EFFECTS OF INSTITUTIONAL FACTORS, FARM AND FARMERS' CHARACTERISTICS ON TECHNICAL EFFICIENCY AND COMMERCIALIZATION OF FRENCH BEAN PRODUCTION AMONG SMALLHOLDER FARMERS IN SELECTED COUNTIES, KENYA

BETH WANGARI KAMAU

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

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DECLARATION AND RECOMMENDATION

Declaration

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

Signature: ………………………… Date: ………………………………………..
Kamau Beth Wangari
NM25/45702/20

Recommendation

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

Signature: ………………………… Date: ……………………………………..…
Prof. Moses M. Muraya, Ph.D
Chuka University

Signature: ………………………... Date: ……………..…………………………
Dr. Grace Abucheli, Ph.D
Chuka University

DEDICATION

This work is dedicated to my parents, Samuel Kamau and Susan Wanjiru, as well as my siblings Mary, John, and Peter, and to all of my friends.

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ABSTRACT

French bean production makes a significant contribution to the GDP, employment, farmers' income, and welfare. However, french bean farming involves many practices thus more capital is required; as smallholder farmers must invest approximately KES 311,353 per hectare of land for the french bean growing season. There is an observed 4.1% french bean demand increase in Kenya. Despite this, smallholder french bean yield is low which is 5.93 to 7.91 tonnes per hectare, compared to the world's potential yield of 9.88 to 14.83 tonnes per hectare. Hence, smallholder farmers receive low returns which may also lead to a decline in commercialization level. Therefore, the study sought to identify smallholder french bean farms and farmers' characteristics as well as to determine the effect of institutional factors, farm and farmers' characteristics on technical efficiency and commercialization of french bean production respectively. The study was carried out in areas diversifying in french bean production such as Machakos, Kajiado, Taita Taveta, Bungoma, and Trans Nzoia Counties, Kenya. Cross-sectional data on the 2021 production season was collected from 288 french bean farmers from selected counties using a cluster random sampling technique. A semi-structured questionnaire was used to collect data on institutional factors, farm, and farmers' characteristics. Data was analyzed using Stata version 17 and SAS version 9.4. Descriptive statistics was used in the characterization of smallholder french bean farms and farmers. Cobb-Douglas function under the stochastic frontier approach was used to determine the effect of institutional factors, farm and farmers' characteristics on french bean production technical efficiency. French bean production technical efficiency level among french bean smallholder farmers was found to be 86.07%. These findings suggest that given the prevailing resources, smallholder french bean farmers can still increase current production by 13.93%. Variables such as land size, manure quantity, certified seeds, second-generation seeds, fertilizer, and planting labor increased the output of french bean farmers. As a result, an increase in either input will result in an increase in french bean production. Results from the inefficiency model indicated that gender, education level, distance to market and experience all had positive and significant impact on french bean production technical efficiency. The positive effect implies that increase in any of them by one units holding other factors constant increases french bean production technical efficiency by corresponding units. Whereas, increase in soil testing negatively and significantly ($p < 0.01$) decreases french bean production technical efficiency. Tobit model was used to assess the impact of institutional factors, farm, and farmer characteristics on french bean production commercialization. The results showed that 60.09% of french bean smallholder farmers were commercialized. Results further showed that gender and age positively and significantly ($p < 0.05$) affected french bean commercialization. Household size distance to market and access to training services had a negative and significant ($p < 0.05$) effect on french bean production commercialization. The negative coefficient implies that increase in any of this factors holding other factors constant reduces french bean production commercialization. This study encourages french bean smallholder farmers to increase use of certified seeds, quantity of fertilizer, land size and manure. Male-headed households and educated farmers should be encouraged to start growing french beans. The government should establish institutions to ensure the formation of markets in french bean growing areas, thereby reducing the distance covered by these farmers when marketing french bean produce and motivating these farmers to produce more and thus deliver more output to the market.

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ABBREVIATIONS AND ACRONYMS

CIAT	International Centre for Tropical Agriculture
DEA	Data Envelope Analysis
DFID	Department for International Development
DHM	Double Hurdle Model
EABRN	East African Bean Research Network
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistical Database
FPEAK	Fresh Produce Association of Kenya
GDP	Gross Domestic Product
GOK	Government of Kenya
HCD	Horticultural Crops Directorate
KNBS	Kenya National Bureau of Statistics
MOALF	Ministry of Agriculture, Livestock & Fisheries
NDO	Netherlands Development Organization
SFA	Stochastic Frontier Approach

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Agriculture remains the leading sector in stimulating economic growth in Kenya due to liberation, political stability, continued government support, and the provision of an enabling environment (Nyoro, 2019). It contributes directly and indirectly to Gross Domestic Product (GDP) annually at 26% and 27% respectively [Kenya National Bureau of Statistics (KNBS), 2019]. Other opportunities in the agricultural sector include employment, rural development, export diversification, and poverty alleviation [Food and Agriculture Organization (FAO), 2020]. The agriculture sectors comprise; horticulture, livestock, fisheries, forestry, and industrial and food crop production. Horticulture (cut flowers, vegetables, and fruits) and industrial crops (tea and coffee) contribute 76.5% of agriculture GDP (Kamau, 2017; KNBS, 2020).

The horticulture sector is the fastest-growing agricultural sector and the third foreign exchange earner after tea and tourism as it earns about 150 billion Kenya shillings annually, contributing significantly to the Kenyan economy [Horticultural Crops Directorate (HCD), 2021]. The success of the horticulture sector can be associated with technical training availability, more market access, and the adoption of up-to-date technology in this sector (Tyce, 2020). To assure quality produce, players in the industry train and support exporters and producers on the approved international requirement on production measures (Fulano *et al.*, 2021). The main crops produced and exported in this sector are cut flowers and vegetables, contributing to 38% and 35% of total fresh produce exports, respectively (HCD, 2021). The primary vegetables produce include french bean, sugar snap, snow pea, and Asian vegetables (Ikiba, 2017).

French bean *(Phaseolus Vulgaris L.)* originated from Mexico, South and Central America, where it has been grown for at least 5000 years as an indigenous crop (Salaue, 2019). The legume was introduced in Africa and Europe by Portuguese and Spanish explorers, and by the 19th century, it became common in France as *haricot verts* hence the name french bean (Ngelezi, 2017). Today french bean is grown worldwide and used as an alternative to other legumes, for example, common beans and cowpeas. China, is the leading producer of french bean globally, as it produces approximately 80% of the entire world's french bean output which is equivalent to a productivity level of 15.07

to 20.02 tonnes per hectare. From 2017 to 2019, China recorded an increase in french bean production (FAOSTAT, 2020). This increase can be attributed to the high demand for legumes, and vegetables in the domestic and export market improved inputs, and availability of labour (Ling, 2017). Other reasons include favourable climatic conditions, improved soil fertility, intercropping, and the adoption of innovations that reduce production costs, i.e., greenhouse farming (Rahimikhoob *et al.,* 2020). In Africa, Egypt is the leading french bean producer with an average production of 288 000 tonnes (FAOSTAT, 2020). This production level can be attributed to opportunities such as adopting quality inputs, irrigation methods, improved farming methods, and promotion of resource conservation methods (Attia, 2019).

In Kenya, there is an observed decline in french bean production in the years 2017, 2018, and 2019 that is from 41,686, 41,051 to 40,416 tonnes, respectively. Kenya's smallholder produces approximately 5.93 to 7.91 tonnes per hectare, which is below the world's expected yield potential of 9.88 to 14.83 tonnes per hectare (HCD, 2020). There is a gap between actual and expected french bean yield, which could result from losses associated with production inefficiency (Ikiba, 2017). This gap could be attributed to high intensive labour, low-quality seeds, small-sized land, inadequate funds, pest and diseases, and lack of market, training, support services, and credit access. Consequently, the smallholder farmers usually get low output, which generally translates to low income (Kibet, 2019).

In Kenya, french bean is mainly grown by smallholder farmers in warm areas in the Central, Eastern, Rift Valley, Western and Coastal regions. These areas include Kajiado, Taita Taveta, Bungoma, Machakos, Trans-Nzoia, Muranga, Kiambu, Kirinyanga, Meru and Nakuru counties. The central region is the major french bean-producing region in Kenya (Masinga *et al.,* 2014; KNBS, 2019). About 80% of french bean growers in Kenya are smallholder farmers, and 20% are large-scale farmers (Kok *et al.,* 2019). The popular french bean varieties grown by the farmers include Samantha, Paulista, Army, Serengeti, Julia, and Teresa. Since french bean production takes place throughout the year, a high level of inputs is required (Ngelezi, 2017).

French bean production is capital-intensive due to required farming practices (Ondieki *et al*., 2012; Kibet, 2019). More than 50% of french bean production costs include labour costs [Department for International Development (DFID), 2018]. Smallholder farmers must set aside approximately KES 311,353 per hectare of land for french bean production in Kenya (Masinga *et al.,* 2014; Tonui, 2017). Elsewhere, for example in Egypt, the production cost is lower, approximately KES 82,637 per hectare of land for french bean production (Mohamed *et al.,* 2018). The high production cost in Kenya could partly be due to production inefficiencies, which can be attributed to poor farming systems, resulting from institutional factors (institutional services, credit access, and organizational membership), farm (land allocation and production inputs) and farmers (age, occupation, experience, education level, gender, and household size) characteristics leading to low yield. Therefore, there exists a knowledge gap in identifying determinants of technical efficiency in french bean production.

Since the 1950s, Kenya has been exporting french bean to Europe, with the main importing countries being France, Belgium, the United Kingdom, Holland, and Germany. According to KNBS (2019), french bean contribution to the balance of trade was 7.1 % representing 1.5% of total annual exports. Despite an increase in French bean export demand in Kenya of 4.1% by 2020, benefits from this sector may bypass smallholder farmers, who are the industry's bulk producers (HCD, 2020; Pasquali, 2021) These could be brought about by critical challenges faced by smallholder farmers as a result of changes in export markets that threaten produce procurement (Henson *et al.,* 2008; Vermeula *et al.,* 2008; Gichuki *et al.,* 2019). Inspection of whether farmers meet the required standards, found that compliance cost, could lead to income reduction, especially for smallholder farmers as it charges 9.51 USD/tonne/year or 3.8% product cost (Gichuki *et al.,* 2019). Due to the high production cost involved most smallholder farmers end up selling their produce to brokers at a lower cost ranging between KES 40 to KES 60 and an average of KES 70 per kilogram if one bypasses brokers. This farm gate price offered by brokers represents about 8% price of french bean sales in European supermarkets, thus most of the french bean smallholder farmers receive very little from their sales (Fulano *et al.,* 2021).

Many challenges are facing the french bean value chain for domestic and export markets, thus limiting its production (Kok *et al.,* 2019). These include access to quality inputs and equipment, pests and diseases, and limited infrastructural services (markets, financing services, and support services). High-quality standards must be met during french bean production, which is challenging for smallholder farmers, mainly for the export market (Mburu, 2020). If these qualities are not met, the smallholder farmers sell french bean at a lower price, thus, most smallholder farmers may end up losing their market share (Kamau, 2017). Since french bean is a crucial sub-sector owing to the adoption of required standard thus increasing export demand. However, an increased land subdivision in the central Kenya region has resulted in continuous french bean production on the same piece of land, increasing chemical concentration in the soil and resulting in substandard output (Matere, 2020). Therefore, exporters are looking for new diversifying areas adaptable to french bean production such as Kajiado, Machakos, Taita Taveta, Bungoma, and Trans Nzoia Counties to ensure quality output. Thus there was the need to identify institutional factors, farm and farmers' characteristics affecting french bean productions' technical efficiency and commercialization in new frontier Counties.

Studies on technical efficiency determinants among different crops have been carried out (Ambetsa *et al.*, 2020; Okoror & Areal 2020; Mwangi *et al.*, 2020). Also, understanding commercialization determinants is a way of unlocking constraints affecting french bean sector development. Most research has also identified factors affecting agricultural crop commercialization (Ingabire *et al.,* 2017; Rabbi *et al.,* 2019; Regesa *et al.,* 2019; Kahenge *et al.,* 2021). Factors such as credit, market, and extension services access, education level, distance to the nearest market, family size, use of improved seeds, household size, farmer's age, land allocation, experience, and group membership were found to affect technical efficiency and commercialization of crop production independently and significantly (Mamo *et al.,* 2017; Rabbi *et al.,* 2019). These study revealed that institutional factors, farmers, and farm characteristics determine the technical efficiency and commercialization of crop production.

Although several studies have been conducted on technical efficiency and commercialization of smallholder crop production, there is limited information on technical efficiency and commercialization of french bean in the new frontier french beans growing Counties. These Counties have different agro-ecological conditions, farms, and farmers' characteristics, and therefore findings from studies from the traditional french bean growing Counties may not apply to the case of french bean production technical efficiency and commercialization in these counties. Thus a study to bridge this gap in identifying the effect of institutional factors, farm and farmers' characteristics on technical efficiency and commercialization of french bean production in selected Counties of Kenya was necessary.

1.2 Statement of the Problem

Input requirements for french bean production in Kenya are very costly, due to production inefficiencies, compared to those in other countries such as Egypt. French bean smallholder farmers must invest approximately 2609.83 USD per hectare which is high compared to that of a country like Egypt 692.68 USD. Despite this, Kenya's smallholder french bean potential yield is low compared to the regional and world average yield. Low returns on french bean sales have also been observed, possibly as a result of the use of sub-optimal inputs, yielding low-quality outputs, as well as low farm gate prices. As a result of low yields and returns, the majority of smallholder farmers lose market share due to inconsistent supply. Crop productivity and output can be increased by increasing input use or utilizing improved farming methods. Thus, if french bean smallholder farmers produce for commercial purposes, they must improve their efficiency with available resources to increase production and supply to the market. Studies on factors affecting commercialization and technical efficiency in french bean production among smallholder farmers are limited in Kenya. Therefore, there was a need to identify the determinants of technical efficiency and commercialization of french bean production.

1.3 Objectives of the Study

1.3.1 General Objective

The study investigated the effect of institutional factors, farm and farmer characteristics on technical efficiency and commercialization of french bean among smallholder farmers in selected Kenyan counties.

1.3.2 Specific Objectives

i. To characterize smallholder french bean farms and farmers' in selected Counties of Kenya.
ii. To determine the effect of farm characteristics on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya.

iii. To determine the effect of farmers’ characteristics on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya.

iv. To determine the effect of institutional factors on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya.

1.4 Research Question

Based on specific objectives, the research sought to answer the following questions:

i. How are smallholder french bean farms and farmers characterized in selected Counties of Kenya?

ii. What are the farm characteristics affecting technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya?

iii. What are the farmers' characteristics affecting technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya?

iv. What are the institutional factors affecting technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties of Kenya?

1.5 Significance of the Study

The results of this study are expected to provide better understanding of the effect of institutional factors, farmers and farm characteristics on technical efficiency and commercialization of french bean production among smallholder farmers. Development of policy recommendations may contribute to the attainment of the Kenya vision 2030 on economic performance through the efficient production and increase in commercialization of french bean. The findings of this study are expected to provide insight to agriculture policymakers in developing appropriate programs and policies in the french bean production sector that can lead to an increase in efficient production and an increase in commercialization level. Results could provide guidelines to the extension officer in the study area and Kenya on the type of information to disseminate to the french bean farmers to ensure maximum production and market sale. The findings of this study may shed light to further studies on technical efficiency and commercialization in the french bean sector.

1.6 Scope of the Study

The study targeted french bean smallholder farmers in Machakos, Taita Taveta, Bungoma, Trans Nzoia, and Kajiado Counties, Kenya. The counties were selected because their soil and climatic condition favours french bean production, making these areas to be high producing french bean zones in the Eastern, Coastal, Western, and Rift valley regions. The target population was 2080 households. The research was carried out in March and April 2022, and data on the second production season of french beans in 2021 was collected. Elements of the study were institutional factors, farms, and farmers' characteristics.

1.7 Assumption of the Study

During the research period, existing technology in french bean production was assumed to be constant. As a result, french bean smallholder farmers in the study area were assumed to be producing at the same technological level. Relevant institutional factors, as well as farm and farmer characteristics, were considered.

1.8 Operational Definition of Terms

Commercialization	The ratio of the value of french bean output sold to that of the value of total output.
Efficiency	Probability of producing maximum output from given units of resources.
Farm	Area of land devoted to French bean production.
Farmer	Someone who engages in producing either of the French bean varieties for household consumption and sale.
French bean	An immature and edible pod of *Phaseolus vulgaris L.* Also known as green bean, *mishiri, haricot verts,* fine bean, or snap bean.
French bean Production	Refers to the quantity of french bean produced in terms of tonnes.
Institutional factors	Human devised restrictions that form human interactions such as extension services, farmers' groups, and financial institutions.
Smallholder farmer	Someone who produces french bean from at most two and a half hectares of his arable land.
Technical efficiency	Occurs when maximum output is produced from a given amount of inputs.
Yield	The amount of french bean harvested per unit area of land in kilograms.

CHAPTER TWO
LITERATURE REVIEW
2.1 Overview of French Bean Production
French bean is a major vegetable crop, produced mainly for export purposes, especially for the European market (HCD, 2020). In Kenya, french bean production occurs mainly in warm-wet areas, for example, Machakos, Kirinyanga, Kajiado, Bungoma, Nakuru, Uasin Gishu, Muranga, Trans Nzoia, Kisumu Taita Taveta and Kiambu County (Masinga *et al.,* 2014; HCD 2020). Production falls into two seasons: a low season from June to September and a high season from September to March (Otieno *et al.,* 2017). There are three differentiated types of growers; large farmers, small farmers and emerging french bean growers. There are also small to medium farmers who grow french bean primarily on contracts, with commonly produced varieties including Samantha, Paulista, Army, Serengeti, Julia, and Teresa (Ngelezi *et al.,* 2017).

