Original Research Article

Analysis of Production, Socio-Economic and Institutional Factors Affecting Technical Efficiency of Smallholder Banana Producers in Kirinyaga Central Sub-County, Kenya

ABSTRACT

Banana provides food, nutrition security and income for most households and is fourth most popular food crop in the world after wheat, maize and rice. Despite its significance, full potential of banana production in Kenya remains unexploited by smallholder producers due to low technical efficiency especially in the utilization of farming inputs due to production, socio-economic and institutional issues, among other factors. In Kirinyaga County, the actual banana production is estimated at 4-18 tonnes per acre against the potential of 30-40 tonnes. Despite the limited supply of resources for production, attainment of highest possible levels of technical efficiency is key to achieving efficiency in banana farming. The study analyzed the effects of production, socio-economic and institutional factors on technical efficiency among smallholder banana producers in Kirinyaga Central Sub-County, Kenya. A cross-sectional research design was used in this study. Questionnaire was administered randomly to 402 respondents' selected using multi-stage sampling technique. Data was analyzed using Stata version 17 and SPSS version 25. Descriptive statistics described the production, socio-economic and institutional factors. A stochastic frontier analysis approach was used to model the efficiency levels using Cobb-Douglas functional form estimated using the maximum likelihood technique. The study showed that technical efficiency varied between 0.93% to 95.45% and average technical efficiency of 83.14%. The study found that manure and planting materials had positive effects on technical efficiency whereas land size had negative impact. The findings established that age of decision maker and size of the household had negative effects whereas education, experience, producer group membership and market access had positive effects on technical efficiency. The study advises people with high levels of education to get into banana farming because smallholder producers with greater levels of education demonstrated high levels of production efficiency. Additionally, to improve technical efficiencies, farmer group development and membership are encouraged and also extension services should be made more accessible.

Key Words: Technical efficiency, Socioeconomic factors, institutional factors, smallholder banana producer

1. INTRODUCTION

Banana (*Musa spp*) is a tropical crop produced in approximately 130 countries worldwide [1]. It is rated number four as a food crop among developing nations after wheat, maize and rice [2]. In addition, banana production act as employment and income source to smallholder farmers in high production areas. Ninety-eight percent of whole world banana come from undeveloped nations [3] and is one of the most consumed fruit and helps to meet both food and nutritional security for smallholder producers. Banana is a high-value commercial fruit and highly demanded [4]. It has become the most consumed and exported fruit in the world and is grown on smallholder farms and large plantations around the world [5]. Fifty percent of all domestic horticulture production is contributed by banana production [6]. According to FAO [7], more than 1000 varieties of banana exists in the world and Cavendish banana is the most popular type and merchandized.

More than 60% of the global banana production is from Brazil, China, Ecuador, India, Philippines, Indonesia [8] and approximately land area of 5.6 million hectares are dedicated to its production [9]. The world's largest banana grower is India, accounting for around 15% of the total worldwide area and 29% of the global overall output [1]. India produces an average of 39 million tonnes annually [10]. Eighty percent of banana fruits produced globally are locally consumed and 20% are exported [8]. According to Voora et al. [11], banana is among the most traded fruits in the world and in 2018 around 155 million tonnes were produced and traded [12]. According to FAOSTAT [13], several factors

affected banana trade in 2021 including banana production shortages and the continued spread of banana plant diseases. In Africa, approximately 70 million people rely on banana to support their financial needs [14] and it has been reported being among the most significant food security crop for Africa's Central, Eastern and Western regions [15]. It has been observed that sustainable production of banana crops could play a critical role in Africa's food security and advance economic growth in the region [66]. Eastern and West Africa are some of the well-known banana growers in Africa with Uganda, Cameroon, Tanzania and Kenya producing the most [16]. Further, about 2.3% of all worldwide total banana harvested is produced in West Africa. The top banana-producing nations in the West Africa region include Côte d'Ivoire, Liberia, Guinea and Mali. The world's biggest producer of highland bananas is Eastern Africa and it contributes around 20% to global banana production [17]. The majority of Africa's bananas are produced in Uganda and most of the grown bananas are the cooking *Matooke* and the brewing *Mbidded* types [18].

In Kenya, banana production is mainly on small scale and aids in meeting the nation's food needs [10]. In some regions of the country, minimal irrigation is done but the output is primarily rain-fed and has the potential to benefit the smallholder producers as well as other participants in the value chain [19]. Common varieties grown include the cooking types: Uganda green, *Mutahato*, *Nusu Ng'ombe*, and *Gradi shisikame*, whereas among the dessert options include: apple banana (*Ndizi sukari*), *Bogoya*, *Bokoboko*, Chinese Cavendish, Gros Michel, giant Cavendish, *Kampala* and *Muraru* [20]. Additionally, in Kenya banana constitutes one among the most significant basic crops, accounting for 14% of the country's overall crop value and 20% of the total food consumption [21]. Banana also accounts for around 32% of all fruits exported foreign earnings in Kenya [22]. The ripe banana is among the fruits that city dwellers consume most, whereas plantains are the second most popular fruit across all socioeconomic levels [6]. Banana production is largely practiced in the Eastern, Western and Central areas [23] and its output consumed locally [24]. Meru, Kirinyaga, Muranga, Kisii, Tharaka Nithi, Kiambu, and Taita Taveta are the most productive counties, with a total production of 17%, 11%, 9%, 8%, 8% and 5%, respectively [25].

In Kirinyaga County, the major fruits grown in order of importance are banana 34.85%, Mango 20.13%, Pineapple 15.52%, avocado 9.90%, water melon 5.67% and Pawpaw 4.73%. Banana production in Kirinyaga County was estimated at 117,356 tonnes in 2017 and 152,409 tonnes in 2018 [26]. Banana farming is a popular choice among farmers because of its adaptability for cultivation within the region, great market demand, and relatively simple management of the crop [27]. A study by Kairu (28) in Kirinyaga found maximum harvest of banana at 108,000 kgs and a minimum of 400 kgs and this translates to actual production of 4-18 tonnes per acre against the potential of 30-40 tonnes per acre. Further, Kairu [28] found that out of the 302 respondents, 153 indicated that their banana production remained the same, 210 respondents their area under banana cultivation ranged between 0.1 to 0.3 acres indicating that small pieces of land were allocated for cultivation of banana.

