivity Relationship Based on a Relatively Wide Range Of Farm Sizes: Evidence From Kenya. *American Journal Of Agricultural Economics*, Vol 101,4, Pp.1140-1163. Https://Doi.Org/10.1093/Ajae/Aaz003

Muzeza, N. T., Taruvinga, A., & Mukarumbwa, P. (2023). Analysis Of Factors Affecting Technical Efficiency of A1 Smallholder Maize Farmers Under Command Agriculture Scheme in Zimbabwe: The Case of Chegutu And Zvimba Districts. *Cogent Economics & Finance*, *11*(1), 2163543.

Mwangi, T. M., Ndirangu, S. N., & Isaboke, H. N. (2020). Technical Efficiency in Tomato Production among Smallholder Farmers in Kirinyaga County, Kenya. *African Journal of Agricultural Research*, *16*(5), 667-677.

Mwendia, A. S. (2019). An Investigation of the Drivers of Diversification to Banana Farming among Households in Meru County, Kenya. *Unpublished Masters of Arts in Geography. Kenyatta University, Nairobi*.

Narcisse, M. (2017). Socio-Economic Factors Affecting Technical Efficiency of Small Holder's Maize Production in Rwanda (*Doctoral Dissertation, Thesis, Kenyata University, Kenya*).

Nchare, A. (2007). Analysis of Factors Affecting the Technical Efficiency of Arabica Coffee Producers in Cameroon.

Ndirangu, S. N., Mbogoh, S. G., & Mbatia, O. L. E. (2018). Evaluation of the Elasticity of Farm Output among Smallholder Farmers in Selected Agro-Ecological Zones of Embu County, Kenya.

Nguyen-Thi-Lan, H., Fahad, S., Ho-Ngoc, N., Nguyen-Anh, T., Pham-Van, D., Nguyen-Thi-Viet, H., & To-The, N. (2023). Crop Farming and Technical Efficiency of Tea Production Nexus: An Analysis of Environmental Impacts. *Journal of the Saudi Society of Agricultural Sciences*, *22*(3), 158-164.

Nickolas, S. (2021). Which Inputs are Factors of Production? *Investopedia*. Retrieved On March, 2022 from: Https://Www.Investopedia.Com/Ask/Answers/032715/What-Inputs-Are-Considered-Be-Factors-Production.Asp

Njue, N. I. (2015). Identity, Abundance and Management of Banana Thrips in Embu County, Kenya. *Master of Science Thesis, University Of Nairobi*.

Ntabakirabose, G. (2017). An Economic Analysis of the Factors Influencing Maize Productivity and Efficiency in Rwanda: A Case Study of Gatsibo District (*Doctoral Dissertation*, JKUAT).

Nyamamba, K. A., Ouna, T. O., Kamiri, H., & Pane, E. (2020). Effects of Land Use Change on Banana Production: A Case Study of Imenti South Sub-County of Meru County in Kenya. *Britain International of Exact Sciences (Bioex) Journal*, *2*(3), 640-652.

Obaga, B.R. & Mwaura, F.O. (2018). Impact of Farmers' Participation in Banana Value Addition in Household Welfare in Kisii Central Sub-County. *International Academic Journal of Social Sciences and Education*, 2(1), Pp.25–46

Obwona, M. (2006). Determinants of Technical Efficiency Differentials amongst Small- and Medium Scale Farmers in Uganda: A Case of Tobacco Growers. *African Economic Research Consortium*. Retrieved On April, 2022 from: Https://Opendocs.Ids.Ac.Uk/Opendocs/Bitstream/Handle/20.500.12413/2237/RP%20152.Pdf?Sequence=1

Ochilo, W. N., Nyamasyo, G. N., Kilalo, D., Otieno, W., Otipa, M., Chege, F., & Lingeera, E. K. (2019). Characteristics and Production Constraints of Smallholder Tomato Production in Kenya. *Scientific African*, *2*, E00014.