Rain-fed production is only achieved in areas with well-distributed rainfall of approximately 900-1200 mm per year. However, irrigation is recommended for supply maintenance, especially during the low season (Sabri, 2018). French bean can be grown in a wide range of soil conditions, however, it does well in silt loam to heavy clay soils. Heavy soils with poor drainage and alkali soils are not suitable for french bean production, thus soils with an optimum PH of 6.5-7.5, which should be rich in organic matter and well-drained is recommended (Meena *et al.,* 2017). An optimum temperature of 20-25 ^{O}C is favourable for production. A seed rate of 24 to 51 kg/hectare depending on the variety of certified seeds and fertilizer rate of 197 kg/hectare diammonium phosphate [DAP] and 148kg/hectare calcium ammonium nitrate [CAN] (Sigh *et al.,* 2019).

French bean diseases include root rots, angular leaf spots, bacterial blights, powdery mildew, and rust. To control them french bean farmers use field hygiene, certified seeds, recommended insecticides, and crop rotation. French bean harvesting begins after 6-8 weeks after planting, which takes around three weeks. The most sensitive french bean production stages include; germination, flowering, fruiting, and harvesting, which requires a lot of dedication and capital investment of about Ksh 311,353 thousand per hectare in Kenya (Tonui, 2017). French bean farmer is expected to obtain a 14.83 tonnes/hectare yield in 2-3 weeks (Ngelezi *et al.,* 2017).

Despite the observed 4.1% french bean demand in the export market, there is an observed production decline over the years which can be attributed to production inefficiencies and a decrease in the area harvested with french bean (FAO, 2020). Kenya's smallholder french bean potential yield is estimated at 5.93 to 7.11 tonnes per hectare which is low compared to the world's potential yield of 9.88 to 14.83 tonnes per hectare (HCD, 2020). China is the leading world producer of the french bean, averaging around 15.07 to 20.02 tonnes per hectare (HCD, 2020). Also, the area harvested with french bean as well as average production is observed to decrease from the year 2015 to 2019 (FAOSTAT, 2021). Table 1. below shows the area and production of french bean in Kenya.

Table 1: French bean production for the year 2015 to 2019 in Kenya.

Year	Area Harvested (ha)	Production (Tonnes)
2015	3753	45166
2016	3570	42321
2017	3434	41686
2018	3304	41051
2019	3179	40416

Source: FAOSTAT, (2021)

Factors such as high production and compliance costs, pests and diseases, the use of low-quality inputs, insufficient labor, small land sizes and a lack of support services, credit access, and market access have all contributed to a decline in smallholder french bean production (Muriithi, 2008; Kibet *et al.,* 2019). The area harvested with the French bean has decreased as a result of these factors. To address production issues, the East African Bean Research Network (EABRN) and the International Centre for Tropical Agriculture (CIAT) have launched research programs to support French bean production by developing seeds that are resistant to biotic stress, have a high yielding potential, and have high pod quality (Kimutai, 2018). However, high french bean production has not been achieved, due to the fact that most smallholder farmers do not have the financial resources to implement use of these inputs (Chemining'wa, 2011; Kimutai, 2018).

Due to increased demand in both the domestic and export markets, french bean production looks promising. There is no certainty of increased production with improved french bean seed varieties, rather smallholder farmers must incorporate other measures such as the use of agro-chemicals and fertilizers to attain higher production level (Joyce, 2016). As a result, the most important factor is how farmers combine available resources to maximize output. It was therefore critical to comprehend the technical efficiency within which smallholder french bean farmers combine resources in order to maximize returns using current technology. These were achieved by determining factors affecting commercialization and technical efficiency in french bean production among smallholder farmers in selected counties in Kenya.

2.2 Characterization of Crop Farms and Farmers'

Farm characteristics that influence crop productivity include cultivated crops, land tenure, land use, farm size, the seed used, labour, irrigation, fertilizer, and agrochemical use (Lipton, 2010). Variables such as seed use, labour, irrigation use, farm use, and size have been identified to be used in procedural development for the classification and grouping of farms for crop production (Riveiro *et al.*, 2008; Edleman, 2006). A review of smallholder farmers' characterization of predictive farm characteristics predicted the following variables for a testing database area under cultivation, work distribution, availability of labour, input supply, and facilities (Nyambo *et al.*, 2019). Also, a study to investigate on-farm diversity and resource use efficiency in east Africa considered the following variables in farm characterization land use pattern, agro-chemical and fertilizer use, and farming activities (Kansiime *et al.*, 2018).

Various variables have been reported regarding smallholder farmers' characterization, which include gender, household size, education level, and farming experience (Nyambo *et al.*, 2019). Teremwa *et al.* (2021) used both components principal component analysis and cluster analysis to characterize smallholder farmers, the following variables: education, experience, occupation, household head/decision-maker, and household size. Boza *et al.* 2019 characterized small vegetable-growing farmers in central Chile using descriptive statistics. Where farmer’s age, education level, experience, and household size were important variables considered. Farm and farmers’ characterization was of importance to policymakers in articulating strategies that focus on increasing production and commercialization level. Therefore, this study emphasized the need to characterize smallholder french bean farms and farmers' characteristics, where the descriptive statistics method was adopted for characterization.

2.3 Effect of Farm Characteristics on Crop Production Technical efficiency and Commercialization

2.3.1 Land Allocation

An increase in population has led to a rise in pressure on agricultural land. Land fragmentation has been observed to increase in these areas, forcing farmers to diversify among various crop alternatives that are more profitable (Barasa *et al.,* 2019). Studies on determinants of technical efficiency among smallholder farmers using the Stochastic Frontier Approach (SFA) have found the land size to positively and significantly affect crops' technical efficiency (Getahun & Geta, 2017; Barasa *et al.,* 2019). A study by Mwangi *et al.* (2020) assessed technical efficiency in tomato production among smallholder farmers in Kirinyaga County, Kenya, using the Cobb-Douglas function and Tobit multiple regression. Results indicated that land size inversely and significantly affected technical efficiency. Contrary, M̆bogo (2020) analyzed the technical efficiency, profitability, and market diversity among smallholder tomato farmers using SFA. The findings indicated that land size had a negative and significant impact on tomato production technical efficiency.

Studies on the evaluation of factors influencing crop commercialization have found farm size and proportion of land used for crop production have a positive impact on crop commercialization (John, 2021; M'ithibutu *et al.,* 2021). A study by Ejeta (2020) analyzed determinants of commercialization of tomato crop in Southern Ethiopia using Heckman's two-stage model. Results indicated that land allocated to tomato production significantly affects the commercialization level. From discussed studies, land size affects technical efficiency and commercialization of crop production due to the reason that land is the primary factor of production. However, the effect of land size on technical efficiency and commercialization of french bean production among smallholder farmers in selected counties remained unclear.

2.3.2 Seed Use

Studies on technical efficiency among smallholder farmers have found improved seed use to negatively and significantly influence the technical efficiency of crop production (Dessale, 2019; Tesfaw *et al.,* 2020). Contrary, Ogunmodede & Awotide (2020) assessed the determinants of leafy vegetable technical efficiency among farmers using the SFA. Results indicated that the seed variety used positively influenced leafy vegetable technical efficiency. Tenaye (2020) analyzed the technical efficiency of smallholder agriculture in Ethiopia. Results indicated that seeds used influenced the technical efficiency of agriculture production. A study on technical efficiency, profitability, and market diversity among smallholder farmers in Kirinyanga county found that seed use positively and significantly affects technical efficiency (Mbogo, 2020).

A study to analyze the determinants and effect of agriculture commercialization among smallholder farmers in Tanzania using the Double Hurdle Model (DHM) revealed that improved seeds use and accessibility of input on credit improve farmers' commercialization (Mbegallo, 2016). Kahenge (2020) analyzed the adoption and commercialization of soybean among smallholder farmers in Chipata, Zambia using DHM. Results showed that access to quality seeds significantly and positively affects the soybean commercialization level. Regesa *et al.* (2020) examined determinants of smallholder fruit commercialization in Ethiopia using DHM. Results indicated that the use of improved fruit seeds affects smallholder fruit farmers' commercialization level. From the reviewed literature, seed use has a significant effect on crop production technical efficiency, and commercialization, perhaps since an increase in seed use increases plant population. However, there existed a knowledge gap in determining the effect of seed used on french bean technical efficiency and commercialization in selected counties.

2.3.3 Labour

An assessment of determinants of technical efficiency in sugarcane production among smallholder farmers using SFA has been carried out. Results showed that labour access positively and significantly contributed to sugarcane technical efficiency (Ambetsa *et al.,* 2020; Adhikari *et al.,* 2019). Barasa *et al.* (2020) assessed technical efficiency determinants among farmers using SFA. Results indicated that labour costs used positively influenced leafy vegetable technical efficiency. Andaregei & Astatkie (2020) assessed determinants of technical efficiency of potato farmers and the effect of constraints on potato production in Northern Ethiopia using SFA. Results indicated that labour is a statistically significant factor that affects potato yield. These reviews indicated that labour is an important factor in production that cannot be ignored.

Analysis of the adoption and commercialization of soybean among smallholder farmers in Chipata, Zambia was carried out using DHM. Results indicated that labour use significantly and positively affected soybean commercialization at a 1% significant level (Kahenge, 2020). Abate *et al.* (2020) examined the implications of intra-rural migration on crop output commercialization in Ethiopia using household commercialization index [HCI] and propensity matching scores. It was found that labour migration affects crop production which is interdependence with crop output commercialization. Therefore increase in labour use leads to increased production raising farmers' output commercialization. Contrary, an assessment of the pathway of vegetable commercialization among farmers in Eastern Indonesia found labour to negatively affect the commercialization level of vegetable crops among farmers (Maryyono *et al.*, 2017). Reviewed studies showed that labour affects crop production technical efficiency and commercialization. However, the effect of labour on technical efficiency and commercialization of french bean in selected counties had not been identified.

2.3.4 Agrochemicals and Fertilizer use

Crop diseases, insects, pests, and soil fertility are among the major contributors to low yield (Kamau, 2019). Studies on determinants of crop technical efficiency using SFA have found agrochemicals and fertilizer to be statistically significant affecting crop production technical efficiency (Tenaye 2020; Astatkie, 2020). Mwangi *et al.* (2020) examined technical efficiency in tomato production among smallholder farmers in Kirinyanga county, Kenya using the Tobit model. Fertilizer use was found to be significantly and positively affecting the technical efficiency of tomato production. Similarly, a study on technical efficiency, profitability, and market diversity among smallholder farmers in Kirinyanga county found out fertilizer use to be positively and significantly affects technical efficiency (Mbogo, 2020). Barasa *et al.* (2019) assessed the technical efficiency of potato farmers in Trans Nzoia County and the results indicated that fungicides had no significant effect on production.

Tesfay (2020) investigated whether fertilizer adoption enhances smallholders' commercialization in Northern Ethiopia using DHM. Results indicated that fertilizer adoption has a positive and significant effect on-farm productivity. Thus through productivity gain, fertilizer use had a strong and positive impact on smallholders' commercialization. M'ithibutu *et al.* (2021) evaluated the factors influencing vegetable commercialization among smallholder farmers in Kenya using principal component analysis. It was revealed that 68.4% accounted for variability in agrochemical abuse. This explained the negative influence of agrochemical use on vegetable commercialization. Owusu & İşcan (2021) assessed the drivers of farm commercialization in Nigeria and Tanzania using the probit model. Results showed that chemical use significantly and positively influences farm commercialization and increases the likelihood of market participation. From the studies, agro-chemical and fertilizer use affects commercialization however, their effect on technical efficiency and commercialization in the selected counties was unknown.

2.3.5 Irrigation Use

Alam (2012) assesses determinants of potato production and technical efficiency at the farm level in Pakistan using the SFA model. Results indicated that irrigation water use significantly determines the technical efficiency of potato production. Astatkie (2020) analyzed determinants of potato farmers among smallholder farmers in Ethiopia using the Cobb-Douglas stochastic frontier model and Tobit model. The study indicated that irrigation water use is a statistically significant factor affecting potato yield. Adhikari *et al.* (2020) examined the impact of variety type and irrigation on the technical efficiency of potato farmers in Teral, Nepal using stochastic production frontier. It was found that irrigation use has a significant positive impact on the technical efficiency of potato production. Where irrigated farms had a higher technical efficiency level of 71% compared to non-irrigated farms with 69%.

GC & Hall (2020) assessed the commercialization of smallholder farming in rural western middle hills of Nepal. Results indicated that more than a third of the farmers were not motivated to engage in agricultural activities due to lack of irrigation water thus fear of production risks due to extreme climatic conditions. Tufa *et al.* (2014) assessed the determinants of horticultural crop commercialization among smallholder farmers in Ethiopia using DHM. 80% of households were found to be commercialized. Results showed that access and use of irrigation water determined horticultural crop commercialization. Krause *et al.* (2019) investigated on welfare and food security effects of commercializing African indigenous vegetables in Kenya using continuous propensity score matching and endogenous switching regression. Results indicated that irrigation water use influenced African indigenous vegetable commercialization. The above studies signify the importance of irrigation water use in crop production technical efficiency and commercialization but the effect of irrigation water use on technical efficiency and commercialization of french bean was not known.

2.4 Effect of Farmers' Characteristics on Crop Production Technical Efficiency and Commercialization

Several studies have investigated the relationship between farmers' demographic characteristics and technical efficiency as well as commercialization. These characteristics include age, gender, education, experience, household size, and occupation (Bhadel, 2020). Different researchers have found demographic factors to significantly affect the technical efficiency as well as commercialization of agricultural produce (Nau *et al.,* 2018; Abate *et al.,* 2019). Studies on the investigation of determinants of technical efficiency among different crops have shown that farmers' age, education level, farming experience, occupation, and year of education positively and significantly influence technical efficiency (Keba & Milkias, 2018; Barasa 2020; Adhikari *et al.*, 2020). Ambetsa (2020) did an assessment of the determinants of technical efficiency in sugarcane production among smallholder farmers in Malava, Kenya using SFA. Results showed that household size, occupation, education level, and farmers' experience positively and significantly contributed to sugarcane technical efficiency. While age negatively influenced sugarcane technical efficiency.

An assessment of wheat commercialization determinants among smallholder farmers using DHM revealed that household head, education level, age, experience, and occupation positively and significantly determine crop commercialization. While family size negatively and significantly influenced farmers' commercialization (Mamo *et al.*, 2020). Kahenge (2020) investigated on adoption and commercialization of soybean among smallholder farmers in Chipata, Zambia using DHM. Results established that education level, occupation, gender, age, household size, and marital status of the farmer influenced the adoption and commercialization of soybean. Abate *et al.* (2021) assessed the determinants of commercialization among smallholder wheat farmers in Northern Ethiopia using DHM. Results indicated that age, educational level, household size, experience, and market experience significantly affect smallholder wheat farmers' market participation. From reviewed studies, farmers' characteristics (household size, education level, age, gender, experience, and occupation) cannot be assumed to affect the technical efficiency and commercialization of french bean. Therefore, there was the need to build knowledge on the effect of farmers' characteristics on technical efficiency and commercialization of french bean in selected Counties.

2.5 Effects of Institutional Factors on Crop Production Technical efficiency and Commercialization

2.5.1 Extension Services

Studies have found extension services to positively and significantly affect crop production technical inefficiency among farmers using the SFA model (Dredawa, 2019; Ambetsa *et al.*, 2020) . A study to estimate sugarcane farm technical efficiency and its determinant in Malava, Kenya, found that extension services positively and significantly impact technical efficiency. It was concluded that policies that ensure quality extension services for smallholder farmers should be formulated and implemented (Ambetsa, 2020). Also, a study by Getahun & Geta (2017) suggested that female-headed households should be engaged in training and extension, and households' education should be increased through formal and informal training. Therefore there is a need to establish a strong linkage between extension agents and farmers to maintain efficient operation.

Studies to identify determinants of crop commercialization among farmers using DHM have found extension services to significantly affect farmers' commercialization levels (Gachuhi *et al.,* 2020; Abate *et al.,* 2021). Similarly, Mihretie (2020) analyzed the commercial engagement of smallholder farmers in wheat commercialization at the farm level in Northwestern Ethiopia using the Tobit model. The mean commercialization index was found at 0.21 with extension services found to be positively and significantly affecting the commercialization activities of wheat farmers. An assessment on determinants of smallholder fruit commercialization in Ethiopia using the probit model found extension services to significantly affect commercialization level (Regesa *et al.,* 2019). Studies have shown extension services significantly influence technical efficiency and commercialization among different crops. However, researchers had not demonstrated the effect of extension services on technical efficiency and commercialization in french bean production in selected Counties.