Several factors have an impact on banana output which cut across socio-demographic factors, agronomic and management practices [20] and among them are diseases, subpar agronomic techniques, pests, and a lack of access to sanitary and reasonably priced suckers. Additionally, pest and disease prevalence in the soils has an impact on soil fertility while increased soil temperature allows the spread of banana soil-borne illness, hence negatively influencing the production of banana. Lack of provision and accessibility to extension services and proper plantation management, marketing and climatic factors also affect banana production [29; 30]. Karienye and Kamiri [19] also noted that land use changes, fluctuating labour costs and soil water retention affects banana production. Despite the challenges, banana production is an economic revenue source with a strong potential for profit for a nation thus a rise in its level of production efficiency would lead to a society that is nourished and secure in its food supply and a positive influence on rural growth [31]. Given that there is a huge demand for banana fruits especially in towns [6; 31], a country's food supply would increase and producers would receive more money if production efficiency were to increase. An increase in banana output would result in more job prospects, more revenue, and better food security. This is crucial to achieving Kenya Vision 2030 as well as

achievement of the Big Four Agenda by the national government as well as the sustainable development goals. Comparing farmer performance and locating the causes of inefficiencies in production is made easier with the use of technical efficiency measurements [32]. To assess technical efficiency, it is crucial to consider a farmer's performance and the variables that influence efficiency [33]. As a result of inefficiencies in production there is a necessity to investigate technical efficiencies in agricultural production, especially among smallholder banana producers.

2. METHODOLOGY

2.1 Description of Study Area

The study was carried out between December 2022 and February 2023 in Kirinyaga Central Sub County, Kirinyaga County within Mt. Kenya region. Kirinyaga County is bordered to the north and west by Nyeri County, to the west by Murang'a County, and to the east and south by Embu County [34]. The County covers a total surface area of about 1,478.1 kilometer squared. Kirinyaga Central Sub County is amongst the five sub counties in Kirinyaga County. The Sub County's overall land area is approximately 173.6 square kilometers and a population of 122,740 [34]. The Sub County is organized into four wards: Mutira, Kanyekiini, Kerugoya and Inoi. The research area experiences bimodal rainfall, having prolonged precipitation through March until May and short rainfall throughout October into December, with amounts varying from 1,212 mm to 2,146 mm [35]. The range of temperatures is 8.1 °C to 30.3 °C on average. Agricultural production is the major source of earning, and most of the farmers (70%) are smallholders [36]. In addition, 87% of the county's population relies on it for their primary source of earnings, making it the most significant activity. Agriculture accounts for 72% of the incomes received by households and banana is among the major crops grown [37].

2.2 Sample size

The sample size of this study was 402 smallholder banana producers who were obtained from major banana producing areas in Kirinyaga County which included Mutira, Kerugoya, Kanyekiini and Inoi wards. Daniel and Cross formula [38] was used to determine the sample size

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

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

2.3 Research design and sampling technique

This study used a cross sectional research design. The design made it possible to collect quantitative statistics on inputs as well as outputs in one period in the production year 2022. The research design enabled an assessment of production, socioeconomic and institutional factors that characterize smallholder banana producers at a certain moment [39]. In order to choose the farmers who would make up the sample, the study used a multistage sampling technique. In the first stage Kirinyaga Central Sub-County had been selected from the five Sub-Counties and four wards purposively selected from the Sub-County. Secondly, within each of these chosen wards, farmers were selected randomly. Respondents in the study were chosen using simple random sampling from the wards.

2.4 Data Analysis

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

In the context of the Cobb-Douglas production function, this study employed the stochastic frontier model in identifying the production variables. The stochastic frontier model was defined in accordance with the models of Levin [40] and Battese [41] as below:

$$Y_i = f(X_i\,;\beta)\exp(V_i - \cup_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

where i = 1, 2… 402 farmer, Y_i is banana yield of 402 producer, X_i is a vector of the quantities of farm inputs used in banana production, $f(X_i\,;\,\beta)$ is an appropriate Cobb Douglas production function. Under the assumption that $(X_i\,;\beta)$ utilizes the log linear Cobb-Douglas form equation, then equation (v) can be expressed as;

$$lnY_i = \beta_0 + \beta_i lnX_i + V_i - \cup_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

β's are parameters, V_i is the random error that has a mean of zero and is related to uncontrolled variables like measurement error and climatic conditions that are beyond of the control of producers. $\cup_i$ is the inefficiency which is sometimes called the one-sided error term. The following was the specification of the Cobb Douglas production function for the banana growers in the study area:

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

where, *In* = is the natural logarithm, X_1 is labour used (Man-days), X_2 is manure quantity (wheelbarrow), X_3 is land size under banana production (acre), X_4 is planting materials (suckers), Y_1= total Quantity of banana (kg), βi= Parameter to be estimated, V_1= are random variables which are assumed to be independent of *U* identical and normally distributed with zero mean and constant variance N (0, δ_v^2), *U*= it represents production technical efficiency. Technical efficiency of the banana farmers is defined to be the ratio of observed output (Y_i) to the corresponding frontier output (Y_i *) using the existing technology and so the technical efficiency of the farmers is denoted by;

$$TE = \frac{Y^i}{Y_i^*} = \frac{exp(\beta X_i + V_i - \cup_i)}{\exp(\beta X_i + V_i)} = \exp(-\cup_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (iv)$$

where, Y_i=observed banana production level, Y_i * = predicted level of banana production. The producers' level of technical efficiency is expressed as a value ranging from zero to one [42]. A farmer who has a value of one is considered to be technically efficient and zero totally inefficient farmer. The study employed the Stochastic frontier model in investigating the impact of socio-economic and institutional variables on technical efficiency in banana production. The model was utilized to conduct a regression analysis using the efficiency scores as the dependent variable and socio-economic and institutional variables as the independent variables. The connection between socio-economic variables, institutional variables and technical efficiency were analyzed using stochastic frontier model and was applied as below:

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

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

where: U_i ~ N (0,σ^2) and β are vectors of explanatory variables and unknown parameters respectively. Y_i * is a latent variable and Y_i is a technical efficiency score and U_i is the error term.The stochastic frontier model used in the analysis was as in equation (*x*) below:

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

where, TE_i= technical efficiency, δ_0 is the intercept of the function while δ_1, δ_2 , … δ_9 are unknown scalar parameters to be assessed and X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, are age, gender, education, farming experience, household size, credit access, access to extension services,

group membership and access to market. The ω is the error term which is presumed to be normally distributed.