Ochola, D., Ocimati, W., Tinzaara, W., Blomme, G. & Karamura, E.B. (2015). Effects of Water Stress on the Development of Banana Xanthomonas Wilt Disease. *Plant Pathology 64*(3):552-558.

Ofori-Appiah, Y., Onumah, E. E., & Asem, F. E. (2022). Efficiency and Productivity Analysis of Pineapple Farmerss in the Akwapim-South District of Ghana: A Distance Function Approach. *African Journal of Science, Technology, Innovation and Development*, *14*(2), 512-522.

Okonya, J. S., & Kroschel, J. (2015). A Cross-Sectional Study of Pesticide Use and Knowledge of Smallholder Potato Farmers in Uganda. *Biomed Research International*, *2015*.

Olarinde, L. O. (2011). Analysis of Technical Efficiency Differentials among Maize Farmers in Nigeria. *African Economic Research Consortium*, Nairobi. January 2011

Olumba, C. C., & Onunka, C. N. (2020). Banana and Plantain in West Africa: Production and Marketing. *African Journal of Food, Agriculture, Nutrition and Development*, *20*(2), 15474-15489.

Omache, N. (2016). *Factors Influencing Agricultural Productivity in Kenya: A Case of Nyathuna Ward in Kabete Sub-County, Kiambu County* (Doctoral Dissertation, University Of Nairobi).

Omondi, W., Bett, H., & Njagi, T. (2020). Influence of Collective Action Participation on Technical Efficiency among Smallholder Producers: A Case of Banana Farmers in Kisii and Nyamira, Kenya. *Journal of Food Security*, *8*(3), 105-116.

Onuwa, G. C., Mailumo, S. S., Chizea, C. I., Onemayin, J. J., Idris, R. S., Abalaka, E. A. & Ebong, A. C. (2022). Technical Efficiency in Cowpea (Vigna Unguiculata) Prodction in Kanke, Plateau State, Nigeria. *FUDMA Journal of Agriculture and Agricultural Technology*, 8(1): 372-382.

Otitoju, M. A., & Arene, C. J. (2010). Constraints and Determinants of Technical Efficiency in Medium-Scale Soybean Production in Benue State, Nigeria. *African Journal of Agricultural Research*, *5*(17), 2276-2280.

Oyetunde-Usman, Z., & Olagunju, K. O. (2019). Determinants of Food Security and Technical Efficiency among Agricultural Households in Nigeria. *Economies*, *7*(4), 103.

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533-544.

Paltasingh, K. R., & Goyari, P. (2018). Impact of Farmer Education on Farm Productivity under Varying Technologies: Case of Paddy Growers in India. *Agricultural and Food Economics*, *6*(1), 1-19.

Pillay, M., Ashokkumar, K., Arun Siva Shunmugam, K., & Elayabalan, S. (2012). A Case for Molecular Breeding in Musa. Genetics, Genomics and Breeding of Bananas, Page 280–297. Https://Doi.Org/10.13140/2.1.1246.7205

Reifschneider, D., and Stevenson, R. (1991). Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency. *International Economic Review*, 715-723

Rekhi, S. (2022). The Production Process (With Diagram). *Economics Discussion*. Retrieved From Https://Www.Economicsdiscussion.Net/Theory-Of-Production/The-Production-Process-With-Diagram/19900.

Rukwe, D. T., & Zubairu, E. A. (2019). Determinant of Technical Efficiency of Sesame Production in Kurmi Local Government Area of Taraba State, Nigeria. *Journal of Agriculture and Veterinary Science*, *12*(1), 43-51.

Runo, B., Nyangena, W., & Githiaka, K. (2009). Technical Efficiency amongst Coffee Framers in Kenya: A Case Study Of Githunguri Division, Kiambu District. *Masters Thesis*, University Of Nairobi.

Saliu, L. A., Abdulrazaq, S. A., & Yetter, F. E. (2017). Socioeconomic Analysis of Soybean Production among Small Scale Farmers in Kaduna State, Nigeria (No. 2223-2019-1818).