2.5.2 Finance or Credit Access

Siaw *et al.* (2020) examined the ripple effect of credit accessibility on technical efficiency among maize farmers in Ghana using the instrumental variable approach and SFA model. Results showed that farmers who had access to agricultural credit were at a higher technical efficiency level by 8% than those who had no access. Also, factors such as off-farm income and access to credit were found to significantly affect technical efficiency. Mehmood *et al.* (2017). An assessment of the influence of liquidity constraints on technical efficiency among wheat farmers in Pakistan using the SFA model was carried out. The inefficiency model indicated that; off-farm income and household savings affected technical efficiency levels. Credit size had a positive and significant effect, while credit interest rates had a negative and significant impact on wheat farmers' technical efficiency. Ambetsa *et al.* (2020) assessed determinants of technical efficiency in sugarcane production among smallholder farmers in Malava, Kenya using SFA. Results showed credit access positively and significantly contributed to sugarcane technical efficiency.

Gebre *et al.* (2021) investigated determinants of sorghum commercialization in Southwest Ethiopia using the Tobit model. Results indicated that the credit amount received influenced significantly the degree of sorghum commercialization. An assessment of factors affecting the adoption and commercialization of crops among smallholder farmers using DHM found credit access to be significantly affecting crop commercialization. This could be a result of an increase in credit would lead to an increase in production thus more output is sold. Rabbi *et al.* (2019) investigated factors affecting smallholder rice farmers' commercialization using the Heckman two-step model. Results showed that credit access and income from rice sales significantly affected the commercialization of rice production. Seyke *et al.* (2020) investigated on effect of credit access on agricultural commercialization among farmers in Ghana using endogenous switching regression. Results indicated that credit access stimulates higher technical efficiency and commercialization level in crop production. Hence, it was important to analyze the effect of credit access on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties.

2.5.3 Organization Membership

Ma *et al.* (2018) investigated on effect of agricultural membership and apple farm farmers' technical efficiency using the cobb-Douglas stochastic production frontier. Results showed that the efficiency level is much higher for farmers who are members of a cooperative relative to non-members. Similarly, Bartova & Fandel (2020) estimates the effect of membership in agricultural producer organizations' on-farm technical efficiency in Slovakia using a two-stage meta-frontier approach. Results indicated that membership in a producer organization significantly and positively impacted farm technical efficiency. Likewise, Olagunju *et al.* (2021) investigated the impact of agricultural cooperative membership maize technical efficiency in Nigeria based on the SFA model and propensity score matching. The result showed that Cooperative members had higher technical efficiency than non-members.

Kahenge *et al.* (2021) assessed socio-economic factors affecting soybean commercialization among smallholder farmers in Zambia using the Tobit model. Organizational membership was found to significantly influence soybean commercialization. Also, Ingabire *et al.* (2017) conducted a study to analyze determinants of bean commercialization among smallholder farmers in Rwanda using DHM. Results showed that 30% of respondents participated in the market with an average commercialization index of 0.42 with household group membership significantly affecting bean commercialization. The literature shows that a farmer's participation in an organization/cooperative significantly affects farmers' agricultural produce technical efficiency and commercialization. This could be as a result of through this group farmers can easily adopt technologies leading to production increase and thus more output to the market. Therefore, it was important to assess the impact of french bean farmers' organizational membership on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties**.**

2.6 Econometric Models Approaches

2.6.1 Approaches for Measuring Technical Efficiency in Crops Production

To measure technical efficiency in crop production among farmers, either non-parametric or parametric approaches can be used. The difference between the two approaches is found in the assumption from which each approach is based. That is, the frontier functional form and whether a random error is included. The commonly non-parametric approach used is Data Envelope Analysis (DEA), as it compares input and output combinations based on available data only (Ndirangu *et al.,* 2017). It is based on technical efficiency measures proposed 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 stochastic frontier approach (SFA) is the commonly used parametric approach. It involves production function estimation approximation with an already established function (Aigner *et al.,* 1977; Meeusen and Van den Broeck, 1977). The SFA function comprises three components: inefficiency error, measurement error, and deterministic production function (Abdul & Isgin, 2016). Maximum likelihood is then used to estimate technical efficiency (Benedetti & Zucaro 2019). The SFA is asymptotically more efficient than the ordinary least square method 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 the study area, french bean production was likely to be affected by factors beyond farmers' control, such as changes in weather conditions, and natural hazards. Thus, SFA helped in capturing errors that could arise during the study. Cobb-Douglas and Translog production are the commonly used types of SFA. This study used the Cobb-Douglas form of SFA with a log-log functional form following its merit in application in determining factors affecting the technical efficiency of crop production (Barasa, 2019; Kamau, 2020; Mwangi *et al.,* 2020; Omondi *et al.,* 2020; Okoror & Areal, 2020). The stochastic frontier production model by Aigner *et al.* (1997) and Meeusen and Van den Broeck (1977) is expressed as,

$$\ln Y_i = \beta_0 + \sum \beta_i \ln X_{ij} + e_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where ln is the natural logarithm, Y_i represents output for the i^{th} french bean smallholder farmer, β_i represents unknown parameters to be estimated, X_{ij} represents farm inputs of the i^{th} farmer, $e_i = v_i - u_i$ represents the residual random term. V_i captures measurement errors while U_i represents technical inefficiency models. According to Battese and Coelli (1995), U_i can be expressed by the following function,

$$U_i = Z_i\delta + e_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Z_i represents specific farmers and institutional factors variables relating to technical inefficiencies, while e_i is normally distributed with zero mean and variance.
The following function denotes the technical efficiency of the i^{th} farmer.

$$TE_i = Y_i/Y_i^* \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where TE_i is the technical efficiency and Y_i^* is thepredicted french bean production level and Y is the observed french bean production level. If Y_i is equals to Y_i^* then TE = 1 (100%). Y_i^* is fixed in U_i, which makes the difference with Y_i. If $U_i = 1$, then $Y_i = Y_i^*$ showing that production lies along the frontier and from the given amount of inputs, farmers obtain maximum output. While if U_i is less than one implies that production occurs below the stochastic frontier showing inefficiency in production.

2.6.2 Approaches for Measuring Commercialization

Several econometric models have been used to study agricultural farmers' commercialization. The application of these models depends on available data and the question at hand. Logit and probit models are used in binary responses, i.e., on data collected to identify if there is commercialization or not (Woolridge, 2002). The double hurdle model and Heckman model permit two separate stochastic processes for intensity and incidence of adoption(Komarek, 2010). The Tobit model or censored regression model (Tobin, 1958) are used to measure the decision and extent of commercialization in one step (Martey *et al.,* 2012). Tobit assumes variables that influence the incidence of adoption also influence its intensity of commercialization. This study assumed that the decision and extent of commercialization of french bean among smallholder farmers in selected Counties of Kenya were determined by the same factors thus Tobit model was used. The censored or Tobit model assumes that the observed dependent variable Y_i for observations i=1,….., n satisfying:

$Y_i = \max (Y_i^*, 0)$……………………………………………………..……………(4)

where the Y_i^* is a latent variable generated by a linear regression model given as:

$Y_i^* = \alpha_0 + \alpha_i X_i + \mathcal{E}_i$……………………………………………………………………(5)

where α_0 represents intercept, α_i represents the coefficient of parameters to be estimated, X_i represents vectors of conforming independent variables and $\mathcal{E}_i$ is the error term which is assumed to be independently and normally distributed.

2.7 Theoretical Framework

2.7.1 Production Theory of the Firm

Every firm seeks to obtain the maximum return possible from a given set of resources. The theory of the firm is built on the idea of rationality calculating optimizing agents using a production function (Saari, 2006). The output level is said to change as the input level changes (Amadou, 2007). To achieve technical efficiency, a farmer must produce maximum output from available inputs within the current level of technology (Fare *et al.,* 2013). Farmer's production function will be expressed as:

Y= F (Ld, L, K, M, T, t)……………………………………………………………(6)

Given that: Ld- land and buildings, L- labour, K- capital, M- material, T- technology, and t- time. Y represents the output, and on the right-hand side, we have farm inputs. The objective of any producer is to maximize profit by either reducing production costs or increasing output. Production inefficiency can reduce output from a technically possible point (Lobo *et al.*, 2013). It is expected that as more inputs are used in production, the output should increase responsively. Hence smallholder french bean farmer's production function was derived and expressed as:

Y = f (land, labour, seed use, irrigation use, available technology)……………….... (7)

The technology level was assumed to be constant during the study period; thus, it is vital to identify the maximum inputs available to determine the maximum french bean output level.

2.7.2 Utility Maximization Theory

An average farm household in a developing country produces a range of goods and services that can be used either for sale or home consumption. Also, farm production processes use their own produced or market purchase outputs. Therefore every farm faces an optimization problem based on costs and benefits arising from participating in either input or output market. Nevertheless, market failures are pervasive in developing countries, leading to non-separable modelling; thus, consumption decisions are affected by sales decisions (Ellis, 1993). Modelling households under market failure will use utility maximization as the objective function (Mather *et al.*, 2012; Awotide *et al.*, 2016). According to microeconomic consumer theory, a rational household is assumed to maximize utility by choosing levels of goods and services consumed, produced, inputs used, sold, and bought subject to resource, income, and technology constraints (Azam *et al.*, 2012). Using given K_i inputs, households can produce Q_i outputs to consume C_i or sell Z_i.

Therefore, assuming there are no transaction costs, the neo-classical subjective utility maximization for commercialization equilibrium will be given as,

Max U (C_i, Z^c)……………………………………………………………………. (8)

Subject to: Income constraint, resource constraint, and production technology constraint. The income constraint suggests that the total value of sales and the sum of all exogenous income equals all household purchases. Resource constraint means that quantities sold, consumed, and used in production cannot be more than production, purchased goods, and endowment (Azam *et al.,* 2012). Key *et al.* (2000) & Azam *et al.* (2012) developed an optimal solution conditional on a market participation regime that leads to high utility. The decision and intensity to participate in the market can be represented by,

$$Q_{si} = (P_i^m, T_i^{fs}, T_i^{ps}, Z^q, Z^c, E_i, A) \quad (9)$$

$$Q_s = (P_i^m - T_i^{ps}, Z^q) \quad (10)$$

where; P_i^m is the market price, A is the exogenous transfer of income, E_i is the total endowment of good i, Z^q is the production technology characteristics, Z^c is the household characteristics, T_i^{fs} is the fixed transaction cost and T_i^{ps} is the proportionate transaction cost. Equation 9. Implies that binary decision to commercialize or not is affected by fixed and proportional transaction cost while intensity is affected by proportionate transaction costs equation 10. Once fixed costs are covered, they do not affect commercialization intensity (Azam *et al.,* 2012).

2.8 Conceptual Framework

Figure 1. shows how the study was conceptualized. Institutional, farm, and farmer characteristics may affect the technical efficiency and commercialization of french bean production in line with policies and climatic conditions. Land size, land tenure, the seed used, irrigation use, and labour, which are the main inputs in production, may positively or negatively affect either the technical or commercialization of french bean production. Proper allocation of these characteristics may lead to improved technology and commercialization of french bean production. It, therefore, leads to increased output, farmers' income, and welfare. Maximum french bean production depends not only on the input used but also on how farmers combine resources. Past studies, for example, Rabi *et al.* (2020) and Kahenge *et al.* (2021) showed that farmers' characteristics (age, education level, experience, gender, occupation, household size) affect the technical efficiency and commercialization of crop production.

Institutional factors included variables such as organizational membership, credit access, market access, and support services and information. Organizational membership provides farmers with new ideas for promoting efficient resource use. Credit access provides smallholder farmers with capital to cater to production costs, i.e., hired labour, inputs, and irrigation water. Access to support services assists farmers in adopting improved farming methods and thus more output, which fetches high market prices. French bean market access lowers transaction costs incurred by the farmers; therefore, more farmers are motivated to engage in production due to high returns.

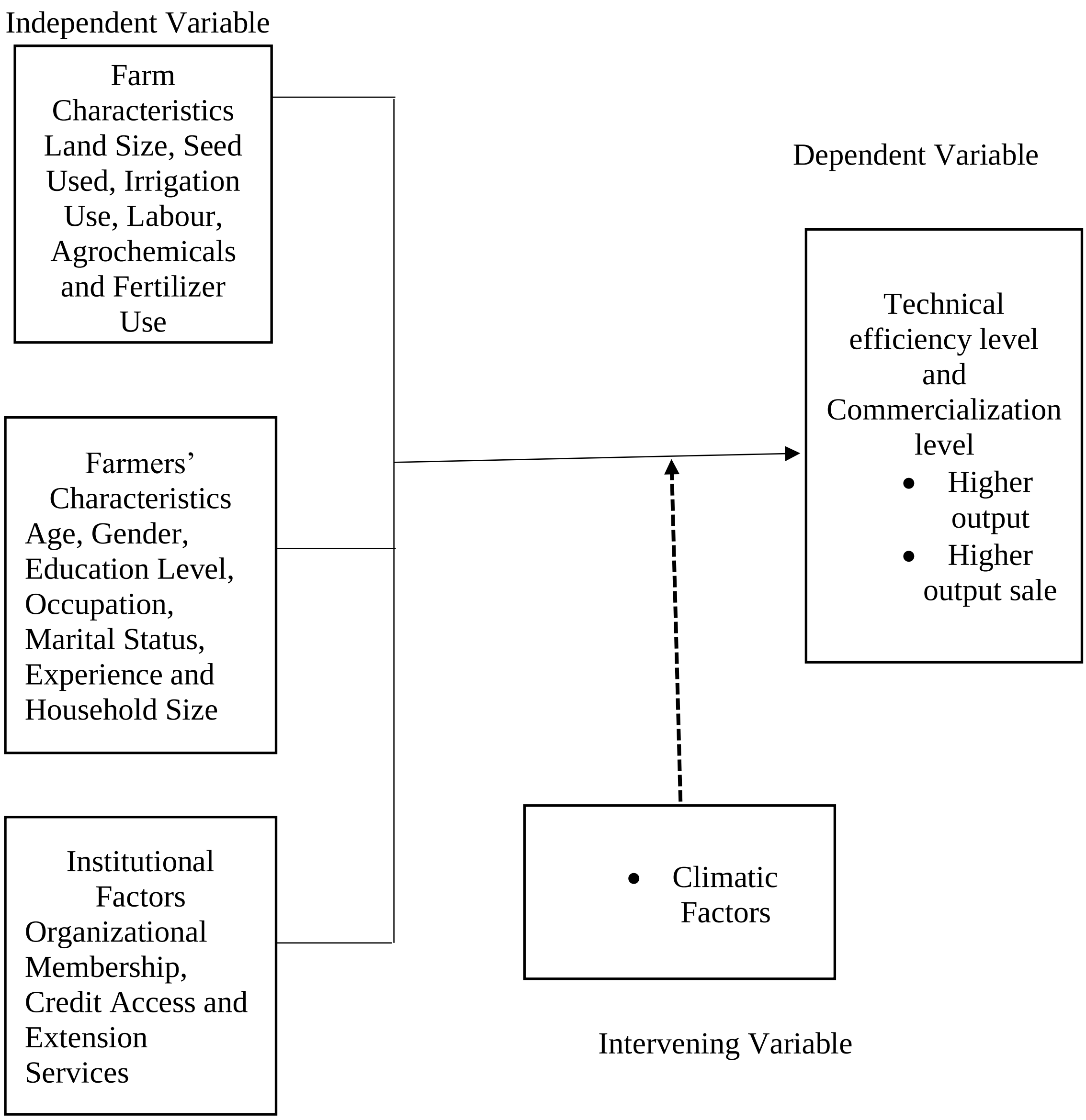

Figure 1: Conceptual Framework
Source**:** Author's Conceptualization

Intervening variables also affect the technical efficiency and commercialization of french bean, given the available resources. Climatic factors such as rainfall and drought affect farmers' technical efficiency and commercialization level as they exogenously affect day-to-day farmers' operations. A farm is said to be technically efficient if it produces maximum output from minimum inputs. Thus more output will be sold, yielding more income. Attainment of technical efficiency and commercialization of crop production by a farmer increases their income and achieves food security for the economy as a whole.

CHAPTER THREE
METHODOLOGY

3.1 Study Area

The study was carried out in Kenya in five (5) Counties: Machakos, Taita Taveta, Bungoma, Kajiado, and Trans Nzoia County. The Counties were chosen because of their favourable climatic and soil conditions for french bean production, making these areas high producing french bean zones in the Eastern, Coastal, Western, and Rift Valley regions. They were also discovered to be to new areas diversifying in french bean smallholder production in Kenya. Characteristics of each study area (County) are discussed below.

Kajiado County covers an area of 21,292.7 km^2 and lies between an altitude of 500m and 2500m above sea level and is characterized by low rainfall of an average range between 800mm-1,250mm, infertile soil, and high temperatures. Only 8% of its land is suitable for rain-fed agriculture. There are two rainy seasons experienced; long rains from March to May and short rains from October to December. The county is located between longitude 36^O 5' east and 37^O 5' and between latitudes 1^O 0' south (Amwata, 2013). It has a population of 1,117,840 where 560,704 are male, and 557,098 are female, with 51 people per km^2 as the population density and the average household size being 3.5 people. The average land size per farmer is 3.8 hectares (KNBS, 2019). The soil PH in Kajiado county is 5.0 to 8.0, with grey sandy soil to the east and black-cotton soil to the west (Otieno *et al.*, 2022).

Machakos County covers 6,208 km^2 and lies between an altitude of 1,000m to 1,600m above sea level and an average annual rainfall between 829mm/32.6inch with high rainfall in April, May, November, and December. The temperatures average is 18.9 ^{O}C/66.1 ^{O}F. The county is located between longitude 36^O 45' and 37^O 45' East and between latitudes 0^{O}45' to 1^{O}31' South (Mbithi, 2018). It has a population of 1,421,932 where 711,191 are female, 710,707 are males, and 34 intersexes, with 229 people per km^2 as the population density, 265,400 households, average household size being 5 people. The average land size per farmer is 2.19 hectares; hence, smallholder farming is commonly practiced (KNBS, 2019). Soil pH in Machakos County varies from 4.60 to 7.77, with red loam soils slightly acidic and black clay soils moderately alkaline (Gevera *et al.*, 2021).