3. RESULTS AND DISCUSSION

3.1 Summary of descriptive statistics of variables used

The summary of the descriptive statistics of the variables used during the study are presented in Table 1. According to the findings of this study, the average size of land under banana production was about 0.4 acres with some smallholder producers having farms as small as 0.1 acres and others as large as 5 acres. This confirms that banana production in Kirinyaga Central Sub County consists of smallholder producers. During this study, it was observed that banana production faced competition from other alternative farming activities. In addition, due to small land size available producers may have to use land in a technically efficient manner. The findings by this study are consistent to those reported by Omondi et al. [23], that a large proportion of producers cultivated banana in plots between 0.03 acres and 0.79 acres. This study's findings indicated that the average total amount of labour was 10-man days ranging from 7 to 14-man days. The findings of this study contradicted those of Eutycus [10] who found that the average labour used in banana production was 108.8-man days per year in Meru County, Kenya.

Table 1: Summary of descriptive statistics of the variables

Variable	Mean	Std. Dev	Min	Max
Land size (acres)	0.429	0.615	0.1	5
Labour (man days)	10.336	2.128	7	14
Agrochemicals (wheelbarrows)	200.682	157.262	5	4600
Planting materials (suckers)	195.898	170.052	10	2300
Age of decision maker	53.940	6.971	24	85
Gender (1=Male, 0= Female)	0.866	0.341	0	1
Household size (number)	4.169	1.180	1	12
Education (Years of schooling)	10.891	2.748	0	18
Farming experience (years)	12.420	4.015	3	32
Credit access (1=yes, 0=no)	0.572	0.495	0	1
Extension Access (1=yes, 0=no)	0.144	0.352	0	1
Market distance (kilometer)	12.248	4.833	0	24
Farmer organization (1=yes, 0=no)	0.0572	0.233	0	1

The average amount of agrochemicals (manure) used in banana production was 200.68 wheelbarrows and it ranged from five to 4,600 wheelbarrows. Agrochemical application directly increases the fertility of the land which in return is expected to increase banana yields of the producers. Muthee et al. [65] established that only 15% of the producers in Embu applied manure and other fertilizers to their banana plantations and this affected production. Debebe and Dagne [64] in their examination of the socio-economic factors influencing banana production in Ethiopia found that majority of producers (70.77%) growing banana were not applying fertilizer in their banana farms. Omondi et al. [23] reported that fertilizer was not used by the majority of producers to produce banana in Kisii and Migori counties and that the average amount of organic fertilizer utilized by those that used fertilizer was 118.27 kg compared to 1.17 kg of inorganic fertilizer per acre.

The mean number of banana suckers grown by the smallholder producers in the study area were 196 per acre ranging from 10 to 2300 suckers (Table 1). Number of banana suckers planted by a producer is significant since it greatly affects the total yields produced. Even if there is a sufficient supply of other inputs, output will be low if the correct quantity and quality of suckers are not used. This study's findings are not in agreement with Sharma et al. [63] who established that the average number of banana suckers planted in Nepal were 2,034 per hectare.

The findings demonstrated that the mean age of smallholder banana producers was 54 years old,

ranging from 24 to 85 years alongside standard deviation of 6.771 years. The findings showed that most of the banana producers surveyed were in the age range of 47 and 61years indicating that the study area has many of the middle-aged farmers participating in banana production (Table 1). This imply that the bulk of producers are in their prime of life, economically energetic and fruitful age bracket and can therefore carry out successful farming. The findings of this study concur with those of Sharma *et al*. [63] who reported that the typical household heads' age among banana producers in Nepal was approximately 51.84 years and was ranging from 22 to 82 years. The results of this study are contrary to those of Eutycus [10] who found that majority of banana producers in Meru, Kenya, were middle aged and ranged between 31-40 years.

The findings of this study shows that age plays an essential part on the availability of labour for carrying out farming activities and is among the most essential socio-economic determinant that affects a producer's decision-making as production is being done. It is also possible that decision makers' age in production of banana is a major determinant in embracing of innovation in the banana sector. This study established that most decision makers among the banana producers were men (86.57%), whereas only 13.43% were female. This implies that most smallholder banana producers' households are controlled by males and therefore banana production decisions are made by males. This may indicate that more men than women are actively engaged in the cultivation of banana reflecting gender inequality among smallholder banana producers in Kirinyaga.

During cultivation of bananas, a producer's gender may be important, especially when family labour is the primary source of labour. It's possible that male producers put in more labour than female producers do. When identifying the underlying reasons of smallholder producers' low efficiencies, the producers' gender is a crucial consideration. There is a possibility that men are typically more muscular over female producers, allowing them to manage farming duties easier compared to female producers, which can make female producers less effective than male producers. At the same time, in comparison to their female counterparts, men possess greater accessibility to resources as well as expertise needed to grow crops more effectively. Findings from this study are in line with Bhatta *et al*. [4] and 67. Farah and Visetnoi [67] who found that majority of banana producers in Nepal and Somalia, respectively, were males. In addition, majority of banana producers in Kisii, Nyamira and Embu counties were male [20]. The findings of this study contradict Eutycus [10] who noted that majority (56%) of small-scale banana producers in Meru County were females.

The mean household size was four people with a least family having one person and 12 people maximum. The results imply that there could be availability of family labour amongst smallholder banana producers in Kirinyaga Central Sub County. The number of people in a family may determine the availability of workers eligible for manual work to perform farm activities mostly during banana planting, distribution of manure, weeding and harvesting. As a result, total number of inhabitants staying in a farmer's home might have an impact on the amount of agricultural production through the availability of manpower and also helps to cut off labour costs. The findings of the current study were in disagreement to those by Sharma et al. [63] who found that the mean household size among banana producers in Nepal was six people.

The sampled banana producers had a mean education level of 10 years of formal education, from zero up to 18 years range insinuating that some producers had low levels of education. The highest possible level of schooling a producer has attained may influence their decision making in the process of production as it impacts the farmer's capacity to receive and make use of the production data offered and to adopt new and advanced technologies. This is in return expected to increase technical efficiencies in production as producers can make the most of the resources at their disposal to increase yield. According to the outcomes of this study, the mean educational level among respondents was high school.

The findings of this study were that on average, smallholder banana producers had 12 years of experience in banana production with 3 years as the least, and 33 years at the most (Table 1). Experienced producers may offer accurate information and possess in-depth knowledge of banana growing and this would translate to higher technical efficiencies and productivity. There is a possibility that experience is crucial in

increasing output because it is normal to expect that the more time one spends working in a given occupation, the better they get at performing tasks. Eutycus [10] found that on average banana producers in Meru County, Kenya, had experience of 10 years. Contrary to the outcomes of this research, Vinayagamoorthi et al. [8] while examining the experience of the farm households found that most producers (54%) were having 20 years of farming experience demonstrating that the producers had a wealth of knowledge in banana growing in Tamil Nadu, India.