Sapkota, M., Joshi, N. P., Kattel, R. R., & Bajracharya, M. (2017). Technical Efficiency and Its Determinants on Maize Seed Production in Palpa District, Nepal.

Shaibu AA, Maji EA, Ogburia, MN (2012). Yield Evaluation of Plantain and Banana Landraces and Hybrids in the Humid Agro-Ecological Zone of Nigeria. *Journal of Agricultural Research and Development* 2(3):74- 79.

Sharma, M., Chandra Dhakal, S., Adhikari, R. K., & Tiwari, U. (2021). Profitability, Productivity and Resource Use Efficiency of Banana Production in Hetauda-Dumkibas Road Corridor, Nepal. *Cogent Food & Agriculture*, *7*(1), 1917134.

Shettima, B. G., Amaza, P. S., & Iheanacho, A. C. (2015). Analysis of Technical Efficiency of Irrigated Vegetable Production in Borno State, Nigeria. *Journal of Agricultural Economics, Environment and Social Sciences, 1*(1), 88-97.

Siaw, A., Jiang, Y., Ankrah, T, M., Agbenyo, W., Ntim-Amo, G., Osei, D, F., & Ankrah, E. (2020). The Ripple Effect of Credit Accessibility on the Technical Efficiency of Maize Farmers in Ghana. *Agricultural Finance Review*.DOI-10.1108/AFR-05-2020-0068.

Simonyan, J. B., Umoren, B. D., & Okoye, B. C. (2011). Gender Differentials in Technical Efficiency among Maize Farmers in Essien Udim Local Government Area, Nigeria. *International Journal of Economics and Management Sciences*, *1*(2), 17-23.

Sui, F., Yang, Y., &Zhao, S. (2022). What Affects the Production Technology of Labor-Intensive Agricultural Industries in the Context of Labor Aging? An Empirical Study Based on the Garlic Production in Lanling. *Sustainability 2022, 14*, 48. Https://Doi.Org/10.3390/Su14010048

Sulaiman, M., Abdulsalam, Z., Damisa, M., & Siewe, F. (2015). Resource Use Efficiency in Sugarcane Production in Kaduna State, Nigeria: An Application of Stochastic Frontier Production Function. *Asian Journal of Agricultural Extension, Economics and Sociology*, *7*(2), 1-11.

Taiy, R.J., Onyango, C., Nkurumwa, A., & Ngetich, K. (2017). Socio-Economic Characteristics of Smallholder Potato Farmers in Mauche Ward of Nakuru County, Kenya. Universal *Journal of Agricultural Research, 5*, 257-266.

Tamirat, N., & Tadele, S. (2023). Determinants of Technical Efficiency of Coffee Production in Jimma Zone, Southwest Ethiopia. *Heliyon*, *9*(4).

Tasila Konja, D., Mabe, F. N., & Alhassan, H. (2019). Technical and Resource-Use-Efficiency among Smallholder Rice Farmers in Northern Ghana. *Cogent Food & Agriculture*, *5*(1), 1651473.

Tenaye, A. (2020). Technical Efficiency of Smallholder Agriculture in Developing Countries: The Case of Ethiopia. *Economies*, 8(2), 34.

Thabethe, L. S. (2013). Estimation of Technical, Economic and Allocative Efficiencies in Sugarcane Production in South Africa: A Case Study of Mpumalanga Growers (*Doctoral Dissertation, University Of Pretoria*).

Tiruneh, W. G., & Geta, E. (2016). Technical Efficiency of Smallholder Wheat Farmers: The Case of Welmera District, Central Oromia, Ethiopia. *Journal of Development and Agricultural Economics, 8*(2), 39-51.

Tolno, E., Kobayashi, H., Ichizen, M., Esham, M., & Balde, B.S. (2016). Potato Production and Supply by Smallholder Farmers in Guinea: An Economic Analysis. *Asian Journal of Agricultural Extension, Economics and Sociology 8*(3):1–16

Tukara, R., & Ashindo, Z. (2019). Determinant of Technical Efficiency of Sesame Production in Kurmi Local Government Area of Taraba State, Nigeria. *Journal of Agriculture and Veterinary Science, 12*(5)43-51.