Taita Taveta County covers 17,083.9 km^2 of which 11,100 km^2 is within Tsavo East and West National parks; the remaining 5,876 km^2 consists of smallholder farms, water bodies, ranches, and sisal farms (Karvonen, 2019). It lies between an altitude of 500m to 2228m above sea level and an average annual rainfall range between 440mm in lowlands to 1900mm in highlands with high rainfall in April, May, November, and December. The temperatures average is 22.2^{O}C (Omayio, 2020). The county is located between longitude 36.565889 east and between latitudes 3^{O}23'7.31'' South. It has a population of 340,671 where 167,327 are female, 173,337 are males, and 7 are intersex, with 19 people/km2 as the population density, 97,334 households, and average household size of 3.5 people. The average land size per farmer is between 2.6 hectares; hence smallholder farming is the most practiced. Large-scale farms (sisal plantations) occupy 7400 ha each on average, food crops is 18,125 ha, and horticulture is 3296 ha (Jaetzoldt, 2010; KNBS, 2019). Taita Taveta County soils range from dark reddish brown to dark, well drained to excessively drained, shallow to extremely deep, sandy loam to clay, friable to firm and compact, with a PH range of 4.5 to 7. (Onyamgo, 2019).

Bungoma County covers 2,206.9 km^2 and lies between an altitude of 1,200m to 4,321m above sea level and an average annual rainfall range between 188mm/7.1 inch with high rainfall in late March, April, May, October, November, and December. The temperatures average is 20.3-22.5 ^{O}C (Sirma, 2020). The county is located at longitude 34.5584^{O} East and latitudes 0.5695^{O} North. It has a population of 1,670,570 where 858,389 are female, and 812,146 are males, with 753.95 people per km^2 as the population density, 358796 households, and average household size is 4.6 people. The average land size per farmer is 4 hectares; hence, smallholder farming is commonly practiced (KNBS, 2019). Bungoma County soils range from naturally fertile deep rich Andosols to Nitisols with PH values in the range of 5.8 to 7 (Makokha, 2016).

Trans Nzoia County covers an area of 2,469.9 km^2 and lies between an altitude of 1,800m to 2,000m above sea level, with high rainfall in March, April, May, October, November, and December and an average of 1000 to 1200 mm (Andayi, 2018). The temperatures average is 10-27 ^{O}C. The county is located at longitude 34.9507^{O} East and latitudes 1.0567^{O} North (Muthoni *et al.*, 2020). It has a population of 990,341 where 501,206 are female, and 489,107 are males, with 396.9 people per km^2 as the population density, 223,808 households, and an average household size is 3.9 people. The average land size per farmer is 1 hectare; hence, smallholder farming is the most practiced type (KNBS, 2019). Trans Nzoia County has well-drained dark red volcanic clay soils with a PH range of 4.5 to 7 (Nyanga, 2018)

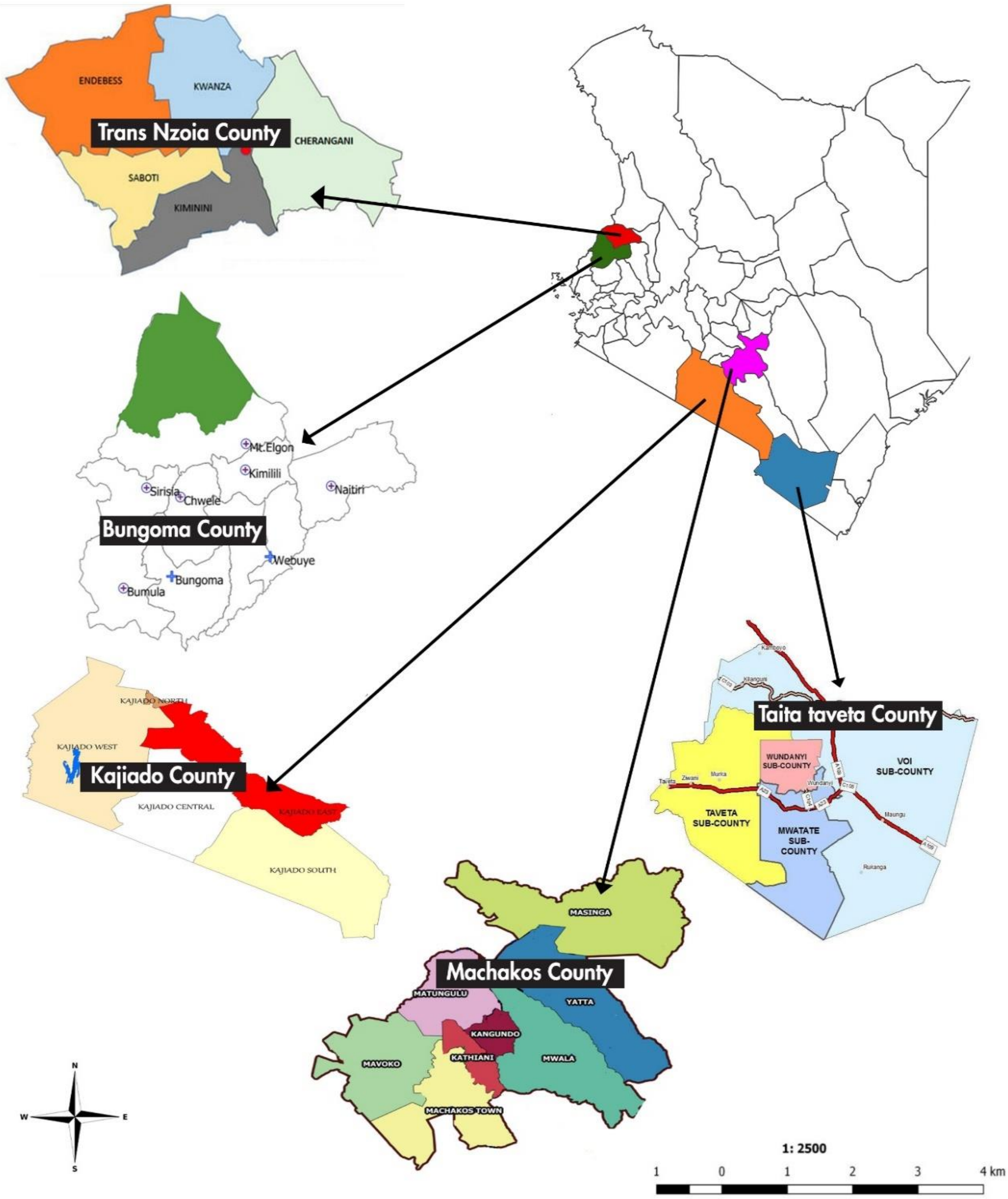

Figure 2: Map of the study area; Machakos, Kajiado, Taita Taveta, Bungoma, Trans Nzoia Counties.
Source: Geocurrents (2016)

3.2 Research Design

The study adopted a cross-sectional research design. The design allowed the employment of both quantitative and qualitative data analysis methods (Al Hariri, 2016). This design helped in the description of institutional factors, farms, and farmers' characteristics of smallholder french bean farmers in Kajiado, Machakos, Taita Taveta, Trans Nzoia, and Bungoma County. The research was carried out in March and April 2022, and data on the second production season of french bean in 2021 was collected..

3.3 Target Population

The target population was obtained purposively from the five counties; Machakos, Taita Taveta, Bungoma, Kajiado, and Trans Nzoia, since they are the major french bean producing areas in the Eastern, Coastal, Western, and Rift Valley regions of Kenya, respectively. The target population encompassed all french bean smallholder households, french bean farmers, from the five purposively selected counties; Machakos, Taita Taveta, Bungoma, Kajiado, and Trans Nzoia. The target population was 2080 households (Table 2).

3.4 Sample Size Determination and Sampling Procedure

3.4.1 Sample Determination

The sample size was computed using Cochran's (1977) formula, simplified as,

$$\mathrm{n} = \frac{Z^2\ P\ (1-P)}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

where, n is the sample size; the study assumed a 95% confidence level; thus, Z, equal to the confidence interval level, is 1.96, and e is the sampling error, which equals 5%. P was the expected proportion assumed to be 0.75 (Negash, 2007; Abera *et al.*, 2016).

The sample size was given by,

$$\mathrm{n} = \frac{1.96^2 \times 0.75\ (1-0.75)}{0.05^2} = 288.12 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Therefore, a sample size of 288 was used.

3.4.2 Sampling Procedure

From each County, one sub-county was selected for study. From the selected sub-counties, a list of french bean smallholder farmers was generated with the help of the ministry of agriculture extension officer to aid in the respondents' selection. From the list of smallholder farmers from each sub-county respondents were randomly selected. The number of french bean households to be sampled from each selected sub-county was calculated using the given formula and distributed as shown in Table 2.

$$No. of\ respondents/County = \frac{\text{Households per selected sub−county}}{Number\ of\ French\ bean\ household} x Sample\ size \quad (13)$$

Table 2: French bean household target population and sample size

County	County target population	Selected sub-county	Selected sub-county target population	Sample size per selected Sub-county
Machakos	376	Kangundo	174	52
Taita Taveta	426	Wundanyi	194	59
Kajiado	498	Kajiado South	226	69
Bungoma	361	Webuye East	164	50
Trans Nzoia	419	Kwanza	180	58
Total	2080		945	288

Source: HCD (2020) and Author's sampling design

3.5 Research Tool

A semi-structured questionnaire (Appendix 1) was used to collect data from the respondents. The questionnaire was organized into the following main parts; household identification, farmers' characteristics (age, education level, occupation, experience, household size, and gender), farm characteristics (land allocation, seed, manure, irrigation, labour, fertilizers, and agrochemicals), institutional factors (organizational membership, extension services, market access, and credit access) and produce distribution (amount of french bean produced and how it is distributed).

3.6 Pilot Study

The questionnaire was pre-tested one week before the commencement of data collection. The pilot survey was carried out in Subukia sub-county, Nakuru County, which has similar climatic conditions as that of the selected Counties. Twelve questionnaires were administered to randomly selected smallholder household french bean farmers. According to Bell *et al.* (2018), a minimum sample size of 12 respondents is applicable for a pilot study. Pilot study was done to check whether the questionnaire would collect relevant data.

3.6.1 Validity

The study used the judgment approach of content validation through conducting an intensive literature review to identify what questions are to be included in the questionnaire. Academic supervisors and experts in the french bean field for example ministry of agriculture extension officers helped in achieving the questionnaires' validity.

3.6.2 Reliability

Cronbach alpha coefficient was used to test for the questionnaire's reliability. The scale reliability was found to be 0.7319. 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 (0.7319) was greater than 0.7, the instrument was reliable for use in the study.

Table 3:. Reliability test results using the Cronbach Alpha

Variable	Value
Average Interim covariance	0.3664
Number of items in the scale	21
Scale reliability coefficient	0.7319

3.7 Data Collection

Data was collected in March and April of 2022. A semi-structured questionnaire was used to collect data on the second french bean production season 2021 (Appendix 1), wich was administered through face-to-face interviews with the respondents. Data on household identification, farmers' characteristics, farm characteristics, institutional factors and produce distribution was collected.

3.8 Data Analysis

Collected data was analyzed using the computer software Stata version 17 and SAS version 9.4. Descriptive statistic was used in characterizing french bean farms and farmers. For example measures of dispersion, central tendencies such as medium, mode, and mean frequencies and percentages, and measures of variability from which inferences were drawn. Cobb-Douglas stochastic production function measured the level of technical efficiency and the effect of institutional factors, farm and farmers characteristics on french bean production technical efficiency among sampled french bean smallholder farmers. The model was applied since french bean production was likely to be affected by factors beyond farmers' control, such as changes in weather conditions, and natural hazards where SFA helped in capturing errors that could arise during the study. The Tobit model was further used to determine the effect of institutional factors, farm and farmers characteristics on the commercialization of french bean production. Tobit model was appropriate for the analysis of factors affecting french bean commercialization as the study assumed that factors that affect the decision to commercialize also affect the decision to commercialize. Data on hired labour, family labour, amount of certified and second-generation seeds, and cost of certified and second-generation seeds was subjected to analysis of variance using SAS version 9.4 (SAS Institute, 2013) to determine their effect on smallholder french bean production. Significant means were separated using Least Significance Difference (LSD) at $\alpha = 0.05$.

3.8.1 Institutional Factors, Farm and Farmers' Characteristics Afecting Technical Efficiency in French Bean Production

The Cobb Douglas stochastic equation was given as follows;

$$\ln Y_i = \beta_0 + \sum \beta_i \ln X_{ij} + (V_i - U_i) \ldots\ldots (14)$$

where; $\ln Y_i$ represents natural logarithms of french bean output for 288 french bean smallholder farmers. β_i represents unknown parameters to be estimated, $\ln X_{ij}$ represents natural logarithms of land size, labour quantity, seed quantity, manure, fertilizers and agrochemicals of the i^{th} farmer . $e_i = v_i - u_i$ represents the residual random term. Where V_i captures measurement errors while U_i represents the technical inefficiency model. According to Battese and Coelli (1995), U_i can be expressed by the following function;

$$U_i = Z_i\delta + W_i \text{......} \quad (15)$$

where; Z_i represents covariates relating to technical inefficiencies, including gender, age, experience, education level, household size, organizational membership, credit, market, and extension services access. While W_i is a variable that is normally distributed. Technical efficiency of the 288 french bean smallholder farmers was denoted as,

$$TE_i = Y_i/Y_i^* \text{......} \quad (16)$$

where; TE_i is the technical efficiency, and Y_i^* is the specific farm stochastic frontier. If Y_i is equals to Y_i^* then TE = 1 (100%). Y_i^* is fixed in U_i, which makes the difference with Y_i. If $U_i = 0$, then $Y_i = Y_i^*$ showing that production lies along the frontier and from the given amount of

inputs, farmers obtain maximum resources. While if U_i is less than zero implies that production occurs below the stochastic frontier showing inefficiency in production.

Table 4: Description of variables affecting french bean production technical efficiency

Variable	Variable Description	Measurement	Expected Sign
French Bean Output	Dependent Variable	Kilograms	
Independent Variables			
Age	Household head age	Year	+/-
Gender	Household head sex	Dummy	+/-
Education	Number of schooling years	Years	+/-
Experience	Farming experience	Years	+/-
Household size	Number of family members	Persons	+/-
Farm size	Cultivated farm size	acres	+/-
Labour	Labour used	Man-days	+/-
Seed use	Improved seeds	Dummy	+/-
Irrigation use	Irrigation farming method	Dummy	+/-
Organizational membership	Farmer group membership	Dummy	+/-
Extension services	Extension service	Dummy	+/-
Market access	Market access	Dummy	+/-
Credit access	Credit services access	Dummy	+/-

Source: Author’s compilation from reviewed literature

3.8.2 Institutional Factors, Farm and Farmers' Characteristics Affecting Commercialization of French Bean Production

Household commercialization index [HCI] was first employed to determine a specific household level of french bean commercialization. Therefore HCI was estimated using the following formula:

$$HCI = \frac{\text{Gross value of French bean sale}}{\text{Gross value of all French bean production}} \times 100 \quad \ldots\ldots (17)$$

The Tobit model assumed that the observed dependent variable Y_i for observations i=1,….., n satisfying:

$$Y_i = \max(Y_i^*, 0) \quad \ldots\ldots (18)$$

The determinants of french bean commercialization were estimated using the Tobit model. Where the Y_i^* is a latent variable generated by a linear regression model given as:

$$Y_i = \alpha_0 + \alpha_i X_i + \varepsilon_i \quad \ldots\ldots (19)$$

where: Y_i is the sale volume, α_0 is the intercept, α_i parameters, X_i represents the variables that determine french bean commercialization as shown in table 5 below and ε_i is the error term.

Table 5: Description of variables affecting commercialization of french bean

Variable	Definition	Expected Sign
Dependent Variable		
Value of french bean sold in the market	The value of output sold	
Independent Variables		
Age	Number of years	+/-
Gender	Dummy (Male = 1 and female = 0)	+/-
Education	Number of years of informal education	+/-
Household size	Number of household members	+/-
Farm Size	Land owned per acre	+/-
Support Services	Dummy (1 = Yes ; 0 = Otherwise)	+/-
Credit Access	Dummy (Yes = 1 and 0 = Otherwise)	+/-
Market Access	Distance to market	+/-
Organizational Membership	Organizational membership: 1 if a member and 0 if a non-member	+/-
Off-farm income	Share of total household income	+/-
Experience	Number of years in french bean farming	+/-

Source: Author’s complilation from reviewed literature

3.9 Ethical Consideration

Chuka University's ethical clearance was obtained, and the study met the requirements (Appendix 3). The National Commission of Sciences, Technology, and Innovations (NACOSTI) granted a research permit (Appendix 4). An introductory letter was issued to each County Commissioner, informing them of the study's main goal. In addition, an introductory letter (Appendix 2) was provided to each respondent, informing them of the study's main goal. Research ethics principles were followed to ensure the validity and reliability of the results. To ensure the confidentiality and privacy of respondents' data, the researcher maintained high integrity during data collection and analysis. To avoid plagiarism, the similarity index was also tested using the turntin plagiarism checker.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Response Rate

Results of this study showed that the sampled french bean smallholder farmers accepted to be interviewed, therefore, the response rate was 100% (Table 6). This response rate was achieved by the use of enumerators from the study area whom were conversant with the local language as well as geographical area making data collection easier. An introductory letter (Appendix 2) was also issued to the sampled french bean smallholder farmers which clearly explained the purpose of the study and assurance of confidentiality of the collected data thus gaining trust from the sampled french bean smallholder farmers. This finding was consistent with Mwangi *et al.* (2019) .'s study on the assessment of french bean production in Kariua, Muranga County, Kenya, who discovered that a 100% response rate was achieved among the forty-three interviewed farmers.