The findings showed that 42.79% of the producers lacked the ability to obtain financing, compared to 57.21% of those who had access to credit in Kirinyaga Central Sub County. This imply that majority of the smallholder banana producers in Kirinyaga had accessibility to credit. Credit availability may enable producers to make prompt acquisitions of the inputs they are unable to furnish by themselves. It aids in the improvement of household efficiency by removing financial restraints that can make it difficult for households to make timely purchases of inputs, tools, and farm management decisions. The findings of this study contradict Eutycus [10] who analyzed small-scale banana farming technical efficiency in Meru, Kenya and reported that the majority of producers lacked access to credit. The findings further contradict those of Debebe and Dagne [64] who reported that majority of the banana producers in Ethiopia (64.28%) had no access to credit.

The study's findings demonstrated that out of the banana growers examined only 5.72% were members in a grower's organization. During the study it was observed that majority (94.28%) among the surveyed smallholder banana producers did not belong to a group of banana producers (Table 1). It is possible that the platform provided by producers' associations or groups allows access to information on marketing and the availability of new technology. The groups provide a platform that allow smallholder producers to better organize the sale of their harvested products and sale in large quantities. There is likelihood that where high number of respondents are not involved in group/cooperative activities results in low bargaining powers for producers and also lack of banana market information. Producers belonging in groups may be in a position to receive various agricultural trainings and other financial support. Further, famers in groups probably benefit from different projects and programs that may come up from government or NGOs. The findings of this study differed those of Bhatta et al. [4] who found that majority (80%) of large-scale banana farmers in Nepal were members to farmer organization.

The findings show that 85.75% of banana farmers failed to receive extension services while only 14.43% accessed the services (Table 1). Extension services and training ensures that producers get the information and abilities to help them carry out good agricultural practices and efficient use of available resources. Producers who have access to extension visits and trainings probably stand a chance of profiting from new knowledge, more crop production methods, new farming methods and a desire to adopt modern inputs, all of which could increase their technical efficiency. During the study it was observed that extension services were very weak due to unavailability of enough extension officers. There was a high ratio of extension providers to producers whereby most producers are not reached. The results of this investigation concur with those of Eutycus [10] who established that 69% of the banana cultivators in Meru, Kenya, were not able to access extension services, while only 31% accessed extension services. The findings also agree with those of Debebe and Dagne [64] who found that most of banana producers in Ethiopia (65.58%) had no access to extension services.

The study observed that the distance to closest banana market was 12 kilometers on average, ranging from one to 24 kilometers. Long distances translate to huge transportation and carrying costs which in return affects producers' incomes and production. This study's outcomes oppose those by Sharma et al. [63] who established average distance to the nearest market by banana producers in Nepal was 5.09 kilometers. Debebe & Dagne [64] on the other hand reported that the nearest banana market was 5.428 kilometers away from producers place.

3.2 Technical Efficiency of Smallholder Banana Producers

The findings on the Cobb-Douglas stochastic frontier function showed that smallholder banana producers mean technical efficiency was 83.14%, ranging from 0.93% to 95.45% (Table 2). These findings proved that smallholder

banana producers in Kirinyaga Central Sub County had varied levels of technical efficiencies and that differences in efficiencies may be contributed by inefficiencies in production. Decreasing levels of technical efficiencies could be linked to both inefficient input use and producer-specific characteristics, such as decision-makers age, producers' experience, market distance, lack of participation in producer organizations, inaccessibility to credit and extension services. These findings suggest that given the prevailing input level, smallholder banana producers can still increase current production by 16.86% perhaps through productive management of their orchards. The inefficient producers had technical efficiency score of 0.93%, therefore the producers could increase their existing output by enhancing technical efficiencies because they are utilizing their resources ineffectively as production is being done. The findings of this study differed those of Van Hung et al. [44] who found that banana farmers' technical efficiency varied in Viet Nam and ranged between 89.68% to 97.81% with an average technical efficiency of 95.92%. The findings of the current study differed with Naik et al. [62] who found the mean technical efficiency in banana in India was 70.30%.

Table 2: Technical efficiency of the sampled banana producers

Variable	Mean	Std. Dev.	Min	Max
TE	0.831	0.128	0.009	0.955

3.3 Influence of Production Factors on Banana Production Technical Efficiency

The study sought to analyze the influence of production factors on banana production technical efficiency. The findings of this study showed that land size, planting materials and agrochemicals significantly affected banana cultivation at 5% level of significance (p-value= 0.000<0.05, p-value =0.000<0.05 and p-value=0.000<0.05 for land, banana suckers and manure, respectively (Table 3). The corresponding coefficients for banana suckers used along with agrochemical factors were found positive while that on land was negative. The findings of this study indicated that a rise in the amount of land under banana farming reduces production by 0.438%. This imply that banana production would decrease if producers increase the land allocated to its production. This finding could imply that it's simpler managing smaller pieces of land under banana for optimum production unlike comparatively bigger land pieces. In addition, family labour may be used in smaller farms while larger farms may require additional costs of engaging hired labourers. It is possible that as the size of banana orchards increase management becomes difficult and therefore producers tend to keep just small pieces. The negative effect between technical efficiency and land size was attributed to the worry by farmers that increasing land size their costs of production will also increase. A study by Omondi et al. [23] found that banana farmers who did not participate in groups in Nyamira and Kisii counties had decreased production technical efficiencies with increase in land size and this agrees with the findings of this study. On the other hand, Van Hung et al. [44] established that land size under banana cultivation had a positive coefficient but was not significant to banana production technical efficiency implying that land size has no effect on banana production in Vietnam.

During the study it was observed that planting materials (banana suckers) were a necessary input in banana production. The variable showed a favourable correlation at 1.315. The outcomes implied that increasing the amount of planting materials used will lead to increased banana output by a factor of 1.315. The findings imply that use of correct number of suckers on a farm may results in achieving maximum production. Based on this study finding, use of more banana suckers would lead increased production since many plants will be harvested. Thus, a producer who plants more banana suckers receives higher banana output. Similar findings to this study were reported by Vinayagamoorthi [8] who found that banana suckers were a factor among smallholder banana farmers in Tamil Nadu, India, and affected banana production technical efficiency positively. Banana sucker had noteworthy effect on banana production in Bangladesh where it was reported that a 1% rise in quantity of suckers used would raise the banana yields up to 0.29% [45]. The findings of the current study agree with those of Naik [62] who noted that a 1% increase in the number of

suckers would lead to a 0.3710 per cent increase in the yield of banana in India.