Tumuhimbise, R., & Talengera, D. (2018). Improved Propagation Techniques to Enhance the Productivity of Banana (Musa Spp). *Open Agriculture, 3*(1), 138-145. Https://Doi.Org/10.1515/Opag-2018-0014.

Ugbabe, O. O., Abdoulaye, T., Kamara, A., Mbaval, J., & Oyinbo, O. (2017). Profitability and Technical Efficiency of Soybean Production in Northern Nigeria. *Tropicultura*.

Ullah, A., Khan, D., & Zheng, S. (2017). The Determinants of Technical Efficiency of Peach Growers: Evidence from Khyber Pakhtunkhwa, Pakistan.

United Nations (2013). Facing the Challenges of Climate Change and Food Security: The Role of Research, Extension and Communication Institutions - Final Report. Rome: Food and Agriculture Organization of the United Nations, Wageningen University and UNU-MERIT. October.

United States Agency for International Development (USAID). (2014). Horticulture Validated Report 2014.

United States Agency for International Development (USAID). (2017). Horticulture Validated Report 2016.

Van Hung, H., Van Huong, N., Oanh, T. T. K., Van Chuong, N., Tiep, N. C., Van Ha, T., & Luong, N. T. (2022). Technical Efficiency of Smallholder Banana Production: A Case Study in Viet Nam. *Agbioforum*, *24*(2), 58-64.

Vinayagamoorthi, N., Sekhar, C., Palanichamy, N. V., Harishankar, K., & Balaji, P. (2019). Technical Efficiency of Banana Production in Central Tamil Nadu. *International Research Journal of Agricultural Economics and Statistics*, *10*(1), 122-132.

Voora, V., Larrea, C., & Bermudez, S. (2020). Global Market Report: Bananas. International Institute for Sustainable Development.

Voora, V., Bermúdez, S., Farrell, J. J., Larrea, C., & Luna, E. (2023). Banana Prices and Sustainability. Https://Www.Iisd.Org/System/Files/2023-03/2023-Global-Market-Report-Banana.Pdf

Vu, H.V., Ho, H., & Hoi, L.Q. (2019). Impact of Farmer Education on Production Efficiency: The Case of Rice Farms in Vietnam. *Management Science Letters*, 9(11):1909-1918. DOI: 10.5267/J.Msl.2019.6.002

Wahome, C. N., Maingi, J. M., Ombori, O., Kimiti, J. M., & Njeru, E. M. (2021). Banana Production Trends, Cultivar Diversity, and Tissue Culture Technologies Uptake in Kenya. *International Journal of Agronomy*, *2021*.

Wanjiku, G. G. (2015). Post-Harvest Fungi Diversity and Level of Aflatoxin Contamination in Stored Maize: Cases of Kitui, Nakuru and Trans-Nzoia Counties in Kenya (*Doctoral Dissertation, Kenyatta University*).

World Bank. (2020). Agricultural Technology and Agribusiness Advisory Services Project. Agriculture and Rural Development, African Region. Kampala, Uganda.

Wudineh, G.T., & Endrias, G. (2016). Technical Efficiency of Smallholder Wheat Farmers: The Case of Welmera District. *Journal of Development and Agricultural Economics, Vol. 8*(2), Pp. 39-51, February, 2016.

Yegon, P. K., Kibet, L. K., & Lagat, J. K. (2015). Determinants of Technical Efficiency in Smallholder Soybean Production in Bomet District, Kenya. *Journal of Development and Agricultural Economics*, *7*(5), 190-194.