Table 6. The response rate of the respondents

County	Sub-county	Sample size	Achieved sample size	Percentage
Machakos	Kangundo	52	52	18.06
Taita Taveta	Wundanyi	59	59	20.49
Kajiado	Kajiado South	69	69	23.96
Bungoma	Webuye East	50	50	17.36
Trans Nzoia	Kwanza	58	58	20.14
Total		288	288	100

Source: Authors analysis using primary data (2022)

4.2 Characterization of French Bean Farms and Farmers

4.2.1 Farm Characteristics

The average land size across the five counties is 2.95 hectares (Table 7). The average land size varies significantly ($p < 0.01$) across the counties. The family household land size from Taita Taveta County recorded the least average land size (1.68 hectares) while Trans Nzoia had the largest average land size (5.86 hectares). On average, out of the family land size; 0.40 hectares were rented by the family for crop production (Table 7), with smallholder farmers from Kajiado County recording the highest (1.37 hectare) rented land for farming while none of the respondents from Machakos county rented land for farming. The results of this study indicated that on average 0.87 hectares of land was rented out to other farmers by the household, with smallholder farmers from Kajiado county renting out the largest (2.27 hectares) piece of land while those from Machakos County rent out the smallest (0.27 hectares) portion of land. Results from this study on the average land size, were in line with that of Taiy *et al.* (2017) who reported that the average land size of smallholder potato farmers in Nakuru County was about 2 hectares.

In Kajiado County, french bean smallholder farmers have the largest average land size on both rented in and rented out land. Perhaps this is due to the fact that the majority of the population in this area relies primarily on pastoralist farming, and thus these farmers rent in/out their land to farmers engaged in small-scale farming. (KNBS, 2019). On average of 0.87 hectares of land was used in french bean production, with smallholder french bean farmers from Kajiado county producing french bean on a larger (2.27 hectares) piece of land while those from Machakos county uses an average of 0.27 hectares portion of land in french bean production (Table 7). These findings are in line with Wangu *et al.* (2021) who showed that the land size under french bean production in Kenya was 0.88 hectares. This confirms that french bean production is carried out by smallholder farmers in the study area.

Table 7. Average land size of the sampled french bean farmers

County		Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average	p-value
Land size	Mean	2.16	1.68	3.94	5.72	5.86	2.95	0.0
	Sd	1.24	1.15	2.86	2.50	2.95		
Rented in	Mean	0	0.18	1.37	0.06	0.11	0.40	0.00
	Sd	0	0.43	1.25	0.24	0.36	0.87	
Rented out	Mean	0.27	0.40	2.27	0.36	0.55	0.87	0.00
	Sd	0.09	0.12	0.93	0.20	0.24	0.96	
French bean prodn	Mean	0.27	0.40	2.27	0.36	0.55	0.87	0.00
	Sd	0.09	0.12	0.93	0.19	0.24	0.96	

Rented in land – Land leased by french bean smallholder farmers from other farmers for crop production purposes and SD – Standard Deviation.
Source: Author’s analysis using primary data (2022)

The results of this study showed that majority (63.89%) of the french bean smallholder farmers in the selected Counties own title deeds (Table 8). The distribution of french bean smallholder farmers owning title deeds across the counties varies significantly (p

< 0.01). The study showed that the majority (92%) of the french bean smallholder farmers who onwed land with title deeds came from Bungoma County while the majority (60.87%) of the farmers who owned land with no title deeds came from Kajiado County (Table 8). The type of innovations and activities that a farmer initiates on his farm are determined by the type of land tenure on his parcel of land. Most french bean smallholder farmers in Kajiado may practice french bean production on large pieces of land because most smallholder farmers tend to adopt permanent projects on land they own with tittle deeds while implementing crop production that takes less time on land without tittle deeds. Since french bean is a short-season crop, smallholder farmers in areas where farmers do not own tittle deeds are more likely to produce french bean on larger plots of land. This is evident in that on average french bean smallholder farmers from Kajiado County produces french bean on large piece of land compared to those from Bungoma County (Table 7). This finding was consistent with Otieno's (2022) study on the effects of rural household participation in land markets on agricultural outputs and food security in Siaya County, Kenya, who revealed that the majority of farmers owned land with tittle deeds..

Table 8. Title deed ownership by the smallholder french bean farmers

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average	X^2(df4)	p-value
No	46.15	47.46	60.87	8	10.34	36.11	57.72	0.00
Yes	53.85	52.54	39.13	92	89.66	63.89		

Source: Author's analysis using primary data (2022)

The study sought to investigate whether french bean smallholder farmers use certified seeds as well as whether they were global good agricultural practices (GAP) certified. The result indicates that more than half (78.13%) of the french bean smallholder farmers were not global gap certified (Table 9). Though french bean smallholder farmers' distribution on global gap certification was uneven across the Counties those in Machakos, Kajiado, and Bungoma were not globally GAP certified (Table 9). Certification is expected to bring training for better farming practices to improve french bean quality, productivity, coordination between farmers, exporters, buyers, and product quality checks (Wangu *et al.,* 2021). Therefore, these results on global GAP certification imply that french bean smallholder farmers are likely to attain high-quality output as certification allows french bean farmers to produce within the set standards

In contrast, Lengai *et al.* (2022) study on improving access to the export market for fresh vegetables in Kenya found that the majority of french bean farmers were globally certified, resulting in increased income between the producer and the buyer from certified production.

The results of this study indicate that more than half (56.94%) of the french bean smallholder farmers use certified seeds (Table 9). This can be attributed to the domination of french bean production by youthful french bean smallholder farmers (Table 16), making it easier to adopt modern technology. The use of certified seed varied significantly ($p < 0.01$) among the french bean smallholder farmers across the counties. The percentage use of certified seed ranged from 17.03 % to 100 % in Machakos and Kajiado Counties, respectively. The results showed an uneven distribution in the use of certified seeds across the counties (Table 9). These results imply that most french bean smallholder farmers in Kajiado County have adopted the use of improved french bean which may translate to high french bean output levels. This can be explained from the result on the amount of certified seed used by french bean smallholder farmers has more significant effect on french bean production compared to other counties (Table 10). Hence, french bean farmers smallholder from Kajiado county using certified seeds are likely to attain high production. The findings of this study concur with that of Saleh *et al.* (2018) who established that most the french bean smallholder farmers in Egypt used certified seeds. This results differed wit that of Kingogo *et al.* (2021) who reported that most of french bean farmers didn't use french bean certified seeds in Kenya.

Table 9. Smallholder farmer's certification for GAP and use of certified seeds

County	Machakos	Taita Tav	Kajiado	Bungoma	Trans Nzoia	Percentage	X^2(df4)	p-value
Global GAP certification								
No	100	0	100	100	93.1	78.13	266.21	0.00
Yes	0	100	0	0	6.9	21.88		
Certified seed use								
No	82.69	1.69	0.00	68	79.31	43.06	170.44	0.00
Yes	17.03	98.31	100	32	20.69	56.94		

GAP = good agricultural practices

Source: Author's analysis using primary data (2022)

Labour in Kenya is categorized into family and hired (permanent or temporary). Hired labour is recruited on either a daily/monthly basis to carry out farm operations such as land preparation, planting, weeding, fertilizer, agrochemical application, irrigation, and harvesting. While family labour involves labour provided by either of the household members (Reetz, 2016). Results on the average labour input used by the french bean smallholder farmers are presented in table 10 from the study area. Results of this study indicate that on average french bean smallholder farmers require 114.47 man-days of total hired labour ranging from 0.27 man-days to 384.12 man-days in Machakos and Kajiado Counties respectively (Table 10). The use of hired man-days varied significantly ($p < 0.01$) among the french bean smallholder farmers across the counties (Table 10). However, the number of hired man-days in Kajiado County is significantly different from other Counties. This signifies that the number of hired man-days in Kajiado County has a more significant effect on french bean production compared to those in other Counties. As a result, an increase in the number of hired men for french bean production among smallholder farmers in Kajiado will have a greater impact on production than in other counties.

The results of this study indicated that the french bean smallholder farmers use an average of 66 man-days of family labour for french bean production (Table 10), ranging from 36.88 man-days to 100.18 man-days in Kajiado and Bungoma Counties respectively. The use of family man-days varied significantly ($p<0.01$) among the french bean smallholder farmers across the Counties (Table 10). However, the number of family man-days in Bungoma County is significantly different from other Counties. This signifies that the number of hired man-days in Bungoma County has a more significant effect on french bean production compared to those in Trans Nzoia, Taita Taveta, Machakos, and Kajiado counties (Table 10). Thus, increase in number of family men for french bean production among smallholder farmers in Bungoma will have more significant effect on production unlike from other County. This results differed with that of Wangu *et al.* (2021) who reported that on average 92 man-days of family labour were used for french bean production from his study on the analysis of a french bean Agri-investment in Kenya.

The findings of this study indicate that on average french bean smallholder farmers use 8.83 Kg of certified seed per hectare ranging from 0.29 Kg to 34.62 Kg in Machakos and Kajiado Counties respectively (Table 10). The use of certified seed among smallholder french bean farmers varied significantly ($p < 0.01$) across the Counties (Table 10). However, the use of certified seed among the french bean smallholder farmers in Kajiado County is significantly different from other Counties (Table 10). This signifies that the use of certified seed by french bean farmers in Kajiado County has a more significant effect on french bean production compared to those in other Counties. As a result, increased use of certified seed will have a greater impact on french bean production among Kajiado County's smallholder farmers. The use of more units of certified french bean seeds by french bean smallholder farmers in Kajiado County may be related to farmers' access to certified seeds. Another reason for the high adoption of french bean certified seeds in Kajiado County could be the high education level of the farmers, as educated farmers tend to adopt innovations faster than those with low education levels (Table 15). These findings imply that the majority of french bean smallholder farmers in Kajiado County have adopted the use of improved french bean seeds, which may translate to high levels of french bean output. The findings of this study concur with that of Saleh *et al.* (2018), who established that the majority of french bean smallholder farmers in Egypt used certified seeds for french bea production. The outcomes of this study were in line with Wanjiru (2021), who reported that most of french bean farmers in Kirinyanga, Kenya used french bean certified seed which had significant effect on growth, pod quality and yield levels.

The outcomes of this study indicate that on average french bean smallholder farmers use 1.23 Kg of second-generation seed per hectare ranging from 0 Kg to 2.78 Kg in Taita Taveta and Trans Nzoia Counties respectively (Table 10). The use of second-generation seeds among smallholder french bean farmers varied significantly ($p < 0.01$) across the Counties (Table 9). However, the use of second-generation seed among the french bean smallholder farmers in Trans Nzoia County is significantly different from other Counties (Table 10). This signifies that the use of second-generation seeds by french bean smallholder farmers in Trans Nzoia County has a more significant effect on french bean production compared to those in other Counties. Hence, increasing the use of second generation seed will have a greater impact on french bean production among Trans Nzoia county's smallholder farmers. Perhaps french bean smallholder farmers' use of more units of french bean second generation seeds in Trans Nzoia County is related to the accessibility of second generation seeds compared to that of certified seeds. The results of this study are in contrast with that of Kibet (2019), who reported that most french bean smallholder farmers in Kirinyanga, Kenya use more quantity of certified seeds compared to seond generation seeds, which were obtained from informal sector sources.

The results of this study indicate that on average french bean certified seeds cost Ksh. 492.47 per kilogram ranging from Ksh.102.93 to Ksh.1036.44 in Trans Nzoia and Taita Taveta Counties respectively (Table 10). The cost of certified seed varied significantly ($p < 0.01$) across the Counties among the french bean smallholder farmers (Table 10). However, the cost of certified seeds in Taita Taveta County is significantly different from other counties. This signifies that the cost of certified seeds in Taita Taveta County has a more significant effect on french bean production compared to those in other counties. Therefore, an increase in the cost of certified seed will have a greater impact on french bean production among Taita Taveta french bean smallholder farmers than in the other Counties.

The findings of this study indicate that on average french bean second-generation seeds cost Ksh. 144.43 per kilogram ranging from Ksh.0 to Ksh. 390.96 in Taita Taveta and Machakos Counties respectively (Table 10). The cost of second-generation seed varied significantly ($p < 0.01$) across the counties among the french bean smallholder farmers (Table 10). However, the cost of second-generation seeds in Machakos County is significantly different from other Counties. This signifies that the cost of second-generation seeds in Machakos County has a more significant effect on french bean production compared to those in other Counties. As a result, an increase in the cost of second generation seed will have a greater impact on Machakos french bean smallholder farmers than on the other Counties. According to the study's findings, french bean smallholder farmers in Taita Taveta incur zero costs in accessing second generation seed. This can be explained by the fact that these farmers use their own seeds, thus incurring zero costs (Tirra, 2019).

Table 10. Average hired labour, family labour, amount of certified and 2nd generation seeds, cost of certified and 2nd generation seeds used by the french bean smallholder farmers.

County	Hired labor	Family labor	Amount of certified seed	Amount of 2nd generation seed	Cost of certified seed	Cost of 2nd generation seed
Kajiado	384.16a	36.88c	34.62a	0.29c	794.20b	7.24d
Bungoma	53.56b	100.18a	1.02b	1.73b	133.00d	153.50c
Trans Nzoia	49.34b	63.876bc	0.78b	2.78a	102.93d	225.69b
Taita Taveta	15.34b	64.32bc	0.73b	0c	1036.44a	0d
Machakos	0.27b	75.17ab	0.29b	1.67b	255.00c	390.96a
Average	114.47	65.84	8.83	1.23	492.47	144.43
LSD	64.61	28.09	2.80	0.63	80.26	37.83
F-value	54.75	5.25	261.62	26.72	221.77	144.63
P-value	0.0001	0.0004	0.0001	0.0001	0.0001	0.0001

a,b,c and d represents the significance difference between means at 5% significance level. LSD: least square difference. Second (2nd) generation seeds – own seeds.

Source: Author's analysis using primary data (2022)

The results on the amount of agrochemical applied shows that on average french bean smallholder farmers uses 10.69 litres/ha ranging from 1.42 to 36.79 in Taita Taveta and Trans Nzoia Counties, respectively (Table 11). The usage of french bean agrochemicals differed significantly ($p < 0.01$) across the five Counties (Table 11). The variation in the use of agrochemical across the Counties can be partly attributed to the difference in land size planted with french bean among the smallholder farmers, as indicated that on average french bean smallholder farmers from Trans Nzoia County produces french bean on the largest piece of land (Table 7). The results of this study differ from that of Ngango & Kim, (2019) who indicated on average households use as much as 184 litres of agrochemicals. Despite the side effect of the application of agrochemicals, farmers found them indispensable due to the huge losses that accompany pathogen, pest, and weeds attacks. Oerke (2006) found that pathogens and weeds lead to about 20% to 40% loss of agricultural production across the world. The application of agrochemicals has been found to reduce such losses by controlling pests, diseases, and weeds during crop growth and the postharvest period (Kothari and Wani 2021).

The results of this study also established that the french bean smallholder farmers uses 72.17 Kg/ha of french bean fertilizer, ranging from 12.08 Kg/ha to 225.74 Kg/ha in Taita Taveta and Kajiado Counties, respectively (Table 11). These high rates of fertilizer (planting, top dressing and foliar fertilizer) application per hectare of french bean by smallholder farmers is possible due to evidence that french bean smallholder producers in Taita Taveta are global GAP certified, so they follow recommended fertilizer application rates and thus use the least amount of fertilizer, whereas french bean smallholder producers in Kajiado County are not global GAP certified, so they lack knowledge on minimum fertilizer application units for french bean production. (Table 9). The usage of french bean fertilizer differed significantly ($p < 0.01$) across the five Counties. Application of the required amount of fertilizer on time is important in achieving potential crop productivity (Reetz, 2016). Results of this study concurred with that of Aslani and Souri (2018) study on growth and quality of green bean under foliar application of fertilizer in Kenya, on average french bean smallholder farmers used 70 Kg/ha of chemical fertilizers for the entire french bean production period.

Table 11. The average amount of agrochemicals and fertilizer used by french bean farmers per hectare

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average	F	P-value
Agrochemical used								
Mean	7.06	1.42	7.01	14.91	36.79	10.69	6.1	0.00
Sd	4.73	0.48	4.41	53.28	81.83	36.69		
Fertilizer used								
Mean	17.94	12.08	225.74	30.96	34.72	72.17	152.15	0.00
Sd	18.98	4.82	113.33	16.22	41.46	104.99	18.98	

Source: Author's analysis using primary data (2022)

Water deficit during french bean production may lead to reduced plant height, the number of branches, and low flowering which translate to low french bean production (Sabri, 2018). More than half (50.69%) of the french bean smallholder farmers practice rainfed french bean farming ranging from 0% in Taita Taveta and Kajiado County to 96% in Bungoma County (Table 12). This results varied significantly ($p < 0.01$) among the french bean smallholder farmers across the counties. In addition, most french bean smallholder farmers (72.46% and 98.31%) from Kajiado and Taita Taveta counties respectively are dependent on other water sources (river and boreholes) for french bean production. This can be attributed to unreliable rainfall patterns in the areas, causing french bean smallholder farmers to seek alternative crop production methods. In comparison, there is a high reliance rate on rainfed french bean smallholder production in Machakos, Bungoma, and Trans Nzoia Counties (Table 12). This implies that a decrease in rainfall levels in these areas could have a significant impact on french bean production among smallholder farmers, resulting in low french bean output. Due to the unpredictable rainfall pattern, this may also increase the risk of french bean production among smallholder farmers who rely on rainfed production. Results of this study were in line with Autio *et al.,* (2022), who found that the majority of horticultural smallholder farmers in the Southeast Kenya rely on rainfed farming, with other sources including dams and rivers.