This study's findings showed that the correlation coefficient for agrochemicals was essential as well as favourable implying that using more agrochemicals, mostly manure would significantly increase banana production. The findings indicated that a rise with a unit in the usage of agrochemicals increases yields in banana up to 0.155 units implying that manure is a key input in banana production. In another study, agrochemicals were discovered to be statistically significant and to have a favourable connection with banana yield, meaning that increasing the amount of manure use causes a rise in levels of technical efficiency in Viet Nam [44]. Also, Vinayagamoorthi et al [8] reported that manure variable was significant and had positive influence to banana production where it was observed that 1% increase in manure usage increased banana production technical efficiency by 5.92%.

The findings of this study showed hired labour (man-days) was not significant but produced a positive effect on banana production technical efficiency within the area of study. This implies that hired labour was a key input in banana production. Family labour on the other hand negatively influenced banana production in Kirinyaga Central Sub County but the influence wasn't significant at any given level.

Table 3: Cobb Douglas stochastic frontier results of production factors affecting technical efficiency

Variable	Coefficient	SE	Z	P-Value	95% Confidence interval	
Log land size	-0.438	0.047	-9.26	0.000	-0.531	-0.346
Log family labour	-0.003	0.028	-0.12	0.904	-0.058	0.051
Log hired_labour	0.052	0.046	1.12	0.263	-0.038	0.142
Logplantingmaterials	1.315	0.054	24.43	0.000	1.210	1.421
Logagrochemicals	0.155	0.031	4.96	0.000	0.094	0.216
Constant	0.585	0.261	2.24	0.025	0.074	1.097

3.4 Influence of Socio-economic Factors on Banana Production Technical Efficiency

Maximum likelihood estimates (MLE) of the parameters in the stochastic frontier model are presented in Table 4. Age of decision maker variable proved significant at a 5% significance level but had a negative influence on technical efficiency levels. These findings indicate that increasing producers' age might result in 1.46 decline in banana production technical efficiency (Table 4). The findings show that the technical efficiency of older producer is typically less compared to that belonging to younger producer. The elderly farmers are assumed to be more reluctant to take risks associated with production unlike the young people. It is also possible that older individuals lack physical strength and do not easily accept new farming techniques. Conversely, producers who are younger appear to be enthusiastic, creative, energetic and risk-takers and therefore are more likely to be able to change the agriculture sector than older people. They may seek and obtain extension services which helps them to manage the different farming situations earlier. Younger producers may increase their degree of technical efficiency by investing in innovative and advanced technologies in agriculture, effectively increasing total production. As a result, younger farmers have much higher technical efficiencies. The findings of this study on the age of decision-maker stand consistent with the results of Onuwa et al. [46] which established age had unfavourable effects on cowpea production technical efficiency in Nigeria. In addition, Kristof [47] noted that there was a negative sign in the farmer's age coefficient (-0.002) implying that age and technical efficiency were positively correlated in Namibia. Additionaly, Abubakar and Sule [48] reported that the inefficiency model was adversely impacted by producers' age, which may have suggested that as producers aged, their technical inefficiency also increased. Findings of this study differed from that of Sabruso et al. [49] whose work made a technical efficiency estimate in production of coffee in the Philippines, and discovered that farmers' age is positively related to technical efficiency.

The findings of this study showed that household size had adverse effects on smallholder banana production technical efficiency levels. The findings showed that as household size increases, banana production technical efficiency reduces to the extent of 2.217 (Table 4). During the study it was established that majority of household heads were educated and therefore sent their children to school who then are not involved in active farming and this may lead to decrease in technical efficiency levels. It was established that children participated in banana production during weekends and on holidays. The study's outcomes coincide with those of Ayukpo et al. [50] which highlighted that a rise in family size reduces the level of technical efficiency in fodder productivity in Homabay County, Kenya. It was found that there existed good correlation between technical inefficiency and size of household showing that bigger families are more technically inefficient [51]. The findings of this study differed those of Rukwe and Zubairu [52] who reported that the households' size variable had detrimental coefficient with technical efficiency signifying that a rise in household size raises technical efficiency in production of sesame.

The findings of this study disclosed that education variable had favourable effects on level of technical efficiency implying that increasing smallholder banana farmers' education level by a unit would increase banana production technical efficiency by 1.325 units, *ceteris puribus*. It is possible that education access improves the management and technical abilities of farmers and raises the household's capacity to make use of new and current technology and achieve better levels of efficiency. Education is supposed to help farmers allocate inputs efficiently and also in better management of banana orchards. The outcomes of this research agree with those presented by Dessale [34] who noted that education had positive effects on wheat production technical efficiency in Ethiopia implying that technical efficiency level of less educated farmers was low compared to those who are more educated. Additionally, Van Hung et al. [44] well reported education variable had a good and significant impact on banana production technical efficiency in Viet Nam. In addition, Kristof [47] found that a strong connection existed between the farmers' technical farm efficiency and their level of education. It was determined that education had a negative coefficient, meaning that A1 maize farmers with greater education had higher technical efficiencies than the less educated farmers [53]. Technical inefficiencies are assumed to decrease as education level increases since it improves farmers' abilities to acquire technical knowledge and apply it in production. Contrary to outcomes of this study, Mairabo et al. [54] pointed out that the technical efficiency of soybean growers is unaffected by education in Nigeria. It was observed that education variable was negative and insignificant to bread wheat production technical efficiency [55]. It was also found that the technical inefficiency had a negative relationship with the education level of coffee farmers meaning that farmers' level of education didn't affect their levels of technical efficiencies [56].

The outcomes of this investigation depict that banana farming experience factor was significant at 5% level of significance and produced positive impact on the level of technical efficiency. The findings showed that a year's worth of additional farming experience increases smallholder banana production technical efficiency by 1.712 kgs (Table 4). This could be because more work experience leads to more job knowledge and improves how smallholder banana producers perform tasks on their orchards. This study's findings contradicted those of Eutycus [10] who found that experience in banana cultivation negatively influenced technical efficiency in Meru. This study's outcomes are in line with those of Muzeza et al. [53], which established a negative coefficient on the experience variable, implying that the more knowledgeable A1 smallholder maize producer was more technically efficient. Similarly, Mairabo et al. [54] established experience of producers influenced technical efficiency of soybean production positively.

Table 4: Cobb Douglas stochastic frontier results of socioeconomic factors affecting technical efficiency.

