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## Technical Efficiency among Smallholder Dairy Cattle Farmers in Nyandarua County, Kenya

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### **Abstract:**

*Dairy farming is important due to its role in Kenya's economy. It increases the nation's food security, gives farmers a source of revenue, and creates jobs. The majority of milk drunk worldwide comes from dairy cattle. Dairy cattle rearing has supplanted tea and coffee plantations as the primary source of livelihood across the Rift Valley and central Kenyan regions. The sector remains an integral part of Kenya's economy; overall dairy production has gone down over the past 20 years despite an increase in cattle herds. In addition to the likelihood of an increment in the demand for dairy products and milk due to the growth of urban dwellers, Kenya's dairy farming industry has not yet reached its full potential. Dairy production has been rising in Nyandarua, yet studies demonstrate that there has not been an analogous increase in productivity per cow when compared to the counties next door. The attainment of maximal technological efficiency at the farm level would be essential due to the shortage of production resources (particularly land) for dairy farming and boosting the availability of food, which is amid the Kenyan government's targets. The assessment's two goals are to estimate the technical efficiency of smallholder dairy cattle farmers in the Kinangop sub-county of Nyandarua County, Kenya, and to identify the factors that influence their technical efficiency. A non-experimental research approach was adopted, and cross-sectional data was gathered using questionnaires completed by a sample of farmers. Participants were chosen conveniently due to the lack of a population list to form a sampling frame to take part in the study based on a stratified sample from the ward. Each sampled farmer's quantitative input and output data were gathered. Multiple regression analysis was used in the study in order to identify elements that alter technical efficiency, and a maximum-likelihood estimation approach was employed to establish the stochastic frontier production function. From the results, it was concluded that farmers were 71.1% technically efficient, 95% of the dairy farmers were above average, and only 5% of the farmers were below average. The maximum estimates likelihood coefficients indicated that labour, acres allocated to fodder production, concentrate, and fodder fed to animals per day were positive, although statistically insignificant. However, expenditure on animal health had a negative impact on technical efficiency but was statistically insignificant. The study also establishes that the level of education is a key determinant of efficiency in Kinangop. This study recommends that the smallholder dairy farmers in Kinangop sub-county ought to strive to be technically efficient including hiring labour that can aid in providing labour, joining the various societies that may be critical in providing credit among other services, using concentrates and fodder in dairy farming as well as practicing hay and silage preservation. The study further recommends that the county government of Nyandarua come up with policies that aid citizens in accessing higher education and extension services.*

**Keywords:** Dairy farming, smallholder dairy cattle farmers, Nyandarua County

## 1. Introduction

### 1.1. Background of the Study

Food production has continued to be the center of man's farming objectives. It is one of the oldest arts in the world. It dates back to the civilization of humankind (Clark, 2001). There are approximately a billion heads of cattle in the world, from 996 million in 2021. Dairy cattle are mainly reared for the production of milk, though some other breeds are reared for beef and milk as well. Around 150 million people depend on milk and dairy products as vital food sources and sources of income in the global supply and value-adding chains. 81% of the world's milk comes from cattle, 15% from buffalo, 4% from goats, and the remainder comes from sheep and camels (OECD-FAO Agricultural Outlook 2022 – 2031, n.d.). Pakistan, China, Brazil, Germany, Russia, and France remain the leading producers, each accounting for 3-6% and collectively contributing 39% of the total output. In the preceding years, there has been a notable surge in the global production of cow milk. The volume of cow milk produced worldwide witnessed a substantial increase, rising from 497 (four hundred and

ninety-seven) million metric tons in 2015 to approximately 544 million (Five hundred and forty-four) metric tons by 2022. Notably, liquid milk emerged as the dominant segment within the global dairy market, holding the greatest share in relation to market value. This upward trend in cow milk production underscores the growing significance of this commodity in meeting global demand for dairy products.

In comparison to other major agricultural commodities, milk output is expected to expand at a quicker rate over the next ten years, reaching 1060 Mt by 2031, according to the FAO. Especially in Sub-Saharan Africa and principal (large) milk-producing countries like India and Pakistan — where output is low — the predicted growth in the quantity of dairy-producing animals is likely to be substantial at 1.2% p.a. While global yields are anticipated to expand gradually over the following ten years, there is significant regional diversity in growth rates ('World Food Agric. - Stat. Pocketb. 2021', 2021). While yields in high-income countries are predicted to improve by only 0.5% per year, the highest growth is anticipated in Southeast Asia and North Africa, where the yield growth average is around 1% per year. It is anticipated that yield growth would enhance production more than herd growth in practically every part of the planet.

Dairy cattle farming in Africa has been characterized by low output per cow due to frequent drought and poor breeds. The Maasai, Borana, Fulani, and Tuareg are some African groups with enduring dairy traditions (Ndambi et al., 2015). These communities, among others, practised dairy farming mainly for subsistence consumption. Due to population growth, the demand for milk has increased, which has resulted in the adoption of commercial farming by these communities. A decrease in trucks of land has well contributed to the adoption of modern farming methods. The abandonment of open-field grazing has contributed to the development of intensive and semi-intensive forms of dairy farming across Africa. This is highly attributed to the increased output in Africa. However, Africa only contributes 5% of milk produced globally ('World Food Agric. - Stat. Pocketb. 2021', 2021).

More than a third of the global GDP is accounted for by the livestock sector in developing countries. East African dairy sector output is highly unpredictable. This is attributed to the high dependence on rainfall for fodder production. In Ethiopia, Rwanda, and Kenya, dairy farming is most common in highlands and some Rift Valley regions that are characterized by cool and humid conditions, unlike the rest of the region (Bingi & Tondel, 2015). Forage production and decline in the quality of pasture are highly correlated to the amount of precipitation received in the area. The high temperatures experienced in the region affect the dairy output of exotic breeds. Despite this challenge, exotic breeds continue to produce the highest output per lactation period compared to indigenous breeds like zebu. In addition to low and poor forage, poor animal husbandry and poor genetic base affect dairy output in the block.

#### 1.1.1. Dairy Cattle Farming in Kenya

A notable aspect of Kenya's economic success has been its adoption of agribusiness in the rearing of dairy cattle. In recent years, the smallholder crop-livestock system has been rising, particularly in the densely populated central parts of the nation. Introducing exotic animals by European immigrants to the central highlands marked the beginning of commercial dairy cattle production in Kenya a century ago. White settlers created organizations to help farmers and dairy traders support the dairy industry. These included the Central Artificial Insemination Station (1946), Kenya Dairy Board (1958), Kenya Co-operative Creameries (1925), Naivasha Animal Husbandry Research Station (1935), Veterinary Research Laboratories (1910), and Central Artificial Insemination Station (1935) (Thorpe et al., 2000). Until 1990, KCC enjoyed a monopoly in the industry, and by 1996, the monopoly slowly decreased. The liberation of the sector opened up the entry of private processors. All social strata drink the most processed milk in the pasteurized form (Olok-Asobasi & Sserunjogi, 2001). The dairy sector has continued to do research and development over time. According to Kenya Livestock Breeds Catalogue (2022) from the year 2022, there are roughly 20.6 million cow heads in the nation. Kenya produces more than 60% of its milk from improved breeds, only 25% from indigenous cows, and the remaining from goats and camels. Kenya ranks 5th as countries with the most cattle herd in Africa and the 2nd highest milk-producing country after Ethiopia, which produces 3 billion liters a day. Dairy farming is a major economic activity in Kenya, incorporating 1.8 million smallholder farmers. Dairy output accounts for 14% of Kenya's agricultural GDP, in addition to creating employment. Milk is mainly produced by smallholders, who account for 80% of the total output, whereas 20% is produced by large-scale farms (Aweer Duot Ajak et al., 2020). Despite concerted efforts by both national and county governments to increase milk output, individual cow productivity has remained low across the country. In Kenya, the sector is faced with some challenges, which include seasonality, low output per cow, poor dairy infrastructure (feeder roads, correction points, and electricity), poor breeding programs, and high cost of minerals, concentrate, and supplements. However, the amount of milk produced in Kenya has increased significantly from 591.4 million liters to 801.9 million liters in 2021. This has been attributed to the increase in herd size across the country, contrary to individual cow productivity (*KENYA ECONOMIC SURVEY 2022*, n.d.)

<b>Milk Production in Kenya (2017-2021)</b>						
<b>Year</b>	<b>Unit</b>	<b>2017</b>	<b>2018</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>
Production	million liters	591.4	652.3	685.9	684.8	801.9
<b>Milk Processed into</b>						
Milk & Cream	million liters	410.6	468.4	491.8	457.9	510.5
Butter & Ghee	tones	1127.3	1249.4	1013.4	957.6	1025.8
Cheese	tones	338.3	384.3	305.4	158	176.4

Table 1: Milk Production in Kenya

Source of Data: Kenya National Bureau of Statistics, 2022

### 1.1.2. Dairy Cattle Farming in Nyandarua

Nyandarua County is one of the six counties in the Central Kenya region, located in the north-western part of the region and west of the Aberdare (Nyandarua) Ranges. The county boasts of an overall land size of 3,304 km<sup>2</sup>. According to *KENYA ECONOMIC SURVEY* (2022, n.d.), Nyandarua is the eighth biggest contributor to Kenya's GDP. In the dairy sector, Nyandarua is the second-highest producer nationwide after Kiambu County. The county is constituted of five sub-counties, which are Kinangop, Kipipiri, Ol Kalou, Ol Joro Orok, and Ndaragwa sub-counties, which are further subdivided into twenty-five wards.