APPENDICES

Appendix 1: Introductory Letter

Dear Sir/Madam,

I'm Jackson Mkenye Mativa, a student at Chuka University pursuing a Master of Science Degree in Agribusiness Management. I am conducting a scholarly study on **"Analysis of Production, Socio-economic and Institutional Factors Affecting Smallholder Banana Production Technical Efficiency in Kirinyaga Central Sub-County, Kenya."** The purpose of this study is to partially satisfy the academic requirements for the award of the degree in agribusiness management at Chuka University. I humbly request that you answer the questions honestly. The responses will be treated with the utmost confidentially, and the data will be applied to the study's goals. I appreciate your involvement in the study.

Yours faithfully,

Jackson Mativa
ID No: 28680959
Tel No: 0712773879

Appendix 2: Questionnaire

This study is being carried out to find out the technical efficiency and identify production, socio-economic and institutional factors affecting efficiency among smallholder's banana producers in Kirinyaga County, Kenya. The information will provide information for academic studies. The data required is for the period 2022 production year and all information will be held in strict confidence.

Questionnaire identification

Questionnaire Number ……. Date …….

Sub-County …….....

Ward…….

Part A: Smallholder banana producers' Socio-economic information

1.1Gender of the respondent: Male …….... Female…….

1.2 Are you the household head? Yes……... No……

1.2.1 Occupation …….

1.2.2Age below 20yrs……. 20-30yrs ……... 31-40yrs …….

41-50yrs …… 51-60yrs...……. Above 60yrs……...

1.3 If No in 1.2, indicate your relationship with the household head

1= Wife ……2= Son …….....

3=Daughter …….4= other (specify)……

1.4 Formal education level of the household head (*Please tick where appropriate*)

1. None ……...2. Primary school …….

3. Secondary school ……. 4. College …….

5. University …….

1.5. Marital status of decision maker. *Please tick as appropriate.*

1=Married ……. 3=Divorced ……

2=Single (Never married) ……. 4=Widowed ……

1.6 what is the number of people in your household? (Those who live and depend on you) ……

Adults……... Children……

1.7 For how long have you been growing bananas?

1-5 Years……. 6-10 Years…… 11 –15 Years……

16-20Years…… Above 20 Years

If not the household head, how long has the household head been growing banana? ..... Years

Part B: Inputs used in Banana Production

Planting Materials

2.1 What variety of banana do you have in your field?

Local …… (Name) Improved……. (Name)

2.2 Where is your source of sucker?

Own plantation ……. Local market …….

Other producer……. Research Center ……

University/College ……. Other (Specify) ……

2.3 Do you purchase banana sucker?

Yes …… No …….

If yes, what is price/sucker…….

Land

2.4 What size of land do you have (in acres)? Less than 1 acre ……. 1-3 acres…

3-5 acres …… More than 5 acres …….

2.5 Is the land Rented ……. Acres or owned ……. Acres or Both …… Acres

2.6 How much land do you plan to plant bananas on? (*Tick where appropriate*)

i) 0-0.5 acres …… ii) 0.5-1acres ……. iii) 1-1.5 acres …..... iv) 1.5-2 acres ……. v) Above 2 acres …….

Farm Inputs

2.7 Have you ever used the following inputs?

Organic manure Yes…… No ……

Inorganic fertilizer Yes …… No…….

2.8. If Yes which ones did you use and how much?

Fertilizer		
Type of Fertilizer	Quantity of Fertilizer	Price of fertilizer.(Per Kg)
1.MAP		
2.DAP		
3.TSP		
4.Manure		
5= Other Specify		

Agrochemicals

2.10 Did you use any herbicides in the year 2021? Yes…… No……

If Yes, which one ……. And quantity …… Kgs

Price of herbicides? .....Ksh per ……. (ML, Kg)

2.11 Was your banana plantation affected by any disease or pests?

Yes……. No…….

If Yes, which ones? .....

How did you control? .....

Quantity ……. Price ……

Labour

2.12 What is your primary source of labor? Family……. Hired……. Both……

2.13 How many man-days were spent in the following activities during the year 2022 of banana production?

Activity	Family Labour	Hired Labour
Planting		
Weeding		
Harvesting		
Other		

2.14 What's the price of one-man hour per day for hired labour……Ksh

3.0. Banana Production Yields and Marketing

3.1. How often do you harvest your bananas? …….

3.2. How many kilograms of bananas were harvested in the last one year (2022) ……?

3.3. Were the harvested bananas eaten at home?

Yes ……. No …….....