Variable	Coefficient	SE	Z	P-Value	95% Confidence interval	
Age decision maker	1.460	0.503	2.90	0.004	0.474	2.446
Gender of HH	4.487	4.754	0.94	0.345	-4.830	13.804

Household size	2.217	1.148	1.93	0.053	-0.033	4.466
Education level	-1.325	0.689	-1.92	0.045	-2.676	0.026
Farming experience	-1.712	0.670	-2.55	0.011	-3.025	-0.398
Constant	-58.101	24.436	-2.38	0.017	-105.995	-10.207

3.5 Influence of Institutional Factors on Banana Production Technical Efficiency

The study's findings show that group membership variable was negative implying that membership to farmer group affected technical efficiency positively (Table 5). This study's outcomes demonstrate that belonging to farmer's organization boosts the technical efficiency of banana production by a factor 27.92. It is possible that participation by smallholder farmers in group organizations and cooperatives has a substantial impact on raising production technical efficiency levels. This could imply that farmers who belong to these groups are more productive than those who do not. Membership ensures sharing of valuable information among members, collective selling of farmer produce, access to current market information and bargaining power to be able to get good prices for the products. These findings are in line with Ofori-Appiah et al. [57], who claimed that group participation possessed favourable influence on the technical efficiency of pineapple production in Ghana. In Nepal, the coefficient of cooperative participation was discovered to be negative, meaning that ginger the technical efficiency of producers who belong to such groups is higher than that of nonmember producers [58]. Therefore, there is need for development of initiatives to entice farmers to join and take part in banana cooperatives or other farmer associations or groups within the region of study.

Adeoye [59] analyzed characteristics of vegetable production efficiency in Nigeria and found membership to farmer cooperative significantly and positively influenced technical efficiency indicating that an increase in pepper production efficiency resulted from membership in a cooperative society. Membership to the farmer organization was discovered to be positively significant to fodder production in Homabay, Kenya implying that farmers who are part of the farmer group have a 4.3% increase in technical efficiency [50].

The findings of this study shows that proximity to the market affects smallholder banana farmers' technical efficiency positively (Table 5). According to the findings, an increase of one unit in the distance to the closest market will translate to a rise in technical efficiency of banana production with a factor of 1.583, *ceteris paribus*. Possible reason for this is that farmers perceive that they get better higher prices from urban areas unlike selling produce at farm gate. For smallholder farmers, the distance to the nearest market is a crucial standard measure of the viability of the market for both inputs and outputs and access to market information. Outcomes of this study contradict those presented by Martey et al. [60], where it was discovered that distance to market as having adverse impacts on technical efficiencies in maize production. The findings of this study on market distance contradict those of Endalew et al. [61] which reported the distance to market significantly and adversely impacted teff production technical efficiency.

Distance to the market was important and showed detrimental correlation with tomato production technical efficiency in Asaita district, Ethiopia, indicating that the most effective farmer is one who is close to nearest marketplace as opposed to one who lives a long way off [43]. How far the farm is from the nearest market had positive coefficient but showed insignificant effects to banana production technical efficiency in Ethiopia [44].

4. CONCLUSIONS

The study aimed at determining influence of production, socio-economic as well as institutional factors on smallholder banana producers' technical efficiency in Kirinyaga Central Sub County. The study established that smallholder banana producers had varied technical efficiencies ranging from 0.93% to 95.45%.

Table 5: Cobb Douglas stochastic frontier results of institutional factors affecting technical efficiency.

Variable	Coefficient	SE	Z	P-Value	95% Confidence interval	
Group membership	-27.923	14.150	-1.97	0.048	-55.656	-0.190
Credit access	-4.887	3.647	-1.34	0.180	-12.036	2.261
Extension access	-1.762	5.202	-0.34	0.735	-11.957	8.434
Market distance	-1.583	0.619	-2.56	0.010	-2.796	-0.371
Constant	-58.101	24.436	-2.38	0.017	-105.995	-10.207

Further, the study noted that smallholder banana farmers produced banana at 83.14% technical efficiency level thus they had the potential of increasing their production level by 16.86% given the available resources in the Sub County. The study found that banana production technical efficiency can be increased by increasing number of banana suckers planted, increasing manure usage and maintaining land size allocated to banana production. This study further found that banana production technical efficiency was influenced by age of decision maker, experience of the producer, education level attained, size of households, distance traveled to nearest banana market and membership to farmer group. It was found that an increase in banana farmers' experience, education level, distance to market, and membership in farmer groups would increase banana production technical efficiency, while the increase in age of decision maker and household size decreases banana production technical efficiency.

5. RECOMMENDATIONS

This study recommends that smallholder producers ought to be motivated to increase manure usage in order to improve banana production technical efficiency. Banana producers are to plant more banana suckers in order to improve banana production technical efficiency. There is need for people with higher levels of education to venture into banana production since smallholder banana producers with high levels of education had high levels of production efficiencies. In addition, producers ought to be urged to form and join banana cooperatives or other producer organizations in order to take advantage of opportunities that result from knowledge sharing and shared experiences, receive various agricultural trainings, and other financial support that will ultimately result in higher technical efficiencies. There is also need to make extension services more accessible to smallholder banana producers so they have access to the most recent, pertinent and crucial knowledge about banana farming. There is also a need for deploying a greater number of extension officers to rural regions to help producers in need of extension services.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

8. REFERENCES

1. Dhake, K., Jain, S. K., & Lakhawat, S. S. (2019). Value addition in green banana for rural employment generation. *Food Engineering*, *59*(1), 1-11.
2. Tumuhimbise, R., & Talengera, D. (2018). Improved Propagation Techniques to Enhance the Productivity of Banana (Musa spp). *Open Agriculture,* *3*(1), 138-145. https://doi.org/10.1515/opag-2018-0014.
3. Pillay, M., Ashokkumar, K., Arun Siva Shunmugam, K., & Elayabalan, S. (2012). A Case for Molecular Breeding in Musa. Genetics, Genomics and Breeding of Bananas, pg 280–297. https://doi.org/10.13140/2.1.1246.7205
4. Bhatta, S., Pant, P., Kapri, R., & Mishra, B. P. (2023). Production efficiency of banana cultivation in Chitwan District, Nepal. *Cogent Food & Agriculture*, *9*(1), 2212461.
5. Voora, V., Bermúdez, S., Farrell, J. J., Larrea, C., & Luna, E. (2023). Banana prices and sustainability. https://www.iisd.org/system/files/2023-03/2023-global-market-report-banana.pdf
6. World Bank. (2020). Agricultural technology and agribusiness advisory services project. Agriculture and rural development, African region. Kampala, Uganda.