According to County Government of Nyandarua (2018), dairy farming employs 80% of Nyandarua households. The County has a total dairy herd of 349,300 cows, with the majority of farms ranging two to three dairy cows. The county produces roughly 296 million liters of milk. With an average price of Ksh. 32 per liter in 2019, the sector generated around Ksh. 13 billion to Nyandarua's domestic product. 60% of milk produced is traded in informal markets, with 40% sold in legal markets. Home consumption accounts for 20% of total milk production. The annual per capita milk intake is 114 liters, compared to the national average of 125 liters in Nyandarua and the World Health Organization's optimum amount is 209 liters. Kinangop sub-county contributes 40%, Kipipiri 25%, and Ol Kalou, Ol Joro Orok, and Ndaragwa sub-counties contribute the remainder.

Despite the scarcity of literature on the technical efficiency of dairy cattle producers in Kinangop, various studies conducted in the area (Nyandarua), in general, demonstrate that the farmers are technically inefficient. (Mbugua, J. N., et al., 2012). For example, I focused on strategic and value chain research on smallholder dairy businesses in Central Kenya. Although research has been done on technical effectiveness in other agricultural sub-sectors in the area, none has established the degree of technical effectiveness in the dairy sector and its causes. Waithaka, M.M. et al. (2003) examined the cost of milk production in Kenya based on calculations from the Kiambu, Nakuru, and Nyandarua region's smallholders (R&D) project. Ongwech, W. L., Obel-Gor, C., & Otiende, M. A. (2020) investigated the elements of credit availability amid smallholder dairy producers in the Kinangop sub-county of Kenya.

According to Government of Kenya (2007), the county government has implemented a number of strategic initiatives to achieve an average production of 20 liters per cow per day, up from the current five liters. Dairy genetic improvement is one of them, thanks to a County-subsidized artificial insemination programme run by a Public-Private Partnership in which farmers pay Ksh. 700 for local sperm and Ksh. 1,000 for foreign sperm. In addition to livestock registration with Kenya Stud Book/KLBO, a total of 8,560 cattle were inseminated in 2020. According to County Government Nyandarua, (2018), fodder production, diversification, and conservation technologies should be promoted; feed centers should be created to promote Total Mixed Ration (TMR); there should be establishment of dairy demonstrations and promotion of farms; competitive marketing and value addition should be promoted by providing milk vending machines and coolers (weighing scales, milk analyzers, milk carrying cans/churns, and pasteurizers) to cooperatives; there should be research and distribution of innovative technology; animal health should be supported by building illness testing facilities, conducting vaccination campaigns, and rehabilitating cattle dips. Nyandarua Cooperative Union, other partners, and the Nyandarua County Government are working together to build a milk processing factory (cooling plant, pasteurizers, packaging unit, and product retail outlet). Improvement of extension advisory services, among other things, Notwithstanding coordinated efforts over the last two decades, output still remains poor in the county, particularly in Kinangop. The dairy sector output in Kinangop is 5 litres per day, while large-scale farms in Kenya average 8 litres daily which is farmed below the European average (J. M. K. Muia et al., 2011). J. M. K. Muia et al., 2011). All of these approaches aim to close the output gap between Nyandarua and neighboring counties such as Kiambu, where a cow produces an average of 7.9 liters per day (Staal et al., 2003).

### 1.1.3. Dairy Cattle Farming in Kinangop Sub-County

The Kinangop sub-county runs along the slopes of the Aberdare ranges, about 100 kilometers northwest of Nairobi. It originated in time for the general elections in 1988. There were about 219, 576 persons living in its eight electoral wards by 2022. The primary economic activity in the 822 km<sup>2</sup> region, which has a 20.3 percent natural forest cover, is dairy and crop cultivation. The region uses free grazing and semi-zero grazing together with zero grazing dairy cattle grazing techniques. Holstein Friesians are the most reared breeds, followed by Ayrshire, while Jersey is the least reared. Milk is marketed through brokers, dairy cooperatives, and processing firms for large-scale farms (County Government Nyandarua, 2018).

According to research by (J. Muia et al., 2011), smallholder dairy farmers encounter a number of difficulties, including inadequate road infrastructure, subpar marketing, expensive and scarce inputs and support services, insufficient use of

relevant technology, and little value addition. Despite the numerous obstacles, there is room for expansion for farmers because there is a substantial need for milk and dairy items in metropolitan areas due to the rapid growth of urban dwellers.

The high demand for milk in urban centers can only be met by a high output from the area. However, the continued subdivision of land for settlement poses a challenge to cheap free grazing and mechanization of farm operations. This calls for farmers to efficiently produce the highest possible output per cow economically and technically for increased economic prosperity. This is only conceivable if farmers can produce at the lowest possible cost, suggesting the necessity to point out the elements of technical efficiency in neighborhoods.

### 1.2. Statement of the Problem

Dairy farming is significant due to its impact on the world economy. Dairy cattle milk is the most consumed in the world. Milk and dairy products are vital sources of nutrients and income for nearly 150 million individuals involved in the global production and value-addition chain. Milk output is predicted to rise globally due to an increase in the number of cattle herds. In Africa, the biggest producers are Ethiopia, Kenya, Sudan, and South Africa, where the majority of cattle are crossbred, exotic breeds that produce only 5 to 11 kg per cow per day on average. The output per cow per day in Africa is far less compared to other continents like Europe, with 20 liters per day per cow.

Despite evident variances, Kenyan smallholder dairies follow many of the same practices as other African countries. Rain-fed fodder production is critical for dairy farmers. Cows are fed grass and agricultural leftovers, with the majority of forages being cut and given to the animals rather than grazing. Despite receiving greater government support than contemporary dairy farms in other countries, smallholder farms in Kenya face issues such as overgrazing, insufficient infrastructure, and low productivity per cow. The amount of milk produced in Kenya increased significantly from 591.4 million liters to 801.9 million liters in 2021 see *Table 1*. This was attributed to the increase in herd size across the country, contrary to individual cow productivity and no improvement in technical efficiency levels.

Notwithstanding the promise of increased demand for milk and dairy products, dairy farming in Nyandarua County remains insufficiently utilized. Dairy output has been increasing, but there has been no growth in output per cow over time. According to studies, within two decades, output per cow per day has declined from 8.9-5.68 liter. The studies, however, have not shown whether the level of technical efficiency has worsened over time.

Regardless of the paucity of literature on the technical efficiency of dairy cattle producers in Kinangop, various studies conducted in the region (Nyandarua), in general, reveal that the farmers are technically inefficient. The presence of animal feeds through action directed towards programs, including the use of AI, enriched fodder, and seed ranching, are identified as some solutions to address the low productivity problem. Despite the concerted effort for the past two decades, output has remained low across the county and Kinangop in particular. The full potential of the dairy sector in Kinangop is far off the mark at 5 liters a day, while large-scale farms in Kenya are on an average of 8 litres a day.

The real levels of efficiency in smallholder dairy farms in the Kinangop sub-county have not been measured, necessitating an estimate of technical efficiency in the area. This study thus filled a knowledge vacuum by determining the technical efficiency and factors of technical efficiency in smallholder dairy cattle farmers in the Kinangop sub-county in general.

### 1.3. Research Questions

The assessment sought to answer the following questions.

- What is the degree of technical efficiency in dairy cattle production Kinangop sub-county?
- What are the elements of technical efficiency in dairy cattle production in the Kinangop sub-county?

### 1.4. Objectives of the Study

The general objectives of this study were:

- To evaluate the extent of technical efficiency among smallholder dairy cattle farmers in the Kinangop sub-county.
- To identify the factors that influence technical effectiveness in dairy cattle production in the Kinangop sub-county.

### 1.5. The Scope and Limitations of the Study

The aim of this investigation is to assess the degree of technical efficiency and ascertain the elements altering technical efficiency amid small-scale dairy cattle farmers in the Kinangop sub-county. The selection of the research area was deliberate, as it boasts the highest output potential and stands out as the county with the largest dairy cattle farming community, thanks to its favorable weather conditions. The research employed surveys to collect information on production from farmers involved in dairy cattle farming. The technical efficiency was tested in the Kinangop sub-county's eight wards. This study effort relied on primary data collected through questionnaires completed by the sampled dairy farmers. However, the use of cross-sectional data limited the scope of this study. As a result, the rate of change in technical efficiency for Kinangop sub-county smallholder dairy farmers was not investigated in this study.

### 1.6. Significance of the Study

The evaluation's conclusions would be important to dairy producers, the Nyandarua County government, and the national government. Understanding the factors influencing smallholder dairy farmers' technical efficiency would help them implement best practices that would improve their efficiencies, resulting in a rise in overall output and profit levels per cow. The current study's findings would also be useful to the Nyandarua County administration in informing policy

actions to improve dairy farmers' productive capability, consequently improving food output, job opportunities, and revenue. The data would also aid the authorities devise strategies to improve dairy production efficiency.

### 1.7. Organization of the Study

The investigation was structured into five subsections. In the initial part, the evaluation's context was explored, encompassing both contextual and conceptual challenges. Emphasis was placed on delineating the examination variables and conducting a conceptual analysis to guide the investigation. It also delved into the problem that this study aims to address, its research goals, and the questions it seeks to answer. Additionally, the scope, shortcomings, and organizational framework of the assessment were outlined. The second chapter provided a comprehensive review of empirical and theoretical literature related to the research variables, offering a detailed depiction of the study's setting. This section synthesized key studies that form the basis for discussing the findings and introducing the theory underpinning the research while also identifying significant gaps in empirical investigations.