Table 12. Source of water for french bean smallholder farmers

Source	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average	X^2(df4)	P-value
Run-off	0	0	0	0	1.72	0.35	315.06	0.00
Rooftop harvested	1.92	0.00	0.00	0.00	0.00	0.35		
Well	0.00	0.00	2.90	4.00	4.17	3.12		
River	3.85	98.31	72.46	0.00	5.17	39.24		
Borehole	0.00	0.00	24.64	0.00	0.00	39.24		
Rain fed	92.31	0.00	0.0	96.00	86.21	50.69		
Streams	1.92	1.69	0.00	0.00	1.72	1.04		

Source: Author's analysis using primary data (2022)

The results of this study showed that more than half (57.99%) of the french bean smallholder farmers were using irrigation farming methods ranging from 0% to 97.1% in Machakos and Kajiado Counties, respectively (Table 13). The use of the french bean irrigation farming method varied significantly ($p < 0.01$) among the french bean smallholder farmers across the Counties (Table 13). These results on the irrigation use of the french bean smallholder farmers could be a result that most french bean smallholder farmers from Taita Taveta and Kajiado Counties highly adopt irrigation use due to the availability of river from where they source irrigation water unlike french bean farmers from Machakos, Taita Taveta and Bungoma Counties who mostly depends on rainfed french bean production (Table 13). The adoption of irrigation farming by farmers helps to improve crop productivity (Mwangi & Crewett, 2019). Therefore, variation in irrigation adoption farming across the Counties might contribute to uneven french bean production in the study area. In contrast, Makiini et al., (2020) results found that most (67%) of the respondents in Kibwezi Kenya did not use irrigation methods for tomato production.

Table 13: Irrigation use by the french bean smallholder farmer

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average
No	100	11.86	2.9	98	98.28	57.99
Yes	0	88.14	97.1	2	1.72	42.01

Source: Author's analysis using primary data (2022)

4.2.2 Farmers Characteristics

The results of this study indicated that male farmers constitute majority of decision-makers more than half (82.99%) of the french bean smallholder farmers in the five Counties ranging from 55.93% to 98.08% in Taita Taveta and Trans Nzoia Counties respectively (Table 14). The distribution of french bean smallholders' households' decision maker's gender varied significantly ($p < 0.01$) across the Counties. This implies that most french bean smallholders' households are controlled by males thus most french bean production decisions among the french bean farming families are made by males. These results are in line with Mwangi et al. (2019) who reported that french bean production in Kariua, Muranga County was male-dominated.

Table 14. Gender of the decision-maker in the sampled french bean farmers

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Percentage	X^2(df 4)	p-value
Male	98.08	55.93	78.26	90.0	96.55	82.99	49.36	0.00
Female	1.92	44.07	21.74	10.0	3.45	17.01		

Source: Author's analysis using primary data (2022)

The findings of the study indicated that the average age of the main decision-maker was 43.89 years ranging from 38.03 years to 48.14 years in Kajiado and Bungoma Counties respectively (Table 15). The average age distribution varied significantly ($p < 0.01$) across the Counties (Table 15). French bean smallholder decision makers' age can be a major determinant in the adoption of innovation in the french bean production sector. Younger farmers are perceived to adopt technological change more easily than older farmers. In addition, age plays a significant role in the provision of labour used in farm operations (Kamau, 2019). According to the findings of the study, the majority of respondents were in their productive years. These findings concur with that of Noah *et al.* (2019) study on analysis of factors income-poverty among smallholder farmers I Kirinyanga County, reported that most of french bean farmers had an average age of 45years.

The results of this study showed that the average education years attained by the french bean smallholder farmers was 12 years, ranging from 3 years to 19 years in Machakos and Bungoma Counties, respectively (Table 15). French bean smallholder farmers' average schooling years varied significantly ($p < 0.01$) across the Counties (Table 15). Attainment of education level assists farmers in the adoption of new technology, thus, more educated french bean smallholder farmers can increase the adoption of the use of certified french bean seeds compared to less educated farmers. French bean smallhiolder farmers in Kajiado County uses certified seeds compared to those in Machakos County. This results differed with that of Rosch & Ortega (2019) who reported that most of french bean farmers in Kenya had an average 3.5 years of education.

The findings of the study indicated that on average french bean smallholder farmers had an experience in french bean farming of 4.21 years, ranging from 2.91 years to 6.12 years in Bungoma and Taita Taveta Counties, respectively (Table 15). French bean smallholder farmers' average experience years varied significantly ($p < 0.01$) across the Counties (Table 15). These results imply that french bean smallholder farmers from the study area had relatively low experience in years, which justifies the reason for the choice of the study areas as being new areas diversifying in french bean production. This coincides with Kebede *et al.,* (2017) result which stated that irish potato farmers in Ethiopia had an average farming experience of 4 years. This results differed with that of Chelanga *et al.* (2021) study on determinants of vertical coordination option choices among smallholder french bean producers in Muranga, Kenya who reported that french bean producers had an experience of 10.33 years. Experienced farmers are more likely to make better production decisions regarding the efficient use of farming inputs. The more experienced a farmer is, the more likely he is to make sound decisions.The findings of this study indicate that french bean farmers were moderately experienced. Experienced as well as educated french bean farmers can adopt the best farm management practices which help in production increase.

The results of the study revealed that on average french bean farming households had an average size of 5 people, ranging from 3 people to 7 people in Kajiado and Bungoma Counties, respectively (Table 15). French bean farming households' sizes varied significantly ($p < 0.01$) across the Counties (Table 15). This signifies that most households had a considerable number of people to offer family labour which could cut off labour costs. Also, the results of this study implied that french bean smallholder households from Bungoma County had more family labour compared to that of Kajiado County for french bean production. Results of this study varied closely with that of Kibet (2019) study on effect of smallolder french bean farmers Global-GAP standard risk altitudes on Production in Kirinyaga County, Kenya, who found out that the average household size among farmers was four people.

Table 15. Average age, schooling years, and household size of the among french bean smallholder farmers main decision-maker

County		Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Average	P-value
Age	Mean	47.62	43.41	38.03	48.14	44.34	43.89	0.00
	SD	11.66	11.56	8.64	6.57	5.40	9.8	
Schooling Years	Mean	3.13	14.07	19.07	12.6	12.07	12.64	0.00
	Sd	1.78	1.80	3.02	1.60	2.09	5.61	
Experienc	Mean	5.59	6.12	3.48	3.08	2.91	4.21	0.00
	Sd	2.89	2.76	1.36	0.94	1.03	2.36	
H/h size	Mean	4.23	4.17	2.74	6.66	5.76	4.58	0.00
	Sd	2.01	1.76	2.06	1.67	1.51	2.8	

Schooling years- Number of years one accessed education and household size- number of people who have lived in the french bean smallholder farmers' household. H/h – Household.

Source: Author's analysis using primary data (2022)

The findings of the study showed that the majority of the decision-maker (61.46%) from the study area had attained secondary form four education levels, ranging from 5% to 82.61% in Machakos County and Kajiado County, respectively (Table 16). French bean smallholder farmers' education levels varied significantly ($p < 0.01$) across the counties (Table 16). These results further indicated that the majority (40.38%) of french bean smallholder farmers from Machakos County had attained primary education level (Table 16). Results indicate that most of the sampled french bean farmers had not attained higher education. The attainment of a high level of education by french bean smallholder farmers increases their ability to adopt innovations. Therefore, french bean smallholder farmers with higher education levels are more likely to adopt innovations in the french bean sector than those with low education levels (Ambetsa, 2020). This may lead to improvement in french bean production levels among the french bean smallholder farmers with high levels of education than their counterparts. The findings of this study differed with Ndirangu, (2020) who found out that most of french bean smallholder farmers in Nyeri County, Kenya had attained only attained primary education level.

Table 16. Decision-maker level of education of the french bean smallholder farmer

Education level	Mach akos	Taita Tavet	Kaji ado	Bung oma	Trans Nzoia	Aver age	X^2(df4)	P-value
Informal	3.85	0	0	0	0	0.69	121.49	0.00
Primary std. 1	19.23	0	0	0	0	3.47		
Primary std. 7	15.38	0	7.25	0	1.72	4.86		
Primary std. 8	40.38	23.4	1.45	28	31.03	23.6		
Secondary	21.15	66.1	82.6	66	63.79	61.5		
College/ higher	0	10.2	8.7	6	3.45	5.9		

Source: Author’s analysis using primary data (2022)

The results from this study indicated that the majority (52.43%) of the french bean smallholder farmers practices farming ranging from 36% to 78.26% in Bungoma and Kajiado counties, respectively (Table 17). This results varied significantly ($p < 0.01$) across the Counties (Table 17). The majority of Bungoma County's french bean smallholder farmers appear to rely on farming for a living. However, these smallholder farmers were relatively educated with the majority having attained at least secondary form four education (Table 16). As a result, they are more likely to adopt new farming technologies and thus increase farm productivity. As a consequence, this explains why the majority of french bean smallholder farmers in Kajiado County rely on farming for a living. Mauti (2021) reported similar results that most tomato farmers in Kirinyanga County carried out farming activities as the main economic activity. This shows that farming can be the main source of employment for the study areas’ population.

Table 17. Occupation in terms of hours spent of the french bean smallholder farmers

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Percentage	X^2(df4)	P-value
Housewife	0	11.86	1.45	6	3.45	4.51	108.58	0.00
Casual worker	38.46	18.64	0	16	18.97	17.36		
Self employed	0	13.56	7.25	30	31.03	15.97		
Public/private sector	0	3.39	13.04	12	5.17	6.94		
Unemployed	5.77	6.77	0	0	1.72	2.78		
Farming	55.77	45.76	78.26	36	39.66	52.43		

Source: Author's analysis using primary data (2022)

The findings of the study indicated that the average distance travelled by french bean smallholder farmers from their farm to the market was 4 Km ranging from 1.61 Km to 4.76 Km in Machakos and Kajiado Counties, respectively (Table 18). The distance between french bean smallholder farmers to market differed significantly ($p < 0.01$) across the Counties (Table 18). The study further revealed that french bean smallholder farmer takes an average time of 47 minutes to the market, ranging from 26 minutes to 90 minutes in Machakos and Kajiado Counties, respectively (Table 18). In contrast, Marwa & Manda study on youth farmers benefits from participating in contract farmin in Tanzania reported that distance taken to market by french bean farmers wad 4.64Km. This was in line with Ateka *et al.* (2018) study on technical efficiency and its determinants in smallhlder tea farmers in Bomet County, Kenya who found out that the distance between the tea farmer and the nearest market and his farm is 2.9 Km.

Table 18. Average distance and time to market by the french bean smallholder farmer

County		Machakos	Taita Tavet	Kajiado	Bungoma	Trans Nzoia	Average	F	P-value
Distance	Mean	1.61	2.93	4.76	3.94	4.09	3.54	45	0.00
	Sd	0.93	1.16	1.86	1.28	1.26	1.26		
Time taken	Mean	25.58	36.9	89.77	35.04	37.41	47.3	75	0.00
	Sd	11.87	19.99	40.49	11.74	14.08	33.84		

Source: Author's analysis using primary data (2022)

The results from the study indicated that the majority (49.31%) of the french bean smallholder farmers use the earthed road, ranging from 14.49% to 88.14% in Machakos and Taita Taveta counties, respectively (Table 19). This results varied significantly ($p < 0.01$) across the Counties (Table 19). Earth and footpath roads may become impassible during the rainy season, whereas tarmac and murram roads are passable during both the rainy and dry seasons. As a result on the type of road used, french bean smallholder farmers from Machakos, Taita Taveta, and Trans Nzoia County may have difficulty accessing the market during rainy seasons because most roads used will be impassable. Consequently, most french bean farmers may be encouraged to sell their produce to brokers rather than through a direct marketing process. This may also demotivate smallholder farmers who grow french beans in these areas. Results concurred with Kipkulei *et al.* (2022) study on modelling cropland expansion and its drivers in Trans Nzoia County, Kenya who found out that most the smallholder bean farmers access the output market through the use of earthen roads.

Table 19. Type of road to market used by the french bean smallholder farmer

County	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Percentage
Tarmac	28.85	3.39	21.74	0	3.45	11.81
Murram	15.38	8.47	63.77	52	25.86	34.03
Earth	28.85	88.14	14.49	48	70.69	49.31
Footpath	26.92	0	0	0	0	4.86

Source: Author’s analysis using primary data (2022)

The study findings indicated that the majority (72.92%) of the french bean smallholder farmers did not market their french bean output through collection centers ranging from 0% to 96.61% in Machakos and Taita Taveta counties, respectively (Table 20). These results on the french bean smallholder farmer use of collection centers varied significantly ($p < 0.01$) across the Counties (Table 20). These results imply that low use of collection centers may be a result of a lack of awareness on how to run collections centers due to low education levels (Table 10) as well as the existence of poor roads in these areas for example most roads in Machakos county are earthed which may be impassable during the rainy season thus french bean farmers opt for an alternative marketing channel (Table 19). Phukan *et al.* (2018) also revealed that most of the marketing behavior of vegetable growers in Sikkim uses middlemen instead of collection centers due to financial urgency as well as the lack of cooling storage facilities in these collection centers.

The findings of the study showed that the majority (67.71%) of the french bean smallholder farmers had access to extension services ranging from 44.83% to 95.65% in Trans Nzoia and Kajiado Counties respectively (Table 20). These results varied significantly ($p < 0.01$) across the Counties (Table 20). Perhaps the variation in access to extension services can be attributed to the fact that french bean smallholder farmers in Kajiado County have a high education level, necessitating more efforts in consultation with the extension officer to obtain information on innovations in the french bean production sector (Table 15). Smallholder farmers with a high education level are more advanced and have a better chance of adopting new technologies.. This result differs from that of Mbogo (2020) who found that the majority (78.1%) of the sampled tomato farmers from Kirinyaga county had no access to training services. Results were in line with Muluki *et al.* (2022) study on factors affecting adoption of irrigatiob technologies among smallholder farmers in Machakos County, Kenya who reported that most of this farmers had access to extension services. In contrast, Mukaila *et al.* (2021) study on effects of vegetable production on income and livelihoods of rural households in Nigeria who found that most of farmers had no access extension services.

The results of this study showed that majority (73.61%) of the french bean smallholder farmers did not belong to any cooperative or farmers' organization ranging from 30.77% to 96% in Machakos and Bungoma Counties respectively (Table 20). These results on the french bean smallholder farmers organization membership varied significantly ($p<0.01$) across the Counties (Table 20). This concurs with Mbogo's (2020) study which reported that the majority (62.5%) of the sampled respondents in tomato households had no group membership. The high number of respondents not involved in group/cooperative activities may results in low bargaining powers for farmers and also a lack of french bean market information. Results were in line with Aung & Lee (2021) study on technical efficiency of mung bean producers in Myanmar who reported that most of farmers did not belog to any farmers organization. These results differed from Olagunju *et al*. 2021 who stated that most maize farmers in Nigeria belonged to farmers’ organizations.

Table 20. Collection center use, farmers organization membership, access to training services, and credit access by the respondent

	Machakos	Taita Taveta	Kajiado	Bungoma	Trans Nzoia	Percentage	X^2(df4)	P-value
Collection center use								
No	100	3.39	97.1	78	86.21	72.92	190.01	0.00
Yes	0	96.61	2.9	22	13.79	27.08		
Training services access								
No	51.92	23.73	4.35	34	55.17	32.29	49.74	0.00
Yes	48.08	76.27	95.65	66	44.83	67.71		
Farmers organization membership								
No	30.77	52.54	92.75	96	91.38	73.61	97.96	0.00
Yes	69.23	47.46	7.25	4	8.62	26.39		
Credit access								
No	76.92	62.71	73.91	96	98.28	80.9	34.06	0.00
Yes	23.08	37.29	26.09	4	1.72	19.1		

Source: Author's analysis using primary data (2022)

The results of the study indicated that the majority (80.9%) of the french bean smallholder farmers had no access to credit ranging from 62.71% to 98.28% in Taita Taveta and Trans Nzoia Counties respectively (Table 20). These results on french bean smallholder farmer access to credit varied significantly ($p<0.01$) across the Counties (Table 20). Results of this study concurred with Aung & Lee (2021) study on technical efficiency of mung bean producers in Myanmar who reported that most of farmers did not access credit. Similarly, Chelanga *et al.* (2021) study on determinants of vertical coordination option choices among smallholder french bean producers in Kenya found that most of this farmers did not access credit.