7. Food and Agriculture Organization (FAO). (2022). https://www.fao.org/3/cb9411en/cb9411en.pdf
8. Vinayagamoorthi, N., Sekhar, C., Palanichamy, N. V., Harishankar, K., & Balaji, P. (2019). Technical efficiency of banana production in central Tamil Nadu. *International Research Journal of Agricultural Economics and Statistics*, *10*(1), 122-132.
9. Food and Agriculture Organization Statistics. (20117). Accessed on April, 2022 from: Http://Www.Fao.Org/Faostat/En/-Data/QC.
10. Eutycus, K, M. (2019). Technical efficiency of small-scale banana farming in Meru County, Kenya.
11. Voora, V., Larrea, C., & Bermudez, S. (2020). Global market report: bananas. International Institute for Sustainable Development
12. FAOSTAT. (2020). URL: http://www.fao.org/faostat/en/-data/QC. Food and agriculture organization of the United Nations (FAO). Accessed on, 25 September 2022.
13. Food and Agriculture Organization Statistics. (2022). Accessed on April, 2023 from: Http://Www.Fao.Org/Faostat/En/-Data/QC.
14. Geberewold, A. Z. (2019). Review on impact of banana bacterial wilt (Xhantomonas campestris pv. Musacerum) in East and Central Africa. *Cogent Food & Agriculture*, *5*(1), 1586075.
15. Obaga, B.R. & Mwaura, F.O. (2018). Impact of farmers' participation in banana value addition in household welfare in Kisii Central Sub-County. *International Academic Journal of Social Sciences and Education*, 2(1), pp.25–46
16. Olumba, C. C., & Onunka, C. N. (2020). Banana and plantain in West Africa: Production and marketing. *African Journal of Food, Agriculture, Nutrition and Development*, *20*(2), 15474-15489.Abubakar, S., & Sule, A. (2019). Technical efficiency of maize production in Rijau Local government area of Niger state, Nigeria. *Journal of Agriculture and Veterinary Science*, 12, 63-71.
17. Food and Agriculture Organization (FAO). (2020). Medium-term Outlook: Prospects for global production and trade in bananas and tropical fruits 2019 to 2028. Rome, February 2020.
18. Arinaitwe, I. K., Teo, C. H., Kayat, F., Tumuhimbise, R., Uwimana, B., Kubiriba, J., & Othman, R. Y. (2019). Evaluation of banana germplasm and genetic analysis of an F1 population for resistance to Fusarium oxysporum f. sp. cubense race 1. *Euphytica*, *215*(10), 1-11.
19. Karienye, D., & Kamiri, H. (2020). Trends of Banana Production among Smallholders' Farmers Due to Rainfall and Temperature variations in Mount Kenya Region, Kenya. *Budapest International Research in Exact Sciences (BirEx-Journal) Vol*, *2*(2), 213-227.
20. Wahome, C. N., Maingi, J. M., Ombori, O., Kimiti, J. M., & Njeru, E. M. (2021). Banana production trends, cultivar diversity, and tissue culture technologies uptake in Kenya. *International Journal of Agronomy*, *2021*.
21. Kirimi, F. K., Onyari, C. N., Njeru, L. K., & Mogaka, H. R. (2021). Effect of on-farm testing on adoption of banana production technologies among smallholder farmers in Meru region, Kenya. *Journal of Agribusiness in Developing and Emerging Economies*.
22. Horticultural Crop Directorate (2016). Validation report 2016-2017. Retrieved from http://horticulture.agricultureauthority.go.ke
23. Omondi, W., Bett, H., & Njagi, T. (2020). Influence of Collective Action Participation on Technical Efficiency among Smallholder Producers: A Case of Banana Farmers in Kisii and Nyamira, Kenya. *Journal of Food Security*, *8*(3), 105-116.
24. United States Agency for International Development (USAID). (2017). Horticulture Validated Report 2016
25. Agriculture and Food Authority (AFA). (2016). Horticultural Validated Report 2015-2016.
26. Kenya National Bureau of Statistics (KNBS). (2018). Economic Survey 2018. KNBS, Nairobi, Kenya. http://www.knbs.or.ke

27. Mbaka, J. N., Mwangi, M. and Mwangi, M. N. (2008). Banana Farming as a Business: The Role of Tissue Cultured Planting Materials in Kenya. *Journal of Applied Biosciences*, 9(1): 354 – 361
28. Kairu, E. K. (2020). The Influence of agricultural innovative strategies on banana productivity among smallholder farmers in Kirinyaga County, Kenya (*Doctoral dissertation, Strathmore University*).
29. Murongo, M., Wangai, K. J., Mwine, T. J., & Ayuke, O. F. (2018). Farmer-based dynamics in tissue culture banana technology adoption: a socio-economic perspective among small holder farmers in Uganda. *African Journal of Agricultural Research* 13 (50), pp. 2836-2854.
30. Adhikari, A., Paudel, B., & Pokhrel, A. (2022). Banana Production Status and Its Role on Income Generation and Livelihood Improvement in Chitwan, Nepal. *International Journal of Applied Sciences and Biotechnology*, *10*(2), 93-98.
31. Ministry of Agriculture (MOA) and Rural Development Crop Division Annual Report, Nairobi, Kenya, 2017.
32. Ministry of Agriculture (MOA). Horticultural Crops Production and Consumption Annual Report. Nairobi, Kenya, 2017.
33. Kassa, M. D., Demissie, W. M., & Batu, M. M. (2019). Smallholders' technical efficiency of teff production in Ethiopia. *African Journal of Agricultural Research*, *14*(33), 1641-1648.
34. Dessale, M. (2019). Analysis of technical efficiency of small holder wheat-growing farmers of Jamma district, Ethiopia. Agriculture and Food Security 8(1):1.
35. County Government of Kirinyaga. (2020). http://kirinyaga.go.ke/wp-content/uploads/2021/06/Annual-Development-Plans-2021-22.pdf
36. Government of Kenya (GoK) (2018). Kirinyaga County Government. County Integrated Development Plan 2018-2022.
37. Ministry of Agriculture (MoA) (2011). Ministry of Agriculture, Livestock and Fisheries Strategic Plan 2013-2017. Kenya Vision 2030.Towards an innovative, commercially Oriented and Modern Agriculture. Nairobi, Kenya
38. County Government of Kirinyaga. (2019). http://www.devolution.go.ke/wp-content/uploads/2020/02/Kirinyaga-CIDP-2018-2022.pdf
39. Daniel, W.W. & Cross, C.L. (2013). Biostatistics: A Foundation for Analysis in the Health Sciences. 10th Edition. New York: John Wiley & Sons.Pp 190. Retrieved on November, 2021 from Http://Docshare02.Docshare.Tips/Files/22448/224486444.Pdf
40. Levin, K. A. (2006). Study design III: Cross-sectional studies. *Evidence-based dentistry*, *7*(1), 24-25.
41. Battese, G.E. (1992). Frontier production functions and technical efficiency: A survey of empirical applications in agricultural economics. Agricultural Economics
42. Coelli, J. (1995). An Introduction to Efficiency and Productivity Analysis, 2nd Edition. Springer Science and Business Media, New York, USA.
43. Battese, G.E., & Coelli, T. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20 (2), 325-332
44. Van Hung, H., Van Huong, N., Oanh, T. T. K., Van Chuong, N., Tiep, N. C., Van Ha, T., & Luong, N. T. (2022). Technical Efficiency of Smallholder Banana Production: A Case study in Viet Nam. *AgBioForum*, *24*(2), 58-64.
45. Mohiuddin, M., Hasan, M. R., & Miah, M. M. (2020). Profitability Analysis of Cultivation of Banana Cultivars Sabri and Sagar in Some Areas of Narsingdi District. *Bangladesh Journal of Agricultural Research*, *45*(2), 175-183.
46. Onuwa, G. C., Mailumo, S. S., Chizea, C. I., Onemayin, J. J., Idris, R. S., Abalaka, E. A. & Ebong, A. C. (2022). Technical Efficiency in Cowpea (Vigna unguiculata) Prodction in Kanke, Plateau State, Nigeria. FUDMA Journal of Agriculture and Agricultural Technology, 8(1): 372-382.
47. Kristof, S. K. T. (2022). *Analysis of factors influencing the technical efficiency of maize small-scale farmers of Kavango East Region* (Doctoral dissertation, Namibia University of Science and Technology).