Moving on to the third chapter, the research approach was elucidated, covering aspects such as the employed research design, sampling strategy, description of research tools, and the methods for data gathering and analysis. The fourth section showcased the examination of the study's results. Ultimately, the fifth chapter provided a brief overview of the research's outcomes, conclusions drawn, policy implications, and recommendations for future studies.

## 2. Literature Review

### 2.1. Introduction

This section aims to give an overview of the theoretical and empirical research on technological efficiency in dairy cattle farming and the factors that influence it. First, the theoretical literature was reviewed, and then empirical materials on the assessment of technical efficiency determinants were examined. A summary of the entire body of evaluated material was given in the last section.

### 2.2. Theoretical Literature

This section discussed theories of production, technical efficiency estimation approaches, determinants, and input factor demand.

#### 2.2.1. The Classical Theory of Production

This theory demonstrates that there is a connection between inputs and outputs. The production function (frontier) of a farm can be used to illustrate this relationship. Given a set of inputs, the production boundary shows the highest possible output that a farm can achieve. According to Coelli et al. (2005), the technological possibilities of a farm that uses several inputs in its production can be represented in the following production function:

$$Q=f(x) \dots \dots \dots 2.1$$

In this case,  $Q$  is the output, and  $X$  is a  $N \times 1$  vector of farm inputs such that  $Q = f(X_1, X_2, \dots, X_n)$ . Other inputs that are beyond the decision maker's (farmer's) control, such as rainfall, are equally essential. However, for this study, it would be easier to incorporate them into the overall framework of the function  $f(\cdot)$ . It shall be assumed that the production function is an ideal representation of technological efficiency. Farms that lie along the production frontier are deemed efficient, whereas those below are deemed inefficient (T. J. Coelli et al., 2005). Production can be estimated using various approaches.

#### 2.2.2. Efficiency

It involves juxtaposing the optimal and anticipated values of a process. In the comparison, the ratio of observed to highest potential of output that can be generated from considering a direction of inputs, or the ratio of lowest potential to observed inputs needed to achieve a specific output, are employed (Ndicu et al., 2016). The first analysis of agricultural productivity was by (Farrell, 1957). The scarcity of resources is the major reason for the need for economic agents to operate efficiently. Two forms of efficiency define production at the individual farm level, i.e., allocative and technical efficiency. Technical efficiency evaluates a farm's capacity to get the most out of a specific combination of inputs (Etich, 2013). The term "allocative efficiency" refers to the relationship between the estimated lowest possible production cost and the real production expense. Both allocative and technical efficiency compose the economic efficiency of the farm. For a farm to be profitable, it has to operate efficiently to minimize costs. Different literature has proposed different approaches to estimating technical efficiency (T. J. Coelli et al., 2005; Farrell, 1957; Lovell & Kumbhakar, 2000) both parametric and non-parametric approaches.

#### 2.2.3. Output-oriented Approach

T. J. Coelli et al. (2005) try to respond to the query, "To what extent can the amount of output be proportionally expanded without affecting amounts of inputs?" As illustrated in figure 1, this is elaborated by using one input ( $X_1$ ) and two outputs ( $Q_1, Q_2$ ). The locus  $K_1K$  symbolizes the production potential frontier, whereas the isocost price line is represented by the locus  $Z_1Z$ . If the firm's output occurs at point  $M$ , technical efficiency is demonstrated as  $OM/OJ$ , while technical inefficiency is indicated by extent  $JW$ , which can be defined as  $1 - (OM/OJ)$ . Technical efficiency \* Allocative efficiency equals total efficiency.

$$(TE*AE) = (OM/OJ * (OJ/OW)) \dots \dots \dots 2.2$$



2.3. The Stochastic Production Frontier

Unlike previous approaches, stochastic frontier models have the advantage of separating the impact of shocks due to differences in labor and machinery performance, erratic conditions regarding output, and a pure windfall from an effect of differences in technical efficiency on output. It additionally makes it possible for traditional tests of hypotheses and the assessment of inefficiency impacts in a single phase (Lovell & Kumbhakar, 2000). SFA enables a more accurate estimation of the causes of inefficiency in dairy farms (Kumbhakar et al., 1991). Using a collection of Decision-Making Units (DMUs), this method uses data to econometrically estimate the parameters of a hypothesized function. The stochastic frontier approach was separately put forward by (Aigner et al., 1977) and (Meeusen & van den Broeck, 1977) in the following form:

$$\ln q_i = x_i \beta + v_i - u_i \dots\dots\dots 2.1$$

Where

$q_i$  = output,

$x_i$  = vector made up of the input logarithms.

$\beta$  = set of unknown parameters that must be calculated.

$v_i$  = random error term

$u_i$  = non-zero technical inefficiency element within the error term.

Model 2.1 above accounts for technical inefficiency; additionally, it recognizes the occurrence of haphazard shocks outside the producer’s control, such as rainfall, crises, and so on, that alter the farm’s output level. Equation 2.1 illustrates the stochastic form of a production function, wherein a random or stochastic variable, represented by  $\exp(x_i')$ , constrains the output values from above. This is how the stochastic production frontier appears in its Cob-Douglas version in this instance:

$$\ln q_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i \dots\dots\dots 2.2$$

or

$$q_i = \exp(\beta_0 + \beta_1 \ln x_i + v_i - u_i) \dots\dots\dots 2.3$$

Assuming the amounts of input and output for two producers, let us call A and B, who fit the deterministic part of the model, which shows that there are diminishing returns to scaling. Producer A produces  $Q_A$  amount of output from the inputs represented by  $X_A$ , whereas Producer B produces the  $Q_B$  amount of output from the inputs represented by  $X_B$ . In the absence of inefficiency effects ( $U_A=0$ , then  $U_B=0$ , where  $U_A$  and  $U_B$  represent the ineffective consequences of producer A and producer B, respectively), the representation of the frontier yield is:

$$q_A = \exp(\beta_0 + \beta_1 \ln x_A + v_A) \dots\dots\dots 2.4$$

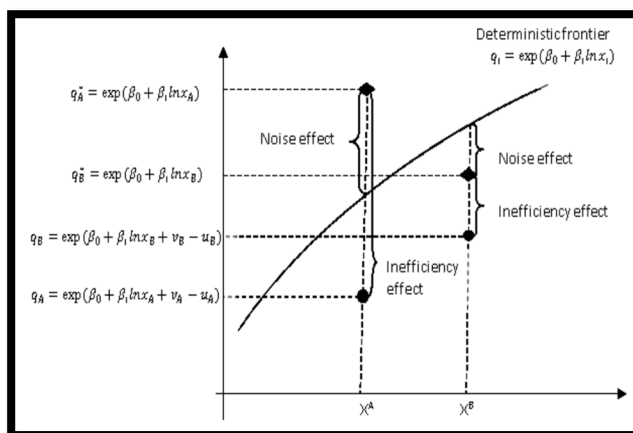


Figure 3: Stochastic Production Frontier  
Source: Coelli et al. (1997)

As pinpointed in figure 3 above, the output of producer A’s frontier is positive, or more than zero ( $V_A > 0$ ). Producer B’s frontier output, on the other hand, is smaller than the deterministic element since statistical noise has a negative (less than zero) impact or  $V_B > 0$ . Moreover, producer A’s measured or real production is lower than the deterministic element of the frontier. This is because  $V_A - U_A < 0$ , or the sum of the impacts of inefficiency and noise, is less than zero (negative). Actual or observed output is above the predictable portion of the frontier when the influence of statistical noise is greater than the effect of inefficiency and more than zero or positive. Technical efficiency, which is an output-oriented technique, is ordinarily expressed as the proportion of real output to the production degree that aligns with the stochastic frontier depicted below.

$$TE_i = \frac{q_i \exp[x_i \beta + v_i - u_i]}{\exp[x_i \beta + v_i]} = \exp(-u_i) \dots\dots\dots 2.5$$

The technical efficiency values vary from 0 to 1, measuring the amount of produce generated by the  $i^{th}$  producer in comparison to the amount generated by a perfectly efficient producer utilizing a comparable level of inputs.

Either of the following approaches can be used to predict the stochastic frontier production function. As a consequence, the ML is the first. The second method is to employ the MOLS methodology proposed by (Richmond, 1974). Finally, either linear or quadratic programming can be used. The earlier method entails maximizing the sum of absolute

residuals with the condition that the total residuals are  $\geq 0$ . Whereas the latter implies reducing the aggregate squared residuals, which are likewise constrained, the total squared residuals are  $\geq 0$ .

Conversely, Coelli, T. J. et al. (2005) contend that the model may be estimated in the same manner using either OLS or ML. The chief drawback of the predictable parametric approach is that it just assesses the impact of measuring error and any other kind of mistake on the frontier. Any departure from the frontier is ascribed to technological inefficiencies. Since it acknowledges random shocks that are outside of the farmer's control, like drought, diseases, pests, and parasites that affect output, the stochastic production frontier analysis would act as the study's foundation.

#### 2.4. Non-parametric Approach

DEA is among the linear programming techniques commonly used; it was advanced by (Farrell, 1957). It creates a convex production frontier by connecting combinations of observed or real best practices. Measuring each firm's performance in relation to the sample of firms' best practices is the aim of DEA. Finding the enterprises that, as evidenced by empirical data, make up either envelopment surface or empirical production function is the main goal of DEA. Businesses are stated as efficient if they are located on the empirical production frontier; consequently, if not, they are not, as demonstrated by Meeusen and van den Broeck (1977).