4.3 Technical Efficiency in French Bean Production

Cobb-Douglas stochastic frontier was used to test for the level and factors affecting technical efficiency among french bean smallholder farmers in selected counties of Kenya. To determine french bean production technical efficiency in the study area one output (amount of french bean harvested) and ten inputs were used. Inputs used comprised of; the area planted with french bean(ha), amount of manure (Kg), amount of fertilizer (Kg), the quantity of certified seeds and second-generation seeds (Kg), required labour for french bean planting, weeding, harvesting, agrochemical, and fertilizer application(man/days). The study found that french bean production technical efficiency levels varied among french bean smallholder farmers ranging from 0.1924 to 0.9788 (Table 21). Smallholder french bean farms with a technical efficiency close to one were more efficient than others (Aung & Lee, 2021).

Results of the cobb-Douglas stochastic frontier function showed that french bean smallholder farmers had a mean technical efficiency of 86.07%, ranging from 19.24% to 97.88% for the Counties (Table 21). These findings suggest that given the prevailing input level, french bean smallholder farmers can still increase current production by 13.93%, perhaps by the adoption of better managerial skills (Table 21). These results also imply that in the case of smallholder farmers who want to efficiently exploit their farm inputs they can reduce input level by 13.93% maintaining smallholders' french bean output level. These result on the technical efficiency level suggests that french bean production technical efficiency varied among smallholder farmers. The difference in french bean production technical efficiency maybe contributed by inefficiencies in production. Therefore, the factors contributing to the french bean technical inefficiency are discussed in table 23. Also, the relatively high technical efficiency in french bean production suggests that they might be a call for these french bean smallholder farmers to adopt new technology for maximum french bean output in the study area in the near future.

Table 21. Technical efficiency distribution scores of french bean smallholder farmers

Efficiency category	Number of h/hold	Percent	Mean	SD	Minimum	Maximum
Total	288	100	0.8607	0.1196	0.1924	0.9788

Source: Author's analysis using primary data 2022

4.3.1 Effects of Farm Characteristics on French Bean Technical Efficiency

Results of this study show that out of the 10 inputs considered in the production function, six (land, manure, certified seeds, second-generation seeds, fertilizer, and planting labour had a significant effect in explaining french bean production variations among the smallholder farmers (Table 22). Land, certified seeds, second-generation seeds, and fertilizer coefficients were found to have a significant ($p<0.01$) effect on french bean production, while coefficients of manure and planting labour had a significant ($p<0.05$) effect on french bean production. Hence these variables were important in explaining french bean production technical efficiency in the study area.

The coefficients of the significant variables were found to be positive. This indicates that as each of the variable increases, french bean production increases.

The land was measured in terms of land size under french bean production during the season under consideration. Results from this study found that an increase in land size under french bean production increases french bean output by 0.5286 units (Table 22). A unit increase in land under french bean increases french bean output by 0.5286 units. This suggests that if french bean smallholder farmers increase the size of land dedicated for french bean production, french bean output will likely increase. Results of this study were in line with Lema *et al.* (2022) study on analysis of the technical efficiency of barley production in Ethiopia, who found out that land positively and significantly affected barley production. Also, Umetsu (2022) study on sustainale farming techniques and rice farm size in Delta reported that there was a positive and significant relationship between farm size and crop production technical efficiency.

French bean seeds' quality is a necessary input in french bean production. Results from this study showed that there is a difference in production increasing depending on whether french bean smallholder farmer uses either certified or second-generation french bean seeds. An increase in the use of french bean certified seeds quantity by one unit will lead to an increase in french bean production by 0.5134 units, while for a unit increase in quantity of french bean second-generation seeds increases french bean production by 0.3483 units (Table 22). This implies that a farmer using certified seeds is more likely to produce more output than one using second-generation seeds. Also, a unit change of a french bean farmer from the use of second-generation seeds to the use of certified seeds will lead to a 0.1651 unit increase in smallholder french bean production (Table 22). Therefore farmer who uses certified french bean seeds obtains higher output. Results of this study were in line with Kodua *et al.* (2022) study on technical efficiency of improved and local maize variety maize seeds farm in Ghana, who reported that farmers who cultivated improved seeds were more technically efficient than their counterparts. Endalew *et al.* (2022) found consistent results that seed use affects teff production.

Results of this study revealed that for a unit increase in the quantity of fertilizer application there will be a 0.0862 units increase in french bean production (Table 22).

Conceivably french bean farmers tested their soil before fertilizer application to identify soil requirements thus, they applied fertilizers that were compatible with the soil requirements. Results were in line with Mwangi *et al*. (2020) who found that fertilizer quantity used, positively and significantly affected tomato production technical efficiency in Kirinyanga County, Kenya. Mwangi *et al.* (2019) reported similar results that quantity of fertiliser applied had a positive anf significant effect on french bea production in Kariua Muranga County, Kenya., the result of this study concurred with that of Abdul *et al.* (2021) who reported that fertilizer use has a positive and significant effect on rice production technical efficiency among smallholder farmers. Also, the outcomes of the study also indicated that a unit increase in the use of manure quantity increases french bean output by 0.0298 units (Table 22). Perhaps this could be a result of an increase in the use of manure that improves soil quality thus improving soil fertility which helps in french bean production increase. Khatiwada & Yadav (2022) found consistent results that manure had a significant effect on ginger production technical efficiency.

The findings of the study show that an increase in planting labour by one unit increases french bean production by 0.0767 units (Table 22). Perhaps this suggests that overworking the planters may not be counter productive as tired workers might adopt non-uniform planting rates and ultimately sub-optimal plant densities. Consequently, reducing the final yield per unit area. Results of this study were in line with Benedetti *et al.* (2019) who reported that planting labour affected tomato production technical efficiency. Nevertheless, weeding, harvesting, agrochemical, and fertilizer labour were found to have an insignificant effect on french bean production.

Table 22: Maximum likelihood estimates of the parameters for the stochastic frontier approach

Variable	Coef.	Std. Err.
Constant	6.0921	0.1503*
Land	0.5286	0.0664*
Manure	0.0298	0.0144**
Certified seeds	0.5134	0.048*
Second generation seeds	0.3483	0.055*
Planting fertilizer	0.0862	0.0269*
Weeding labour	-0.0419	0.026
Planting labour	0.0767	0.0322**
Harvesting labour	-0.0244	0.024
Agrochemical application labour	0.0077	0.021
Fertilizer application labour	-0.061	0.0641
Log likelihood	-125.7673	
Pro > chi2	0.0000	
Number of observation	288	

*, ** represents 1% and 5% significant level respectively.

Source: Author's analysis using primary data (2022)

4.3.2 Effects of Farmers' Characteristics and Institutional Factors on French Bean Production Technical Efficiency

In the second step of the cobb-Douglas stochastic frontier model, the study investigated the farmers' characteristics and institutional factors that affected smallholder french bean production technical efficiency. Out of the 10 variables used in the technical inefficiency model to be estimated through maximum likelihood, 5 were dummy and 5 were continuous variables (Table 23). Hence a positive sign on the coefficient of a variable indicates that a unit increase in the variable causes an increase in technical inefficiency or leads to a decrease in technical efficiency level (Table 23). While a negative sign on the coefficient of a variable indicates that a unit increase in variable leads to a decrease in technical inefficiency or conversely contributes positively to technical efficiency level. Hence a positive coefficient decreases french bean production and vice versa.

Findings of the study indicate that gender ($p < 0.01$), soil testing ($p < 0.01$), experience ($p < 0.05$), education ($p < 0.1$), and distance to market ($p < 0.1$) significantly affect smallholder french bean production technical efficiency (Table 23). Gender, education, experience, and distance to market negatively affect smallholder french bean farmers' technical inefficiency while soil testing affects smallholder french bean farmers' production technical inefficiency positively. The gender variable coefficient is negative thus gender of the household head has a positive effect on smallholder french bean production technical efficiency (Table 23). If the number of male-headed households increases by one unit, the technical efficiency of French bean production increases by 2.0155 units, ceteris paribus (Table 23). This could be due to gender inequality in Kenyan rural areas in terms of ownership of productive resources, credit facilities, and household chores (Table 20).

Most females have ineffective credit access, lack productive resource ownership, and bear reproductive responsibility, which reduces women's participation in crop production (Table 14). Most females have ineffective credit access, lack productive resource ownership, and bear reproductive responsibility, which reduces women's participation in crop production(Table 20). Results show that male french bean farmers are more efficient compared to female farmers (Table 23). This was in line with Khatiwada & Yadav (2022) result that gender negatively affects the technical efficiency of ginger production. Results differed from that of Owusu & Ureta (2022) who reported that to achieve desired crop production, farming households are required to expand women's land ownership. Thus, from this report increase in male-headed households increases crop production technical efficiency ceteris paribus.

Results of this study indicate that education level had a negative coefficient hence a positive effect on french bean production technical efficiency as shown in (Table 23). Increase in french bean smallholder farmer’s education level by one unit increases french bean production technical efficiency by 0.1134 units, ceteris paribus (Table 23). Thus, french bean smallholder farmers with high education levels were more efficient compared to farmers who had low education levels ceteris paribus (Table 23). This could be because education helps french bean smallholder farmers to gain and exploit information on technological changes that would lead to french bean production increase. As a result, more educated french bean smallholder farmers can recognize, interpret and adopt innovations in the french bean sector such as the use of improved seeds, fertilizers and agrochemicals much faster than less educated farmers. These findings were in line with Koye *et al.* (2021) with findings who observed that increase in the number of years of education increases tomato production technical efficiency in Ethiopia. Likewise, Lema *et al.* (2022) found education level had a positive and significant impact on barley production technical efficiency in Ethiopia. imilarly, Andaregie and Astatkie (2020) discovered that education has a positive and significant impact on potato production technical efficiency among Ethiopian smallholder farmers. Gong *et al.* (2019) found that education level had a positive and significant impact on vegetable production technical efficiency.

Results of this study depict that increase in years of experience had a negative and significant ($p<0.05$) effect on french bean technical inefficiency (Table 23). This means, that the more years of experience the french bean smallholder farmer has the more efficient, compared to less experienced. An increase in farmers' experience by one year increases smallholder french bean production technical efficiency by a factor of 0.2059, ceteris paribus (Table 23). This could be because more work experience leads to more job knowledge and improves how french bean smallholder farmers perform tasks on their farms. The study findings are in line with Tesfaw *et al.* (2021) who found that the experience coefficient was negative, implying that the more experienced teff smallholder farmer was more technically efficient. Similarly, Khan *et al.* (2022) established that farmers' experience influenced rice production technical efficiency in a positive and significant way. As a result, more experienced farmers are more technically efficient than less experienced farmers.

Findings of this study indicate that distance to market affects smallholder french bean farmers' technical efficiency positively (Table 23). If the distance to market is increased by one unit, the technical efficiency of french bean production increases by a factor of 0.3827, ceteris paribus (Table 23). Perhaps the positive effect may have been attributed to the reason that most french bean output buyers such as exporters and wholesalers are located in areas far from french farming areas and they are perceived to offer higher prices. Thus, farmers will opt to transport their french bean output at longer distances such as at better prices which will motivate them to increase their production levels. Results of this study contradicts the findings of Martey *et al.* (2019), who discovered that distance to market had a negative effect on maize production technical efficiency. In contrast, Endalew *et al.* (2022) discoverestudy reported that distance to market has a significant and negative impact on teff production technical efficiency. Furthermore, Lema *et al.* (2020) found that distance to market had a negative effect on barley technical efficiency in Ethiopia, implying that increasing distance to market by one unit reduces technical efficiency..

The soil testing variable had a positive coefficient implying that an increase in soil testing among the french bean smallholder farmers decreases french bean technical efficiency (Table 23). An increase in soil testing by one unit decreases technical efficiency in french bean production by a factor of 2.6298, ceteris paribus (Table 23). Perhaps this is due to an increase in soil testing, which may recommend the use of fertilizers, which can lead to chemical concentration in the soil, affecting the chemical requirement of french bean. As a result of poor output quality sales, farmers may be discouraged from growing french bean. The findings differ from those of Edar *et al.* (2021), who discovered that soil testing had a positive effect on crop production technical efficiency in an eco-analysis of Australian crop farms. In contrast, the findings differed from those of Martnez *et al.* (2022), who contend that soil testing has a positive and significant impact on crop production technical efficiency. In contrast, results showed that respondents' occupation (farming), household size, organizational membership, and access to electricity had no significant effect on smallholder french bean production technical efficiency. Table 23 shows the effects of farmer characteristics and institutional factors on the technical efficiency of French bean production.

Table 23: Maximum likelihood estimates of the inefficiency model

Variable	Coef.	Std. Err.
Constant	2.6328	1.3126**
Gender	-2.0155	0.7024*
Education	-0.1131	0.0682***
Occupation	-0.7492	0.4989
Household size	-0.1493	0.1386
Experience	-0.2059	0.1035**
Organization membership	0.2771	0.5627
Soil testing	2.6298	0.8698*
Distance to market	-0.3827	0.2158***
Access to electricity	-0.8897	0.6364
Access to internet	0.693	0.6299

*, **, *** represents 1%, 5% and 10% significant level respectively.
Source; Author’s analysis using primary data (2022)

4.4 Institutional Factors, Farm and Farmers' Characteristics Affecting French Bean Production Commercialization

4.4.1 French Bean Household Commercialization Level

The household commercialization index was first used to determine the level of commercialization among smallholder french bean farmers. First, the output commercialization index which is the ratio of the value of french bean sold to the value of french bean harvested was computed. Input commercialization index which is the total value of inputs purchased in the market to the total value of french harvested was also calculated. Finally, the composite commercialization index was obtained by weighing the mean value of both the input and output commercialization index. The commercialization index gave a range of one to zero. Meaning that households that are more commercialized will be closer to 1 and vice versa. The findings of this study showed that the level of french bean input commercialization among the french bean smallholder farmers averages 27.22% with a minimum of 14.94% and a maximum of 99.65% (Table 24). French bean output commercialization index was found to be 92.96% with a minimum level of 12.48% and a maximum level of 100% (Table 24). French bean smallholders' composite commercialization level was 60.09% ranging from 3.19% to 96.82% (Table 24).

Table 24. Household commercialization index among the french bean smallholder farmers

Commercialization Index	Observation	Mean	Std. deviation	Min	Max
Input	288	0.2722	0.1494	0.0187	0.9965
Output	288	0.9296	0.1248	0.0027	1
Composite	288	0.6009	0.0979	0.03197	0.9682

Source: Author's analysis using primary data (2022)

4.4.2. Effects of Institutional Factors, Farm and Farmers' Characteristics on French Bean Production Commercialization

The results of this study indicate that out of the considered variables gender, age, household size, distance to market, and access to training services significantly affected french bean commercialization (Table 25). French bean smallholder farmers' age and gender are found to positively and significantly ($p < 0.01$) affect french bean commercialization among french bean smallholder farmers (Table 25). In addition, household size, distance to market, and access to training services negatively and significantly ($p < 0.05$) affected french bean commercialization. The gender of the household head positively and significantly ($p < 0.05$) affected french bean commercialization (Table 25). Therefore increase in male-headed households increases french bean commercialization by a factor of 0.0355 ceteris paribus (Table 25). This implied that males headed households were more commercialized than their female counterparts. The findings are consistent with the findings of Otekunrin's (2022) study, which investigated food security, health and environmental factors, and agricultural commercialization in Nigeria and discovered that commercialization has a positive relationship with household head gender. Contrary, Karoga *et al.* (2021) found a negative relationship between household gender and potatoe commercialization in Nyandarua County, Kenya.

The findings of this study depict that age had a positive and a significant effect on french bean commercialization among french bean smallholder farmers (Table 25). This results imply that older french smallholder farmers are more likely to engage in french bean commercialization than youthful french bean farmers. An increase in the age of french bean household heads by one year increases french bean commercialization by a factor of 0.013, ceteris paribus (Table 25). Perhaps this is because older farmers have fewer dependents than younger farmers, resulting in lower consumption of french bean output and thus a higher market surplus. Also, age can be used as a substitute to measure experience level thus increase in age increases farmers' experience. An experienced farmer is used to making a well-versed decision on french bean commercialization. The findings differ from those of Krause *et al.* (2019) study on the welfare and food security effects on vegetable commercialization in Kenya, which concluded that age has a negative and significant effect on household commercialization..

Results from this study show that household size affects smallholder french bean commercialization negatively and significantly ($p < 0.01$) (Table 25). This implies that an increase in french bean smallholders' household size is associated with a reduction in french bean commercialization. From these results, an increase in french bean household size by one unit decreases household commercialization by a factor of 0.0108, ceteris paribus (Table 25). Perhaps because larger households have higher consumption rates, more output will be used for consumption, lowering the market surplus for french bean output sales. The study's findings concurred with those of

Getahun and Muleta (2022), who contend that household size has a negative and significant impact on wheat commercialization in Ethiopia. Results differed from Onwusiribe *et al.* (2021) found a positive and significant relationship between household size and commercialization in Nigeria.

Findings from this study depict that distance to market as measured in kilometers negatively and significantly ($p < 0.05$) level affects french bean household commercialization (Table 25). An increase in distance to market by one kilometer decreases french bean smallholder farmers' commercialization by 0.0081 units, ceteris paribus (Table 25). This could be because increases in distance to market raise farmers' transaction costs due to increases in transportation and input costs, limiting commercialization. This indicates that farmers who are closer to the french bean market are more commercialized than those far from the market. Results of this study supports the findings of Abate *et al.* (2022), who found that distance to market has a negative impact on crop commercialization among Ethiopian smallholder farmers. The study also supports Mihretie's (2021) report, which discovered a negative relationship between distance to market and commercialization among Ethiopian wheat farmers.