48. Abubakar, S., & Sule, A. (2019). Technical efficiency of maize production in Rijau Local government area of Niger state, Nigeria. Journal of Agriculture and Veterinary Science, 12, 63-71.
49. Sabroso, L. M., & Tamayo, A. M. (2022). Technical efficiency estimates of coffee production in davao city, philippines: A data envelopment approach. *European Journal of Economic and Financial Research*, *6*(2).
50. Ayuko, M. S., Lagat, J. K., & Huaser, M. (2023). The Level and Determinats of Technical Efficiency in Fodder Production in Homa Bay County, Kenya. *Open Access Library Journal*, *10*(1), 1-15.
51. Tenaye, A. (2020). Technical efficiency of smallholder agriculture in developing countries: The case of Ethiopia. Economies, 8(2), 34.
52. Rukwe, D. T., & Zubairu, E. A. (2019). Determinant of technical efficiency of sesame production in Kurmi local government area of Taraba state, Nigeria. *Journal of Agriculture and Veterinary science*, *12*(1), 43-51.
53. Muzeza, N. T., Taruvinga, A., & Mukarumbwa, P. (2023). Analysis of factors affecting technical efficiency of A1 smallholder maize farmers under command agriculture scheme in Zimbabwe: The case of Chegutu and Zvimba Districts. *Cogent Economics & Finance*, *11*(1), 2163543.
54. Mairabo, A., Jibrin, S., Audu, H., Salihu, M. Y., & Elisha, Y. (2023). Technical Efficiency of Soybean Production in Niger State, Nigeria. *Fudma Journal of Sciences*, *7*(1), 201-206.
55. Eshete, Y., & Alamirew, B. (2023). Determinants of technical efficiency of smallholder farmers' bread wheat production and implications of seed recycling: A stochastic frontier approach. *F1000Research*, *12*, 502.
56. Tamirat, N., & Tadele, S. (2023). Determinants of technical efficiency of coffee production in Jimma Zone, Southwest Ethiopia. *Heliyon*, *9*(4).
57. Ofori-Appiah, Y., Onumah, E. E., & Asem, F. E. (2022). Efficiency and productivity analysis of pineapple farmers in the Akwapim-South District of Ghana: A distance function approach. *African Journal of Science, Technology, Innovation and Development*, *14*(2), 512-522.
58. Khatiwada, D., & Yadav, P. (2022). Technical Efficiency of Ginger Production in Ilam District of Nepal: A Stochastic Production Frontier Approach. *Advances in Agriculture*, *2022*.
59. Adeoye, I. B. (2020). Factors affecting efficiency of vegetable production in Nigeria: A review. *Agricultural Economics*, *1*, 1-14.
60. Martey, E., Wiredu, A. N., Etwire, P. M., & Kuwornu, J. K. (2019). The impact of credit on the technical efficiency of maize-producing households in Northern Ghana. *Agricultural Finance Review*, *79*(3), 304-322.
61. Endalew, B., Anteneh, A., & Tasie, K. (2022). Technical efficiency of teff production among smallholder farmers: beta regression approach. The European Journal of Development Research, 34(2), 1076-1096.
62. Naik, A. K., Moolimane, C. B., DM, M., & Sri, K. K. (2024). Economic Efficiency of Banana Production in Uttara Kannada District of Karnataka, India. Asian Research Journal of Agriculture, 17(2), 106-115.
63. Sharma, M., Chandra Dhakal, S., Adhikari, R. K., & Tiwari, U. (2021). Profitability, Productivity and Resource Use Efficiency of Banana Production in Hetauda-Dumkibas Road Corridor, Nepal. Cogent Food & Agriculture, 7(1), 1917134.
64. Debebe, A. D., & Dagne, D. (2018). Analysis of Socio-Economic Factors Affecting Banana Production: Evidences from Lowlands of Uba Debretsehay Woreda, Gamo Gofa Zone, SNNPRS. Journal of Economics and Sustainable Development, 9(9), 1-7.
65. Muthee, A. I., Gichimu, B. M., & Nthakanio, P. N. (2019). Analysis of Banana Production Practices and Constraints in Embu County, Kenya. Asian Journal of Agriculture and Rural Development, 9(1), 123-132.
66. Olufemi, O. S. (2024). Exploring banana production in Africa for food security and economic growth—A short review. Food Nutrition Chemistry, 2(1), 125. https://doi.org/10.18686/fnc.v2i1.125

67. Farah, I. D., & Visetnoi, S. (2024). Assessment of Farmworker's Level of Knowledge in Banana Cultivation and its Implication on Productivity Improvement in the Lower Shabelle Region of Somalia. In IOP Conference Series: Earth and Environmental Science (Vol. 1291, No. 1, p. 012006). IOP Publishing.