It includes identifying the producers that make up the empirical production frontier. It is believed that a producer who is situated on the empirical production frontier is efficient, whereas a producer who is not is considered inefficient. There exist two categories of DEA models: variable returns to scale models and constant returns to scale models. Economic generalizations and presumptions regarding the data to be evaluated inform the structure choice (Meeusen & van den Broeck, 1977)

The core tenets of DEA are that it refers to the production frontier as the most efficient, does not enforce functional form limitation on it, and cannot generalize about the error term (T. Coelli et al., 1997). DEA assumes that all unexplained deviations in production symbolize inefficiency because the random error is zero, which may not be the actual case, particularly in agricultural production, which is subject to a number of regular volatility such as weather changes and animal destruction, not to mention omissions and measurement errors. According to T. Coelli (2016), Malmquist DEA provides for the assessment of the rate of change in time and efficiency; however, due to the utilization of cross-sectional data, estimating the rate of change would be difficult in this study. As a result, the utilization of Malmquist DEA in this research is rendered invalid.

#### 2.5. Empirical Literature

Several investigations have delved into this subject matter. Maina et al. (2020) undertook an examination of the economic efficiency of milk production. The researchers concentrated on small-scale dairy farmers in Mukurwe-ini Sub-County, Nyeri County, Kenya. Dairy industry plays a pivotal role, generating and translating 17% to the agricultural GDP annually, making it the most robust sector within agriculture. Small-scale farmers, primarily located in the Central and Rift Valley provinces, contribute significantly to the nation's milk production. Despite similarities in ecological conditions and animal breeds, there are variations in milk production, with some farms achieving 20 liters per cow per day; in contrast, others produce only about 5 liters per cow per day. Mukurwe-ini sub-county in Nyeri County, situated in the Central part of Kenya, was chosen for the research due to its substantial number of dairy farms, coupled with a relatively low milk production per cow. In 2017, the study involved sampling 91 small-scale dairy farmers utilizing semi-structured questionnaires. In addition, cross-sectional data on socioeconomic factors and milk production in the preceding month were generated as part of the research methodology.

The study utilized the Tobit model to examine elements altering economic efficiency, while the Stochastic Frontier model was optimized to assess the technical, distributive, and economic effectiveness of milk production. The average technical efficiency, allocative efficiency, and economic efficiency among farmers were determined to be 68.7%, 91.3%, and 62.6%, respectively. Notably, farmers exhibited high levels of allocative efficiency, suggesting that insufficient technical efficiency was the primary contributor to economic inefficiency. The findings of the study highlight significant inefficiencies in milk production, emphasizing opportunities for enhanced productivity through better resource utilization and cost reduction measures. The results underscore the potential for improvements in the efficiency of production processes, which could lead to increased overall economic performance in the dairy farming sector.

A higher yield of milk can be accomplished via more efficient use of the resources already available, as farmers with increasing returns to scale (IRS) showed. Low milk yield among small-scale producers was shown to be caused by increasing herd sizes, giving animals enough concentration, and increased spending on animals' medical care. Simultaneously, it was found that the technological inefficiencies in milk production were the fault of older farmers. A significant portion of the overall expenditures associated with dairy production was found to be the cost of concentrates and other feeds. The study area's farmers were effective at minimizing costs despite having low resources, as evidenced by their comparatively high allocative efficiency.

Among Mukurwe-ini small-scale dairy farmers, age, household size, the use of dairy farming as the chief source of income, the use of rented labour, and the monthly cost of concentrates were shown to be substantive factors correlated with economic efficiency. The study under consideration looked at broad characteristics that affected technical efficiency but did not look at the cattle breeds that this study would look at. The evaluated study, on the other hand, would enlighten some of the variables to be addressed in this investigation.

In a study conducted by Kinyua (2019), the technical efficiency of small-scale banana farming in Meru County, Kenya, was investigated. In consequence, the primary aims of the research were to compute technical efficiency and identify

factors contributing to technical efficiency in banana farming in Imenti South, Meru, Kenya. This study employed a non-experimental research methodology, with participant farmers providing cross-sectional data through completed questionnaires. A stratified random sampling strategy was utilized to highlight a representative through sampling of farmers for participation in the research.

Research conducted by Kinyua (2019) employed multi-regression scrutiny to identify the factors influencing technical efficiency, and the maximum likelihood approach was utilized to determine stochastic production function. Accordingly, outcomes of the Stochastic Frontier Analysis (SFA) portrayed that small-scale banana growers exhibited an average technical efficiency of approximately 69%. This implies that the farmers were, on average, 31% technically inefficient in their banana farming practices.

The regression analysis of the efficiency model indicated that factors such as access to extension services, size of the farmer's household, gender, land ownership, and prior experience in growing bananas had a negative impact on technical efficiency. Conversely, the farmer's age, highest access to education, access to water for irrigation, and access to credit had positive effects on technical efficiency. Consequently, the study suggests that farmers could benefit from increased access to loans with reduced interest rates. The insights from this reviewed study had a substantial impact on the methodology employed in the upcoming investigation.

Aweer, D. A. et al. (2020) assessed the performance of dairy cattle on smallholder farms in Kenya's Nyeri County, focusing on three main areas: managing young and growing stock, reproductive and productive performance, and feed availability and feeding practices. An aggregate of 200 farmers were randomly selected from each of the study sites, namely Mathira East and Othaya Sub Counties. Information related to feed resources, feeding systems, calf feeding, age at first service, age at first calving, calving interval, milk yield, and lactation duration was assembled using a semi-structured questionnaire. Additionally, samples of both concentrates and forages were collected for quality analysis.

The data was computed using SPSS version 21.0 to reach a conclusive outcome. The most popular feeding technique was stall feeding (74.2%). The concentrates feeds were fed more frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency. The efficiency levels of the farms' performance were not examined in the study that is currently being reviewed. The study focused on feeds and did not measure the efficiency with which feeds were distributed among farms' cows or converted into production. Although the study under evaluation examined animal feeding, the approach used was not applied since this study is not experimental.

Another investigation by Ngeno and Chumo (2021) was conducted to assess the technical efficiency of small-scale dairy farmers in Kenya across different agro-ecological zones. Employing stochastic meta-frontier analysis and region-specific frontiers based on the "true" random effect paradigm, the researchers examined the technical efficiencies, technological gaps, and meta-frontier technical efficiency of small-scale dairy producers in various zones of Kenya. On that account, the empirical study utilized three waves of panel data collected at the household level from different zones.

TE of small-scale dairy producers in Kenya operating in different agro-ecological zones was examined by Ngeno and Chumo (2021). Maximizing stochastic meta-frontier and region-particular frontiers based on the "true" random effect paradigm, they investigated the technical efficiencies, technological gaps, and meta-frontier technical efficiency of Kenyan small-scale dairy farmers in various zones. Three waves of panel data at the home level from different zones served as the basis for the empirical study.

The results showed differences in efficiency indices and that small-scale farmers' milk production is defined by growing returns to scale. Based on the available technology and the climate in each zone, the results show that smallholder dairy farmers' milk yields in all zones fall short of their potential. Additionally, they found that dairy production in Kenya's three agro-ecological zones differed significantly in terms of technology. The study under examination highlights the technological differences between the zones and focuses on comparing them. However, the goal of this examination is to assess the degree of technological efficiency among farmers in the same agro-ecological zone.

According to Kamau et al. (2016) smallholder coffee farmers in Murang'a, Kenya were assessed for their technical efficiency. Two steps comprised the data analysis process. The technical efficiency measures were computed in the first step using the non-parametric DEA model. Technical efficiency ratings that were calculated were subsequently regressed against a range of descriptive variables, including characteristics of households, farm size, and additional indicators related to institutional structures and usage of technology.

A mean technical efficiency of 54% was found in the results. The outcome shows that key factors influencing technical efficiency in coffee production include household size, farmers' age, loan availability, and coffee variety. It was discovered that improved access to financing services that help farmers buy market supplies for coffee operations and the adoption of superior varieties, especially by younger farmers, would increase technical efficiency and, as a result, coffee output. While this study used a Cobb-Douglas technology and stochastic frontier analysis, the prior research used DEA to evaluate technological efficiency.

The investigation by Ayuko et al. (2023) focused on the degree and components of technological efficiency in the production of fodder in Homa Bay County. This study found that fodder cultivation increases income through feed, milk, and livestock sales. They learned that it was anticipated that the bordering countries' need for hay would increase to nearly 500 billion bales annually. Kenya's demand for fodder surged, but supply could not keep up with demand. In response, the ILRI helped create a number of projects to encourage the cultivation of fodder to increase milk yield. In this study, first-hand data was collected from approximately 300 farmers in the Rachuonyo East and South sub-counties through structured questionnaires. The Tobit model and the stochastic Frontier model were employed for analysis. The

outcome from the SFA revealed that the level of TE was affected by factors such as land area, seed quality, planting labor, and weeding labor.

According to Tobit's findings, herd size, group participation, loan availability, household size, and access to training all have an impact on farmers' TE. To boost fodder production, the study advised that farmers increase fodder reservation, planting supplies, and the amount of man-days spent sowing and weeding. The proposed study borrowed and examined some variables from the study under review. However, the methodology of this study differed from the study under review in that it did not use the Tobit model but SFA and Cobb-Douglas function.