3.4. If yes, what quantities ……..…

3.5. If any of the banana were sold, where did you sell?

Neighbors /Farm gate ……. Local market……. Middle men

Cooperative union……Factory ……Other (Specify)……

3.5.1. If YES, please provide the following information

Quantity	Average Selling Price	Total Revenue

3.6 What's the distance between your farm and the banana market?

Less than 5 Km …… 5 Km – 10 Km …….

10 Km – 20Km ……. Over 20 Km …….

3.7. What is the state of the road to the market?

Murrum ……. Tarmac …….

Other (Specify)…….

Part C: Institutional Factors

4.0 Access to Extension Services

4.1 Have you had any visits from extension agents to discuss banana production in 2022?

YES ……. NO …….....

4.2. If YES, please fill the table below.

Provider/extension agent 1=Government 2=NGO 3=Fellow producer 4=other(specify)	2021		
	Topic 1=Planting eg seed rate, spacing 2= Use of agro-chemicals 3=marketing 4= others specify	Number of visits by extension agent	Avg. time for each visit(hrs)

N/B: Extension is a quick, out-of-class information exchange between producers and extension agents.

4.3. Did you go to any extension agents to ask for help if they didn't come to you for banana producing tips?

Yes ……. No …….

4.4. If YES, fill the following table

Provider/extension agent 1=Government 2=NGO 3=Fellow producer 4=other(specify)	2022		
	Topic 1=Planting eg seed rate, spacing 2= Use of agro-chemicals	Number of visits by extension agent	Avg. time for each visit(hrs)

	3=marketing 4= others specify		

5.0: Membership in an Organization

5.1. Are there any groups dealing with banana production or marketing in your area?

Yes …… No ……

5.2.1 If YES, did you belong to any producers' association or cooperative?

Yes …… No …….

5.2.2 Did any household member belong to any of these groups last year?

Yes ……. No ……

Relation with HH head	Group 1= banana producer 2= banana marketing	Year HH member joined	Main activities of the organization	Benefits received by member

5.3. Did any member of the household belong to a local group other than banana group membership in 2021?

Yes …… No ……

5.4. If YES please fill the table below. *Please complete for any household member who belongs to local group.*

Relation with HHH	Organization 1= Producer group 2= NGO project 3=CBO 4=Government Project 5=Other (Specify)	Year HH member joined	Main activities of the organization 1= Financial services (SACCO) 2= Mutual Support 3=Extension Services 4= Marketing agric. Products 5=other(specify)	Benefits received by member

NB: Producers associations include women's associations, youth associations, mutual support group, church, a marketing cooperative, credit or saving group etc.

6.0: Access to Credit

6.1. Did you have access to informal/ formal credit in 2022?

Yes …… No ……

6.2. If YES, fill the table:

Source	Amount	Repayment Period	Purpose
NGOs			
Banks			
Cooperatives			
Intermediaries			
Rotating credit and saving(table banking)			
Others(Specify)			

6.3. If you did not apply, why not?

……

……

……

……

Appendix 3: NACOSTI Research License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **620835**

Date of Issue: **08/November/2022**

RESEARCH LICENSE

This is to Certify that Mr.. Jackson Mkenye Mativa of Chuka University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Kirinyaga on the topic: ANALYSIS OF SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS AFFECTING TECHNICAL EFFICIENCY OF SMALLHOLDER BANANA PRODUCERS IN KIRINYAGA CENTRAL SUB-COUNTY, KENYA for the period ending : 08/November/2023.