Findings of this study indicate that access to training services negatively and significantly ($p<0.05$) affects french bean (Table 25). Results further reveals that, as extension service access increases by one unit, commercialization among french bean smallholder farmers decreases by 0.0365 unit, ceteris paribus (Table 25). Perhaps this might be due to the low education level among french bean farmers in the study area. High household education levels tend to improve farmers' technical and managerial skills as well as farmers' ability to adopt innovations which increases production in the sector. Hence, due to low education levels, most farmers who access training services are unable to implement the practices thus lowering the french bean commercialization. Findings disagree with that of Shibli *et al.* (2021) who found a positive relationship between training services access and commercialization among smallholder farmers in Malysia. Results differ from that of Kirimi *et al.* 2022) who reported that training services access had a positive impact on commercialization of bananas among smallholder farmers in Meru County, Kenya. Findings are consistent with Awotide *et al*. (2012) who reported that training access negatively affects smallholders' rice farmers commercialization in rural Nigeria.

Table 25. Determinants of french bean commercialization among respondents

Household Commercialization Level	Coefficient	Standard error
Constant	0.6149	0.0351 **
Gender	0.0355	0.0153**
Age	0.0013	0.0007**
Occupation	-0.0079	0.0115
Education Level	0.0027	0.0015
Certified seed use	-0.0028	0.0160
Household size	-0.0108	0.0029*
Electricity Access	-0.0011	0.0154
Phone Access	0.0017	0.0175
Distance to market	-0.0081	0.0040**
Farmers organization membership	0.0020	0.0149
Access to training services	-0.0365	0.0132**
Credit access	-0.0068	0.0152
Number of observation	288	
Prob>f	0.0010	
Log-likelihood	277.4761	

*, and ** significance at 1%, and 5% level respectively.
Source: Author’s analysis using primary data (2022)

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Findings

The study aimed at assessing the effect of institutional factors, farm and farmers' characteristics on technical efficiency and commercialization of french bean among smallholder farmers in Machakos, Kajiado, Taita Taveta, Trans Nzoia, and Bungoma Counties of Kenya. The cross-sectional research design was used as it helped in the description of the smallholders' french bean farm characteristics, farmers' characteristics, and institutional factors. Data was collected from 288 respondents obtained through the cluster random sampling technique. Cobb-Douglas production function model was used in determining the effect of institutional factors, farm and farmers' characteristics on french bean production technical efficiency. While the Tobit model was used in determining the effect of institutional factors, farm, and farmers' characteristics on the commercialization of french bean production.

French bean production technical efficiency level in the selected Counties was found to be 86.07%. This findings suggest that given the prevailing input level smallholder french bean farmers can still increase current production by 13.93%. The study sought to determine the effect of farm characteristics on french bean production technical efficiency. The study involved 10 inputs (land size, manure, fertilizer, certified seeds, second-generation seeds, (planting, weeding, harvesting, agrochemical and fertilizer application) labour. Out of the ten inputs, six inputs (land, manure, certified seeds, second-generation seeds, fertilizer, and planting labour) were found to positively and significantly affect french bean production technical efficiency. This results further indicated that an increase in land size allocated to french bean production by one unit, increases french bean output by 0.5286 units, holding other factors constant. An increase in the use of french bean certified seeds quantity by one unit will lead to an increase in french bean production by 0.5134 units, holding other factors constant. For a unit increase in french bean second-generation quantity, french bean production increases by 0.3483 units, holding other factors constant. With a unit increase in the quantity of fertilizer application, there will be a 0.0862 unit increase in french bean production, ceteris paribus. For a unit increase in the use of manure quantity french bean output increases by 0.0298 units, holding other factors constant. An increase in planting labour by one unit increases french bean production by 0.0767 units, holding other factors constant.

The study sought to determine the effect of farmers characteristics and institutional factors on french bean production among smallholder farmers in Machakos, Kajiado, Taita Taveta, Trans Nzoia, and Bungoma Counties of Kenya. Results from the inefficiency model indicated that gender, experience, distance to market and education level positively and significantly affected french bean production technical efficiency. Soil testing negatively and significantly affected french bean technical efficiency. Gender has a negative sign indicating that male-headed households were more technically efficient compared to female counterparts. Also, education level had a negative sign indicating that more educated french bean households head were more technically efficient. Household experience years had a negative sign indicating that the more experienced french bean farmer was the more efficient. Soil testing had a positive sign showing that farmers who had undertaken soil testing were less efficient. Also, distance to market had a negative sign indicating that the more the french bean farmer was distant to the market the more efficienct the farmer was .

Tobit model results indicated that the level of french bean smallholder farmers of commercialization was 60.09%. Further, the study sought to determine the effect of institutional factors, and farm and farmers' characteristics on the commercialization of french bean production in Machakos, Kajiado, Taita Taveta, Trans Nzoia, and Bungoma Counties of Kenya. Twelve inputs (Gender, age, occupation, education level, household size, certified seed use, Distance to market, access to electricity, phone access, farm organization membership, credit access, and training services access) were used in the Tobit model. Results indicated that gender and age positively and significantly ($p < 0.01$) affected french bean commercialization. Household size had a negative and significant ($p < 0.01$) effect on french bean production commercialization, while the distance to market and training service access had a negative and significant ($p < 0.05$) effect on french bean production commercialization. Results further indicated that an increase in the male-headed household by one unit increases french bean production commercialization increases by 0.0355, holding other factors constant. For a unit increase in household head age, french bean commercialization increases by 0.0013 units, holding other factors constant. The study also indicates that an increase in the household by one unit reduces french bean commercialization by 0.0108 units, holding other factors constant. A unit increase in distance to the market reduces french bean commercialization by 0.0081 units, holding other factors constant. However, the result indicated that an increase in training services access reduces french bean commercialization by 0.0365 units, holding other factors constant. This differed from the anticipation that access to training services should increase french bean commercialization.

5.2 Conclusions

The study aimed at determining the effect of institutional factors, farm, and farmers' characteristics on french bean smallholder farmers in selected Counties of Kenya. French bean smallholder farmers were found to be producing french bean at an 86.07% technical efficiency level thus they had the potential of their production level increasing by 13.97% given the available resources across all the counties. From this study french bean production and technical efficiency can be increased by increasing french bean land size, use of certified seeds compared to the use of second-generation seeds, and use of fertilizer and manure. French bean production technical inefficiency was affected by the experience, gender, education, distance to market, and extension services. It was found that an increase in french bean farmers’ experience, education level, distance to market, and male-headed households increase french bean production technical efficiency, while the increase in soil testing activities decreases french bean production technical efficiency.

The study focused on determining the effect of institutional factors, farm, and farmers' characteristics on french bean commercialization among smallholder in the selected Counties of Kenya. It was found that french bean smallholder farmers were commercialized to a 60.09% level both in the export and local market. An increase in french bean smallholder farmers’ age and male-headed households in the study area increases french bean production commercialization. Distance to the french bean market, household size, and access to extension services decrease french bean commercialization among the french bean smallholder farmers in the study areas.

5.3 Recommendations

The following recommendations were made based on the preceding conclusion.

1. To improve technical efficiency and commercialization of French bean production, extension officers and stakeholders in this field should encourage smallholder farmers to increase land size under French bean production, use certified seeds, and fertilizer.
2. Extension officers and field stakeholders should encourage male-headed households to take part in producing french bean, as the increase in male-headed households increases the technical efficiency and commercialization of french bean production. Furthermore, a more educated population should be urged to participate in french bean farming, as a high literacy level aids in increasing technical efficiency and commercialization of french bean production.
3. To reduce the distance covered by these farmers in marketing their french bean produce, the government and field stakeholders should ensure the establishment of french bean markets and institutions in french bean growing areas. Establishing an institution with easily accessible trainers through which French bean farmers can routinely access extension services, as well as monitoring implementation procedures to ensure maximum utilization of extension information.

5.4 Suggestions for Further Studies

The study suggests the following further studies:

1. The study assumed that the technology in Frenchbean production was constant, therefore exploring the effect of technological change on french bean production technical efficiency and commercialization among smallholder farmers in Kenya could be an area of further studies.
2. To analyze the effect of market requirement standards on french bean production technical efficiency and commercialization among smallholder farmers in Kenya.

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APPENDICES

Appendix 1: Survey Questionnaire

Part 1: Household Identification

Serial number	
Date of interview	
County	Code A
Sub-county	
Ward	
Name of household head	
Name of respondent	

Code A: 1. Machakos 2. Taita Taveta 3. Kajiado 4. Bugoma 5. Trans Nzoia

Part 2: Farmers' Characteristics

i.	Gender of the decision-maker	1 = Male 2 = Female
ii.	Gender of household head	1 = Male 2 = Female
iii.	Who is the household decision maker	Code B
iv.	What is the age of main decision maker?	
v.	Marital status of the main decision-maker	Code C
vi.	Level of education for the main decision-maker (schooling years)	
vii.	How long have you been in French bean farming?	
viii.	The main occupation of decision maker in terms of time spent	Code D
ix.	How many people have lived in your household in the last 6 months?	

Code B: 1.Household head 2. Spouse 3. Son/daughter 4. Grandchild 5. Parent 6. Farm manager. **Code C**: 1. Married 2. Single 3. Separated 4. Widowed. **Code D:** 1. Agriculture, mining, fishing, forestry 2. Government employment 3. Employed in business 4. Self-employed 5. Casual labourer

Pat 3: Farm Characteristics

Land Allocation

What is the total area of land operated by the household (acres)	
What is the total area used for crop production (acres)	
What size of the land is owned by household (acres)	
What size of the land is rented (acres)	
How much land do you rent out (acres)	
How much land did you plant french bean in the last season?	
What is the land tenure on the plot under french beans?	
Is your farm GLOBAL GAP satified for french bean?	1=Yes 2= No

Irrigation

1. Do you use irrigation water? 1= Yes [ ] 2= No [ ]

What is the main source of water for crop farming?	Code E
How do you pay for irrigation water	Code F
Are tools used for irrigation optimised to crop irrigation requirements	1=Yes 2= No
What technologies do you use for irrigation application	Code G
What is the average cost for setting up irrigation technology for an acre of land?	
What is the average cost of irrigation for an acre?	

Code E: 1 = Surface run-off, 2 = Rooftop harvested**,** 3 = Well, 4 = River, 5 = Borehole, 6 = piped water**. Code F:** 1. Flat rate, 2. per unit. **Code G:** 1= Surface, 2= Drip, 3 = Sprinkler, 4 = Center pivot, 5= Manual.

Labour

2. How many man-days were spent on the following activities during the last season of French bean production?

	3.1	3.2	3.3	3.4	3.5	3.6
Activity	Labour Distribution					
	Family labour	Hired	Days Worked	Hours worked per day	Labour worked per unit	Total labour cost
Land Preparation						
Planting						
Weeding						
Harvesting						

Seeds

3. Which French beans variety do you plant? ....
4. Do you use certified seeds 1= yes [ ] 2 = No [ ]

	4.1	4.2	4.3
French bean seed category	How many kilograms of seeds do you plant?	What was the average cost of seeds per kg	Average seeds cost
Certified			
Own seed			

Agrochemicals

Where do you source your agrochemicals?	Code H
Do you know the approved list of agrochemicals?	
Do you keep a list of approved suppliers?	
Do you check to confirm the chemicals bought are not expired?	1-= Yes 0 = No
What do you do with expired chemicals?	Code I
Do you read and understand the product label?	1 = Yes 0 = No
Who identifies pest and diseases on your farm?	
How do you protect crop on your farm?	
Who advices on the chemical to use and dosage?	
Who makes recommendations for the application of fertilizers?	
Who determines the application rate?	
What type of agrochemicals did you apply on french beans in the last season?	
In what units do you measure agrochemicals for french beans?	
What types of fertilizer do you use?	
What quantity of planting fertilizer did you use?	
What was the total cost of planting fertilizer used in the last season?	
What quantity of topdressing fertilizer did you use?	
What was the total cost of top dressing fertilizer used in the last season?	
What quantity of foliar fertilizer did you use?	
What was the total cost of foliar fertilizer used in the last season?	

CODE H: 1 = Agrovet 2 = Neighbour 3= Cooperatives 4 = Produce buyer 5 = Service Provider 6 = Other Specify **CODE I:** 1 = Spray anyway 2 = Dispose 3= other specify

Part 3: Institutional Factors

Extension Services

Have you accessed any training related to french bean in the last five years	1 =Yes 2 = No
If yes how many trainings	
Which training did you receive	
When in need, where do you access extension services?	
Do you pay for extension services	1 = Yes 2 = No
In the past 12 months, how many contacts with the extension officer had you had related to French bean farming?	
What support mechanism do you need to support french bean production?	
How do you mitigate the risk associated with growing crops?	Code J

Code J: 1. Insurance 2. Diversification 3. Contract farming 4. Adoption of innovation technology

Credit Access

i.	Have you ever accessed a credit facility/ loan since establishment?	1 = Yes 0 = No
ii.	If yes, what is the total amount of credit (Ksh.) received in the past year?	
iii.	Do you or any other member of your household get income from other activities than crop farming?	1 = Yes 2 = No
iv.	What are the common financial needs for the farmer in regards to farm activities?	
v.	How do you go about meeting the following needs?	1 = Yes 0 = No
vi.	What other sources of income did you and other members of your household have in the last 12 months? Remittances Pension Own-business On farm paid labour Non-farm paid labour Other crop Farming Livestock Farming	

Organizational Membership

5. Are you or your spouse a member of a farmer's organization?
   1 = Yes [ ] 2 = No
6. What was the reason for joining the farmer's organization?
   1= Access to input [ ] 2 = Access to output market

   3= Extension/training services [ ]

7. What did you contribute to the farmer's organization? …………………………………
8. What are the benefits derived from being a member of that group as a market actor?
   ………………………………………………………………………………………
   …….

9. Are you or any member of the household a member of other groups other than the farmers' group?
   1 = Yes [ ] 2= No [ ]
10. To what type of organization did you or any of your household member belong?
    1 = Community/family group [ ] 2 = Saving/credit group [ ] 3 = Labour union [ ]
    4 = Women's group [ ] 5 = Men's group [ ] 6 = Youth group [ ]
    7 = Church Group [ ] 8 = Sport and leisure group [ ] 9= other, please specify…………..

Market Access

i.	Do you sell your produce	**1 = Yes 2 = No**
ii.	If no, what limits your access to market?	
iii.	What is the distance to nearest market?	
iv.	Is time taken to reach the nearest market?	
v.	What type of road do you use to access the market	**Code K**
vi.	Do you have collection centres?	**1 = Yes, 2 = No**
vii.	What quantity of French bean was sold? a. Aggregators b. Producer group c. Exporters d. Traders	
viii.	What are the terms of trade?	
ix.	How is your produce delivered to the market	
x.	What limits your access to markets	

Code K: 1. Tarmac 2. All-weather road 3. Murram road 4. Footpath

Part 4: Produce Distribution

What quantity of produce did you harvest?	
How do you grade the french beans?	
What were the units of measurement?	
What quantity was consumed?	
What quantity was given out?	
What quantity spoiled?	
What was the reason for spoilage	
What quantity was sold?	
Quantities sold to the exporters	
Quantities sold to the wholesaler/traders	
Quantities sold to other buyer	
Average price of produce sold per unit	
Total revenue from sale of produce	

Thank you for taking the time to respond to the questions.

God bless you.

Appendix 2: Introductory Letter

Dear Sir/Madam,

I am Beth Wangari Kamau, a student at Chuka University, pursuing a Master of Science in Agricultural Economics. I am conducting academic research on **'Effects of institutional factors, farm and farmers' characteristics on technical efficiency and commercialization of french bean production among smallholder farmers in selected Counties, Kenya'.** The main aim of this study will be; to partially fulfil the academic requirement for the award of Master's Degree of Agricultural Economics. I hereby request your honesty when answering the following questions. All responses will be treated with confidentiality, and information will only be used to meet the study objectives.

Thank you for participating in the study.

Yours faithfully,

Beth Wangari Kamau

Appendix 3: Chuka University Letter of Ethics

CHUKA UNIVERSITY

Knowledge is Wealth (*Sapientia divitia est*) Akili ni Mali

CHUKA UNIVERSITY INSTITUTION ETHICS COMMITTEE

Telephones: 0612304004
Fax line: 020 2310302

P.O. Box 109 - 60400
Chuka

1st March 2022

REF: CUIERC/ NACOSTI 235
TO: Beth Wangari Kamau

Dear Sir/madam

<u>RE:</u> Effects of institutional factors, farm and farmers characteristics on technical efficiency and commercialization of French bean production among smallholder farmers in selected counties, 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 is1st March 2022 to 1st March 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 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

03 MAR 2022

Dr.Benjamin Kanga
SECRETARY CHUKA UNIVERSITY

Appendix 4: NACOSTI Research License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 297503

Date of Issue: 29/March/2022

RESEARCH LICENSE

This is to Certify that Miss.. Beth Wangari Kamau of Chuka University, has been licensed to conduct research in Bungoma, Kajiado, Machakos, Taita-Taveta, Transnzoia on the topic: **EFFECTS OF INSTITUTIONAL FACTORS, FARM AND FARMERS' CHARACTERISTICS ON TECHNICAL EFFICIENCY AND COMMERCIALIZATION OF FRENCH BEAN PRODUCTION AMONG SMALLHOLDER FARMERS IN SELECTED COUNTIES, KENYA.** for the period ending : 29/March/2023.

License No: NACOSTI/P/22/16494

297503

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

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