Technical efficiency in resource usage was the main topic of (Nyangaka et al., 2009): Evidence from small-scale Irish potato growers in Nyandarua. The study by Mukami (2018) concentrated on the welfare advantages and technical effectiveness of smallholder farmers' snow pea production in Kenya's Nyandarua County. While the two previous papers focused on distinct subsectors, the present analysis concentrated on smallholder dairy farmers.

### 2.6. Overview of Literature

The evaluation of the technical efficiency literature review gives a comprehension of the various elements impacting technical efficiency in agricultural production, notably dairy farming. The studies examined used variables that are consistent with economic theory. As a result, they were useful in defining the variables that would be taken into account in this research. Preceding examinations evaluated revealed that TE in agricultural production is affected by the farmer's gender, educational level, age, breed, land size, and general farm features (Aweer, D.A et al., 2020; Etich, 2013; Maina et al., 2020). The studied literature also demonstrated the possibility of significantly enhancing dairy production, namely by raising farm or producer technical efficiency with no additional increment in inputs. Some investigations did not look into the sources and drivers of technological efficiency, which is what the current study did.

The vast majority of the agricultural production literature analyzed employed Stochastic Frontier Analysis, including (Ayuko et al., 2023; Etich, 2013; Kinyua, 2019; Maina et al., 2020). The present investigation applied the methodology of these previous studies, namely SFA using the Cobb-Douglas function, to determine the technical efficiency of small-scale dairy cattle farming in the study area. In addition, the vast majority of this research, however, focused on the technical efficiency of other agricultural goods, leaving dairy cattle out. Etich (2013) concentrated on the technical efficiency of sorghum farming in Machakos County; Aweer D.A et al. (2020) concentrated on animal feeding and husbandry practices; Kinyua (2019) concentrated on banana farming in Imenti South, Meru County; Kamau et al. (2016) concentrated on technical efficiency among coffee farmers in Murang'a and Ayuko et al. (2023) examined the extent and determinants of technical efficiency in fodder production in Homa Bay County.

## 3. Methodology

### 3.1. Introduction

The section discusses this research's methodology, design of the study, theoretical framework, model specifications, variable description and evaluation, study population and area, sampling strategy and size of the sample, sources of information and types, methods for analyzing data, and ultimately the diagnostic tests, which were performed.

### 3.2. Research Design

This assessment used a design that is not experimental. Furthermore, the study is going to utilize a cross-sectional methodology, which requires gathering production information during a single time period. A quantitative research technique was used in the design. For every farmer sampled, quantitative information on both inputs and outputs was collected. The SFA was used in the study to evaluate farmers' technical efficiency scores and the causes of such efficiency levels.

### 3.3. Theoretical Framework

The classical production function theory served as the foundation for this research. Given the technology threshold, the theory defines how outputs vary due to variations in the amount of inputs. The proposed stochastic frontier production function by Meeusen & van den Broeck (1977) is:

$$Y_i = X_i\beta + (V_i - U_i) \dots \dots \dots 3.1$$

Where:

$X_i$  is a vector of inputs,

$Y_i$  is the  $i^{\text{th}}$  sample farm's output, and

$\beta$  is the parameters that need to be estimated.

On the grounds of this,  $V_i$  is a random error with a constant variance and zero mean, or  $N(0, \delta v^2)$ . It is related to random factors, like weather fluctuations and inaccuracies in production measurement, which are all beyond the farmer's control (a randomized error term that accounts for unwarranted volatility in the data sample); additionally, the error term's non-negative technical inefficiency component is called  $u_i$ .

### 3.4. Model Specification

The specification of the stochastic frontier model is as follows, based on models by T. J. Coelli et al. (2005).

$$Y_i = (X_i; \beta_i) \exp(v_i - u_i) \dots \dots \dots 3.2$$

Where:

$X_i$  is a vector of the input values,  
 $Y_i$  is the farmer's output, and  
 $f(X_i; \beta)$  is a pertinent production function, like a Cobb Douglas or Trans log.

If  $(x_i; \beta)$  adopts the log-linear Cobb-Douglas form, equation 3.2, as a consequence, it can be written as follows:  
 $\ln Y_i = \beta_0 + \beta_1 \ln x_i + v_i - u_i$  .....3.3

Where:

Parameters are represented by  $\beta$ , and the random error with an average of zero,  
 $v_i$  is related to random factors that farmers cannot control, like measurement error, weather, and diseases.  
 $u_i$ , or inefficiency, is a term for a one-sided error.

Cobb Douglas production function for dairy cattle farmers in the research vicinity is as outlined below:  
 $\ln Y = \beta_0 + \beta_1 \ln L + \beta_2 \ln ACRES + \beta_3 \ln QC + \beta_4 \ln FODD + \beta_5 \ln EXP + V - U$  .....3.4

Where:

$\ln$  = natural logarithm  
 $Y$  = total output (liters)  
 $L$  = Labor (man-hours)  
 $QC$  = Average amount of concentrates used per cow per (kg),  
 $ACRES$  = Total area under fodder (acres)  
 $FODD$  = Average amount of fodder per cow per day(kg)  
 $EXP$  = Monthly expenditure on animal health (Kenya shillings)  
 $\beta_i$  = To be estimated parameters.

$V$  = are identical, normally distributed, having random variables with zero mean and constant variance  $N(0, \delta v^2)$  that are thought to be independent of  $U$ .

$U$  = is the technical inefficiency in production.

A farmer's technical efficiency is characterized by the ratio of actual output ( $Y_i$ ) to the corresponding frontier output ( $Y_i^*$ ) achievable with the current technology. Therefore, the technical efficiency of the farm is mathematically expressed as:

$$TE = Y_i / Y_i^* = \frac{f(X_i; \beta) \exp(v_i - u_i)}{f[X_i, \beta + v_i]} = \exp(-u_i) \dots\dots\dots 3.5$$

Technical efficiency arises when  $\exp V = 1$  and  $U = 0$  because  $\exp(V) = 1$ . TE, then, has values between 0 and 1, where 0 represents wholly technically inefficient farms and 1 represents efficient farms. It is crucial to keep in mind that a farmer's technical efficiency decreases with increasing  $U$ . Using SFA and equation 3.4, the first goal—estimating the degree of technical efficiency—would be achieved.

It is only helpful to ascertain if a farm is technically efficient or inefficient if the underlying causes of the efficiency or inefficiency are also found (Admassie & Matambalya, 2002). As a result, the investigation's second phase concentrated on ascertaining the reasons for the sampled farmers' technical efficiencies.  $U$  represents technical inefficiency, while technical production efficiency is represented by  $1-U$ , as explained below:

$$\mu_i = \theta_0 + \theta_1 X_1 + \theta_2 X_2 + \theta_3 X_3 + \theta_4 X_4 + \theta_5 X_5 + \theta_6 X_6 + \theta_7 X_7 + \theta_8 X_8 + \theta_9 X_9 + \theta_{10} X_{10} + \theta_{11} X_{11} + \theta_{12} X_{12} + \theta_{13} X_{13} \dots\dots\dots 3.6$$

Where:

$\mu_i = 1-U$  = the efficiency score for the  $i^{th}$  farmer,  
 $X_1$  = the farmer's gender  
 $X_2$  = the farmer's age  
 $X_3$  = the farmer's educational attainment  
 $X_4$  = Size of the household  
 $X_5$  = Farming experience  
 $X_6$  = Land ownership  
 $X_7$  = Grazing technique  
 $X_8$  = Access to extension services  
 $X_9$  = the farmer's access to credit  
 $X_{10}$  = the farmer's access to irrigation water  
 $X_{11}$  = the breeds of cattle  
 $X_{12}$  = the primary source of income is dairy farming  
 $X_{13}$  = membership to a cooperative society  
 $\theta_0 - \theta_{13}$  calculated inefficiency model coefficients.

The second goal is to investigate the technical efficiency elements of small-scale dairy farmers in Kinangop sub-county, which was determined in conjunction with the first goal by concurrently estimating equations 3.4 and 3.6 using SFA.

Variables	Meaning	Variable Measurement	Expected Sign
<b>Milk Output</b>	The total volume of milk in a month.	Measured in liters	NA
<b>Inputs -L</b>	Labor- the number of man hours	Measurable in hours	+
QC	Quantity of concentrates used in the farm	Measurable in Kgs	+
ACRES	The total area under fodder	Measurable in acres covered by fodder only	+
FODD	The average amount of fodder per cow per day(kg)	Measured in kg	+
EXP	Monthly expenditure on animal health	Measured in Kenya shillings	-
Socio-economic Variables			
Variables	Meaning	Variable Measurement	Expected Sign
X <sub>1</sub>	Farmer's Gender	A dummy variable 1 if male and 0 if otherwise	+
X <sub>2</sub>	Farmer's Age	Measurable by years	+
X <sub>3</sub>	Level of education of the farmer	1=without formal education 2=primary, 3=secondary, 4=tertiary colleges, 5= university	+
X <sub>4</sub>	Household size	No. of household members both children and adults	+/-
X <sub>5</sub>	Farming experience	Measured in years	+
X <sub>6</sub>	Land ownership	A dummy variable 1 if owned 0 otherwise	+
X <sub>7</sub>	Grazing method	A dummy variable 1 if zero-grazing 0 otherwise	+
X <sub>8</sub>	Accessibility to credit services by the farmer	A dummy variable 1 if accessible 0 otherwise	+
X <sub>9</sub>	Accessibility to extension services	A dummy variable 1 if accessible 0 otherwise	+
X <sub>10</sub>	Access to irrigation water	A dummy variable 1 if yes, 0 otherwise	+
X <sub>11</sub>	Cattle breeds	A dummy variable if mixed=0,ayrshire=1,holstein/freshian=2, jersey=3	+
X <sub>12</sub>	Dairy farming as the sole source of income	A dummy variable is 1 if yes 0 otherwise	+
X <sub>13</sub>	Membership in cooperative societies.	A dummy variable is 1 if yes,0 otherwise	

Table 2: Expected Signs, Definition and Measurement of Variables Estimating Efficiency of the Farmer

### 3.5. Study Area and Target Population

The Kinangop sub-county, one of Nyandarua County's five sub-counties, was the subject of the research. It is approximately 100 kilometers north-west of Nairobi, on the slopes of the Aberdare ranges. It formed in time for the 1988 general elections. It is divided into eight electoral wards. The primary economic activity in the 822 km<sup>2</sup> geographical area with a natural forest covering about 20.3 Kha is dairy and crop farming. In the area, dairy cattle grazing regimes such as zero grazing, semi-zero grazing, and free grazing are used. Kinangop sub-county was purposefully chosen since it accounts for 40%, Kipipiri 25%, and the remaining three sub-counties account for the remainder. The most reared breeds are Holstein Friesians, followed by Ayrshire, while Jersey is the least reared.