License No: **NACOSTI/P/22/21694**

620835

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix 4: Chuka University Ethics Letter of Ethics

CHUKA UNIVERSITY

Knowledge is Wealth *(Sapientia divitia est)* Akili ni Mali
CHUKA UNIVERSITY INSTITUTIONAL ETHICS REVIEW COMMITTEE

Telephones: 020-2310512/18
Direct Line: 0772894438
P. O. Box 109-60400, Chuka
Email: info@chuka.ac.ke,
Website: www.chuka.ac.ke

REF: **CUIERC/ NACOSTI 316** 25th October, 2022

TO: **Jackson Mkenye Mativa**

Dear Sir/madam

RE: Analysis of Socio-Economic and Institutional Factors Affecting Technical Efficiency of Small Holder Banana Producers in Kirinyaga Central Sub-County, Kenya

This is to inform you that *Chuka University IERC has* reviewed and approved your above research proposal. Your application approval number is *NACOSTI/NBC/AC-0812.* The approval period is 25th October, 2022 to 25th October,2023.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by *Chuka University IERC.*
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to *Chuka University IERC* within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to *Chuka University IERC* within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days upon completion of the study to *Chuka University IERC.*

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

Dr. Benjamin Kanga
SECRETARY

Appendix 5: Kirinyaga County Commissioner Research Authorization Letter

OFFICE OF THE PRESIDENT
MINISTRY OF INTERIOR AND COORDINATION
OF NATIONAL GOVERNMENT

Telegrams "*COMMISSIONER*" Kerugoya
Telephone. 21053 Kerugoya

countycommissionerkirinyaga@gmail.com

COUNTY COMMISSIONER
KIRINYAGA COUNTY
P.O. BOX 1
KERUGOYA

ADM.1/23/VOL.III/81

11TH NOVEMBER, 2022

Jackson Mkenye Mativa
P.O.Box 109 -60400
CHUKA-KENYA.

RE: RESEARCH AUTHORIZATION ON THE TOPIC: ANALYSIS OF SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS AFFECTING TECHNICAL EFFICIENCY OF SMALL HOLDER BANANA PRODUCERS IN KIRINYAGA CENTRAL SUB-COUNTY, KIRINYAGA COUNTY.

Reference is made to your letter Ref. 620835 dated 8th November, 2022 concerning the above subject matter.

I am glad to inform you that authority has been granted to conduct research on the topic: "***Analysis of socio-economic and institutional factors affecting technical efficiency of small holder banana producers in Kirinyaga Central Sub-county, Kirinyaga County, Kenya***", for the period ending 8TH November, 2023.

By a copy of this letter Deputy County Commissioner Kirinyaga Central Sub County and County Director of Education are requested to accord you the necessary assistance.

for Moses Ivuto
County Commissioner
KIRINYAGA COUNTY.

Copy to:

Deputy County Commissioner
KIRINYAGA CENTRAL SUB COUNTY.

County Director Education
KIRINYAGA COUNTY.

Appendix 6: Kirinyaga County Director of Education Research Authorization Letter

REPUBLIC OF KENYA
MINISTRY OF EDUCATION
State Department of Early Learning and Basic Education

Telephone: 060-21835/0202641217
Email kirinyagacde1@gmail.com
When replying please quote
Ref. No. and date

COUNTY DIRECTOR OF EDUCATION
KIRINYAGA COUNTY
P. O. BOX 96
KERUGOYA

REF.NO.MOE/CDE/KRG/GEN/09/85/104 **11th November, 2022**

JACKSON MKENYE MATIVA
P O BOX 109-60400
CHUKA-KENYA

RE: RESEARCH AUTHORIZATION

Reference is made to your undated letter and further County Commissioner Letter ADM.1/23/Vol.III/81 dated 11th November 2022 on the above subject matter.

I am glad to inform you that authority has been granted to conduct research on the topic: ***"Analysis of socio-economic and institutional factors affecting technical efficiency of small holder banana producer in Kirinyaga Central Sub County, Kirinyaga County, Kenya.***

By a copy of this letter, the Sub County Director is requested to accord you the necessary assistance.

MARGARET MWANGI
FOR: COUNTY DIRECTOR OF EDUCATION
KIRINYAGA

Appendix 7: Research Pictures