Ward	Number of Smallholder Dairy Cattle Farmers
ENGINEER	4,659
GATHARA	4,309
NJABINI KIBURU	3,942
NYAKIO	5,376
NORTH KINANGOP	5,010
MAGUMU	2,150
MURUNGARU	6,093
GITHABAI	4,301
TOTAL	35,840

Table 3: Target Population  
Source: (Ongwech et al, 2020)

### 3.6. Sample Design and Sample Size

This investigation used a stratified sampling approach, with the first phase including the purposeful selection of all eight wards that comprise the Kinangop sub-county to stratum. The convenience sampling approach was also used, which entails selecting random samples from each stratum at the researchers' discretion to participate in the study due to the unavailability of the farmers' list to build a sampling frame. To ensure that the selected sample of farmers is representative of the overall population, the following sampling technique used by Ongwech et al. (2020) was employed.

$$n = \frac{NC^2}{C^2 + (N - 1)e^2}$$

Where:

n0 = represents the sample size,

N = the total population of the study,

C = is the coefficient of variation given as (0.5),

e = level significance given as 0.05.

In general, 100 people

The sample selected was chosen at random from among the wards using the formula below.

$$n_o = \frac{N_i}{N} \times n$$

Where:

N<sub>i</sub> = total population of dairy farmers in the i<sup>th</sup> ward.

N<sub>o</sub> = number of farmers sampled from the i<sup>th</sup> ward.

N = target population.

n = size of the sample.

### 3.7. Data Type and Sources of Data

The assessment collected data from primary sources. In consequence, data was collected in the field by administering and filling out questionnaires. The first section of the questionnaire addressed socioeconomic factors such as the farmer's age, household size, and gender, whereas the second part included production-related questions.

To achieve the study's objectives, a well-structured questionnaire was provided to acquire critical information on dairy cattle farmers. The survey included both closed and open-ended questions.

### 3.8. Data Analysis

First, the dataset collected from the farmers was tallied. This is because the initial objective of the study is to determine the technical efficiency level of small-scale dairy cattle farmers using SFA, and the analysis was conducted in compliance with those goals. The second objective is to investigate the variables that affect the small-scale dairy producers' technical efficiency in the Kinangop sub-county, which was calculated using SFA.

### 3.9. Diagnostic Tests

#### 3.9.1. Heteroscedasticity

The presence of heteroscedasticity does not impact the unbiasedness and linearity of the regression model coefficients. Nevertheless, it has an effect on the estimator's best property, rendering the inference drawn during hypothesis testing worthless. In addition, Breusch-Pagan test was used in the study to test for heteroscedasticity (Gujarati et al., 2009).

#### 3.9.2. Multicollinearity

Multicollinearity causes ambiguity in the regression coefficients and non-finite standard errors in the estimates. According to Gujarati et al (2009), multicollinearity is ubiquitous among variables, but the degree is what matters. The variance inflation factors (VIF) test, as described in (Kinyua, 2019), was employed in this study to assess the incidence of significant multicollinearity.

#### 3.9.3. Normality Assumption of the Random Variable

The error term, or statistical noise, is represented by the symbol  $\mu$  ( $0, \sigma^2$ ) in the conventional linear regression model, which assumes that it has a normal distribution. The impacts of every additional variable that influences the dependent variable under consideration but is not part of the model are incorporated into the error term. However, the omitted elements are believed to be, at most, random and to have a minor effect. The normalcy of the error term in this study was confirmed using the Shapiro-Wilks test, as utilized by (Kinyua, 2019).

## 4. Empirical Findings

### 4.1. Introduction

The chapter presents the findings and discussion of the study, focusing on descriptive statistics and the results of the analysis regarding technical efficiency and technical effectiveness in dairy cattle production in Kinangop sub-county. It

offers a comprehensive overview of the data collected, highlighting key metrics and trends observed among smallholder dairy farmers. The analysis delves into various factors influencing technical efficiency, such as resource utilization, management practices, and environmental conditions. Additionally, the chapter assesses the effectiveness of different production techniques and their impact on overall productivity. Consequently, providing a detailed description of the study's objectives and the corresponding results, the chapter offers valuable insights into the current state of dairy farming efficiency in the region, identifying areas for potential improvement and recommending strategies to enhance productivity and sustainability.

#### 4.2. Descriptive Statistics for Smallholder Dairy Cattle Farmers

The subsequent sections outline the descriptive statistics of the variables of study for technical efficiency among smallholder dairy cattle farmers in Kinangop Sub County, Kenya. The demographic characteristics identified in the study included the farmer's gender, years of experience, level of education, size of their households, and their primary source of income. The study further sought to determine the farming experience, land ownership, grazing techniques, access to extension services, financial services, irrigation, land acreage, employment status, number of hours of hired labor, access to credit facilities and the type of dairy cattle reared.

	Frequency	Percent
Female	40	40
Male	60	60
Total	100	100

Table 4: Summary Statistics for Gender  
Source: Calculations by Author

From the results, it can be noted that 60 percent of the total respondents were male, whereas 40 percent were female. Males are perceived to be engaged largely in dairy farming activities compared to their female counterparts. The results are not in tandem with the findings of Kinyua (2019), which indicated that the gender of farmers had a negative impact on technical efficiency.

	Frequency	Percent
20–40 Years	40	40
41–60 Years	44	44
61–80 Years	14	14
Over 80 Years	2	2
Total	100	100

Table 5: Age of Smallholder Dairy Cattle Farmers  
Source: Calculations by Author

It can be observed that 40 percent of the total respondents in the study were aged between 20 and 40 years, whereas 44 percent were aged between 41 and 60 years, 14 percent were aged between 61 and 80 years, and finally, 2 percent were over 80 years. The age distribution of smallholder farmers is a significant factor in enhancing their technical efficiency. Younger farmers, often more adaptable and open to new technologies and methods, can contribute to higher efficiency levels. Middle-aged farmers typically have accumulated experience and resources, which also positively impacts efficiency. These findings are consistent with the research by Maina et al. (2020), which indicated that age is a substantive factor correlated with economic efficiency, showing that both youthful energy and mature experience play roles in efficient farming practices. Furthermore, the results align with Kinyua (2019), who found that a farmer's age positively affects technical efficiency, suggesting that the combination of youthful innovation and seasoned experience is beneficial for achieving higher productivity in dairy farming.

	Frequency	Percent
Formal Education	2	2
Primary	37	37
Secondary	30	30
Certificate/Diploma	25	25
Bachelor's Degree	5	5
Post Graduate	1	1
Total	100	100

Table 6: Level of Education of Smallholder Dairy Cattle Farmers  
Source: Calculations by Author

From the outcomes, the majority (37 percent) of the participants possessed primary education as their highest level of education, 30% posted secondary education, 25 percent possessed a certificate or diploma, 5 percent held a bachelor's

degree, 2 percent had some form of formal education, and finally, 1 percent possessed a postgraduate degree. The educational attainment of dairy farmers is crucial in determining their technical efficiency. Education influences the skills acquired by the farmers in relation to dairy farming. These findings align with Kinyua (2019), which indicated that higher levels of education positively affect technical efficiency.

	Frequency	Percent
Rent	9	9
Both	32	32
Own	59	59
Total	100	100

*Table 7: Land Ownership of Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

From the results, it can be noted that 59 percent of the respondents owned land, 32 percent both rented and owned land for dairy farming while 9 percent rented the land for dairy farming. Land ownership is critical in enhancing the technical efficiency of dairy farmers. This is because the farmers who own land are likely to cut on costs associated with renting land for carrying out dairy farming activities, including space for zero grazing, grazing lands, as well as lands where fodder can be grown. However, the findings of Kinyua (2019) pointed out that land ownership had a negative impact on technical efficiency. In addition, the results of Ayuko et al. (2023) indicated that the level of technical efficiency was affected by factors including land area.

	Frequency	Percent
No	87	87
Yes	13	13
Total	100	100

*Table 8: Results for Irrigation Farming by Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

It can be noted that 87 percent of the respondents contacted did not practice irrigation in their farms, while 13 percent indicated that they were practising irrigation in their farms. Access to irrigation services enhances farmers' productivity by ensuring the continuous productivity of fodder even during dry seasons. The results are in line with the findings of Kinyua (2019), which indicated that access to water for irrigation had positive effects on technical efficiency.

	Frequency	Percent
No	54	54
Yes	46	46
Total	100	100

*Table 9: Dairy Farming as the Only Source of Income*

*Source: Calculations by Author*

The results indicate that 46 percent of the respondents had dairy farming as their only source of income, whereas 54 percent indicated that, other than dairy farming, they had other sources of income. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs, including concentrates, money for hiring labour, and money for ensuring good animal health, which ultimately has a positive effect on the technical efficiency of the farmers. However, it would reduce the attention and time that is required to enhance the productivity of the dairy cattle.

	Frequency	Percent
Farming Only	39	39
Business	30	30
Employed	30	30
Business and Employed	1	1
Total	100	100

*Table 10: Employment Status of Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

In terms of the employment status of the respondents, 39 percent indicated that they were only practising dairy farming, and 30 percent indicated that other than dairy farming, they were engaged in other businesses. In addition, 30 percent also indicated that other than dairy farming, they were employed and finally, 1 percent indicated that other than dairy farming, they were engaged in other businesses and were also employed. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs, including concentrates, money for hiring

labour, and money for ensuring good animal health, which ultimately has a positive effect on the technical efficiency of the farmers. However, it would reduce the attention and time that is required to enhance the productivity of the dairy cattle.

	Frequency	Percent
No	25	25
Yes	75	75
Total	100	100

*Table 11: Hiring Labour of Smallholder Dairy Cattle Farmers  
Source: Calculations by Author*

On whether the respondents were hiring labour in their dairy farming, 75 percent pointed out that they were hiring labor while the remaining 25 percent were of the contrary opinion. Hiring labour to assist in the activities of dairy farming has a positive effect on the technical efficiency and productivity of dairy farmers. The results are in tandem with the findings of Maina et al. (2020), which indicated that the use of rented labour was shown to be a substantive factor correlated with economic efficiency.

	Frequency	Percent
Low	57	57
Intermediate	39	39
Intensive	4	4
Total	100	100

*Table 12: Level of Mechanization in Dairy Farming  
Source: Calculations by Author*

In terms of the level of mechanization of the smallholder cattle farmers in the Kinangop sub-county, 57 percent indicated that the level of mechanization was low, 39 percent indicated that the level of mechanization was intermediate, whereas the remaining 4 percent were of the opinion that their level of mechanization in dairy farming was intensive.

	Frequency	Percent
Low	58	58
Intermediate	39	39
Intensive	3	3
Total	100	100

*Table 13: Level of Hiring Machinery in Dairy Farming  
Source: Calculations by Author*

On whether the respondents were hiring machinery in their dairy farming, 58 percent indicated low levels of hiring machinery, 39 percent indicated intermediate level, whereas 3 percent were at intensive levels of hiring machinery for their dairy farming.

	Frequency	Percent
No	42	42
Yes	58	58
Total	100	100

*Table 14: Society Membership by Smallholder Dairy Cattle Farmers  
Source: Calculations by Author*

On whether the respondents subscribed to any society membership, the results indicated that 58 percent were members of particular societies while 42 percent had joined any of the existing societies.

	Frequency	Percent
No	14	14
Yes	86	86
Total	100	100

*Table 15: Access to Extension Services by Smallholder Dairy Cattle Farmers  
Source: Calculations by Author*

It is worth noting that 86 percent of the participants showcased access to extension services, while 14 percent did not have access to any extension services in their dairy farming. Extension services are critical in enhancing the productivity of dairy cattle and, hence, the technical efficiency of the smallholder farmers in Kinangop County. The results are not in

tandem with the findings of Kinyua (2019), which indicated that factors, including entry into extension services, had a negative impact on technical efficiency.

	Frequency	Percent
No Access	11	11
Government	9	9
Cooperative Society	22	22
Private Hired Officers	55	55
Farmers	3	3
Total	100	100

Table 16: Provider of Extension Services

Source: Calculations by Author

From the results, participants indicated that:

- 55 percent of the extension services at their disposal were provided by privately hired officers,
- 22 percent of the extension services they could access were provided by cooperative societies,
- 11 percent did not access any of the extension services provided by different groups,
- 9 percent indicated that the extension services at their disposal were provided by the government and
- The remaining 3 percent portrayed access to extension services provided by their fellow farmers.

Extension services are critical in enhancing the productivity of dairy cattle and, hence, the technical efficiency of the smallholder farmers in Kinangop County. The results are not in tandem with the findings of Kinyua (2019), which indicated that factors, including entry into extension services, had a negative impact on technical efficiency.

	Frequency	Percent
No	46	46
Yes	54	54
Total	100	100

Table 17: Access to Credit

Source: Calculations by Author

It can be observed that 54 percent of the respondents had access to credit while 46 percent did not have access to any credit facilities in their dairy farming. Credit services are critical in enhancing the productivity of dairy cattle and, hence, the technical efficiency of the smallholder farmers in Kinangop County. The number of dairy cattle, association participation, financial education, and dairy farming as a major occupation are important factors that influence credit availability (Ongwech et al., 2020). Therefore, the study came to the conclusion that there were important factors influencing farmers' access to credit in the study area and suggested that policies aimed at raising farmers' educational attainment would be crucial to improving farmers' access to credit in the study area.

	Frequency	Percent
No Access	43	43
Others	7	7
Cooperative Society	44	44
Commercial Banks	6	6
Total	100	100

Table 18: Provider of Credit

Source: Calculations by Author

From the results, the respondents indicated that 44 percent of the credit facilities at their disposal were provided by cooperative societies, and 43 percent had no access to credit provided by the different groups. In addition, 7 percent pointed out that they could access credit facilities through other sources, while the remaining 6 percent pointed out access to credit facilities through commercial banks. Credit services are critical in enhancing the productivity of dairy cattle and, hence, the technical efficiency of the smallholder farmers in Kinangop County. The results are in tandem with the findings of Kinyua (2019), which indicated that factors such as access to credit services had a negative impact on technical efficiency.

	<b>Frequency</b>	<b>Percent</b>
No Access	44	44
No	23	23
Yes	33	33
Total	100	100

*Table 19: Credit Repayment from Dairy Proceeds*

*Source: Calculations by Author*

It is clear that 44 percent of the respondents contacted in the study had no access to credit, 33 percent were able to service their loans from dairy proceeds only while the remaining 23 percent were not able to service their loans from dairy proceeds only. Credit services are critical in enhancing the productivity of dairy cattle and, hence, the technical efficiency of the smallholder farmers in Kinangop County. The findings of Kamau et al. (2016) indicated loan availability and improved access to financing services that help farmers buy market supplies for coffee operations. In addition, Ayuko et al. (2023) further indicated that loan availability has an impact on farmers' technical efficiency.

	<b>Frequency</b>	<b>Percent</b>
No	54	54
Yes	46	46
Total	100	100

*Table 20: Zero Grazing as Main Grazing Method*

*Source: Calculations by Author*

On whether the respondents were practising zero grazing as the main method of grazing, 46 percent were in agreement, while 54 percent had other methods of grazing other than zero grazing.

	<b>Frequency</b>	<b>Percent</b>
No	10	10
Yes	90	90
Total	100	100

*Table 21: Use of Concentrates by Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

On whether the respondents used concentrates in their dairy farming, 90 percent agreed that they were using concentrates in their dairy farming, while 10 percent pointed out that they were not using concentrates in their dairy farming. The results of this study indicate that Maina et al. (2020) indicated that giving animals enough concentrates enhanced the productivity of the dairy cattle. The monthly cost of concentrates was shown to be a substantive factor correlated with economic efficiency. Furthermore, the findings of Aweer et al. (2020) indicated that concentrate feeds were fed more frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency.

	<b>Frequency</b>	<b>Percent</b>
Mixed	27	27
Ayrshire	6	6
Holstein/Freshian	66	66
Jersey	1	1
Total	100	100

*Table 22: Cattle Breeds Reared*

*Source: Calculations by Author*

In terms of the dairy cattle breeds reared by the respondents, majority (66 percent) was rearing Holstein/Freshian, 27 percent were rearing mixed breeds, and 6 percent were rearing Ayrshire while 1 percent was rearing Jersey. This indicates that Holstein/Freshian was a common breed reared by smallholder farmers in Kinangop Sub-County.

	<b>Frequency</b>	<b>Percent</b>
No	42	42
Yes	58	58
Total	100	100

*Table 23: Silage Preservation by Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

When asked about silage preservation, 58 percent agreed that they were preserving silage, while 42 percent did not in their dairy farming.

	<b>Frequency</b>	<b>Percent</b>
No	40	40
Yes	60	60
Total	100	100

*Table 24: Hay Preservation by Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

When asked about hay preservation, 60 percent were in agreement that they were preserving hay while 40 percent were not preserving hay in their dairy farms. The results of Ayuko et al. (2023) found that fodder cultivation increases income through feed, milk, and livestock sales. Kenya's demand for fodder surged, but supply could not keep up with demand. In response, the ILRI helped create a number of projects to encourage the cultivation of fodder to increase milk yield. The study advised that farmers increase fodder reservation, planting supplies, and the amount of man days spent sowing and weeding.

	<b>Frequency</b>	<b>Percent</b>
No	49	49
Yes	51	51
Total	100	100

*Table 25: Purchase of Fodder by Smallholder Dairy Cattle Farmers*

*Source: Calculations by Author*

On whether the respondents were purchasing fodder, 51 percent were in agreement that they were purchasing fodder in their dairy farming, while 49 percent pointed out that they were not purchasing fodder in their dairy farming.

	<b>Frequency</b>	<b>Percent</b>
No	5	5
Yes	95	95
Total	100	100

*Table 26: Results for Feeding Farm Residuals*

*Source: Calculations by Author*

On whether the respondents were feeding their dairy cattle on farm residuals, 95 percent agreed that they were feeding their dairy cattle on farm residuals, while 5 percent pointed out that they were not feeding their dairy cattle on farm residuals.

	<b>Frequency</b>	<b>Percent</b>
Yes	100	100

*Table 27: Use of Artificial Insemination*

*Source: Calculations by Author*

On whether the respondents were using artificial insemination, 100 percent agreed that they were using artificial insemination services in cattle breeding. The use of artificial insemination services enhances productivity as it improves the breeds of dairy cattle and, hence, the technical efficiency of dairy farmers in the long run.

	<b>Mean</b>	<b>Std. Deviation</b>
Household size	4.73	2.187
Experience in farming	13.46	12.38
Acres of land owned	2.908	3.65925
Acres of land rented	0.9775	1.4342
Acres allocated to animal grazing	1.0005	1.79693
Acres allocated to fodder production	1.46	1.40682
How many hours of labour do you hire in a day?	4.67	3.269
How much do you spend on hired labour per day?	477	580.553
Concentrates Cost Per 70kg Bag	2617	987.554
Kgs of concentrate per cow per day on average	3.17	2.3173
Kgs of fodder per day per animal	41.83	26.928
Expenditure on purchase of fodder (P.A)	8069.8	13878.5

	Mean	Std. Deviation
Expenditure on animal health (P.M)	2622	4840.35
Dairy animals in the farm	3.72	2.675
Animals milked	2.31	1.916
Liters of milk produced daily	20.975	20.9834
Liters of milk sold daily	18.84	19.591
Milk selling price	42.655	5.6344

Table 28: Summary Statistics for Continuous Variables

Source: Calculations by Author

The mean household size for the study was 5 people. Household size is significant in the provision of labour as well as skills necessary in dairy farming. The results of Maina et al. (2020) indicated that household size was shown to be a substantive factor correlated with economic efficiency. In addition, the results of Ngeno and Chumo (2021) pointed out that household size is a key factor influencing technical efficiency in coffee production. The findings of Kinyua (2019) indicated that factors, including the farmer's household size, had a negative impact on technical efficiency.

On average, the respondents had experience of about 14 years, with a standard deviation of 12.38 years. Prior experience in dairy farming is essential in enhancing the technical efficiency of dairy farmers. It is critical to identify the challenges that the farmers may encounter and the possible solutions that can be adopted by the farmers. In addition, with prior experience, the farmers can use their prior knowledge on the optimal amounts of inputs that they can give the dairy cattle for maximum production and become technically efficient. However, the results of Kinyua (2019) indicated that prior experience in growing bananas had a negative impact on technical efficiency.

On average, the dairy farmers who were the respondents in the study owned 3 acres of land with a standard deviation of 3.66 acres. The size of the land determines the number of dairy cattle that the farmer can rear. It also determines the size of fodder production that is sufficient for the dairy cattle. Thus, land acreage is a significant determinant of the technical efficiency of the dairy farmers. The results of Kamau et al. (2016) indicated that farm size enhances technical efficiency.

On average, the respondents in the study rented at least 1 acre of land with a standard deviation of 1.43 acres. The dairy farmers who were the respondents in the study allocated about 1 acre of land for animal grazing with a standard deviation of 1.8 acres. Renting land for dairy farming is significant as it increases the productivity of dairy farmers, especially the farmers with small parcels of land. It also determines the size of fodder production that is sufficient enough for dairy cattle.

On average, the dairy farmers who were the respondents in the study allocated about 1.5 acres of land for fodder production with a standard deviation of 1.41 acres. Dairy farmers spend about 42 kilograms of fodder per cow per day, with a standard deviation of 26.93 kg. Dairy farmers spend about Ksh. 8,000 per annum on fodder, with a standard deviation of Ksh. 13878.5. Fodder production supplements grazing by the dairy cattle. The results of Ayuko et al. (2023) found that fodder cultivation increases income through feed, milk, and livestock sales. Kenya's demand for fodder surged, but supply could not keep up with demand.

On average, the dairy farmers hired about 5 hours of labour per day with a standard deviation of 3.27 hours. The dairy farmers spent about Ksh.500 on hired labour per day, with a standard deviation of Ksh.580.55. Hiring labour to assist in the activities of dairy farming has a positive effect on the technical efficiency and productivity of dairy farmers. The results are in tandem with the findings of Maina et al. (2020), which indicated that the use of rented labour was shown to be a substantive factor correlated with economic efficiency.

On average, the cost of concentrates per 70kg bag was Ksh.2600, with a standard deviation of Ksh.987.55. Dairy farmers spend about 3 kilograms of concentrate per cow per day, with a standard deviation of 2.32 kg. The results of this study indicate that Maina et al. (2020) indicated that giving animals enough concentrates enhanced the productivity of the dairy cattle. The monthly cost of concentrates was shown to be a substantive factor correlated with economic efficiency. Furthermore, the findings of Aweer et al. (2020) indicated that concentrate feeds were fed more frequently than soya meal, maize germ, handmade dairy concentrate, and commercial dairy meal. It was shown that food deficiencies were the root cause of low reproductive and productive efficiency.

On average, the dairy farmers spent about Ksh.2600 per month on animal health with a standard deviation of Ksh.4840.35. Having other sources of income enhances the technical efficiency of the farmers by enhancing the availability of inputs, including concentrates, money for hiring labour, and money for ensuring good animal health, which ultimately has a positive effect on the technical efficiency of the farmers.

On average, the dairy farmers had about 4 dairy animals in the farm. The dairy farmers milked about 2 dairy animals. The results of Maina et al. (2020) pointed out that increasing herd sizes is a remedy for low milk yield among small-scale producers. Ayuko et al. (2023) further indicated that herd size, group participation, loan availability, household size, and access to training all have an impact on farmers' technical efficiency.

On average, the dairy farmers produced about 21 liters of milk daily with a standard deviation of 20.98 liters. The dairy farmers sold about 19 liters of milk daily with a standard deviation of 19.59 liters. The selling price of milk was about Ksh.43 per liter, with a standard deviation of Ksh.5.63. The results of Maina et al. (2020) indicated that a higher yield of milk can be accomplished via more efficient use of the resources already available, as farmers with increasing returns to scale (IRS) showed. Low milk yield among small-scale producers was shown to be caused by increasing herd sizes, giving animals enough concentrates, and increased spending on animals' medical care. Simultaneously, the technological

inefficiencies in milk production were the fault of older farmers. A significant portion of the overall expenditures associated with dairy production was found to be the cost of concentrates and other feeds.

#### 4.3. Diagnostic Tests

##### 4.3.1. Test for Heteroscedasticity

The linearity and impartiality of the regression model coefficients are unaffected by the presence of heteroscedasticity. However, it does have an impact on the estimator's prime characteristic, rendering the findings from hypothesis testing erroneous. The study tested for heteroscedasticity using the Breusch-Pagan test (Gujarati et al., 2009).

<b>Breusch-Pagan/Cook-Weisberg Test for Heteroskedasticity</b>	
Ho: Constant variance (homoscedastic)	
chi2(1)	= 0.132
Prob > chi2	= 0.0714

Table 29: Heteroscedasticity Test Results

The results, with a p-value of  $0.0714 > 0.05$ , imply that heteroscedasticity is not present.

##### 4.3.2. Multicollinearity

It is worth noting that multicollinearity causes ambiguity in the regression coefficients and non-finite standard errors in the estimates. According to Gujarati et al. (2009), multicollinearity is ubiquitous among variables, but the degree is what matters. The variance inflation factors (VIF) test, as described in (Kinyua, 2019), was employed in this study to assess the incidence of significant multicollinearity.

	<b>Collinearity Statistics</b>	
	<b>Tolerance</b>	<b>VIF</b>
(Constant)		
Age	0.659	1.517
Level of education	0.666	1.501
Land ownership	0.738	1.356
Irrigation farming	0.854	1.171
Dairy farming as the only source of income	0.582	1.717
Employed or in business	0.506	1.977
Hiring labour	0.636	1.572
Level of mechanization	0.291	3.434
Level of hiring machineries	0.261	3.826
Society membership	0.581	1.72
Access of extension services	0.474	2.109
Provider of extension services	0.544	1.84
Accessed to credit	0.119	8.419
Credit provider	0.13	7.683
Credit repayment	0.182	5.503
Zero grazing as the main method of grazing	0.762	1.312
Use concentrates	0.808	1.237
Cattle breeds reared	0.862	1.16
Silage preservation	0.653	1.531
Hay preservation	0.873	1.146
Purchase of fodder	0.728	1.373
Feeding farm residuals	0.797	1.254

Table 30: Multicollinearity Test Results

Source: Calculations by Author

From the results, it can be noted that all the VIF values for the variables identified in the study are  $< 10$ , implying that there is no multicollinearity among the variables in the study.

##### 4.3.3. Normality Assumption of the Random Variable

The error term, or statistical noise, is represented by the symbol  $\mu (0, \sigma^2)$  in the conventional linear regression model, which assumes that it has a normal distribution. The impacts of every additional variable that influences the dependent variable under consideration but is not part of the model are incorporated into the error term. However, the omitted elements are believed to be, at most, random and to have a minor effect. The Shapiro-Wilks test, which was used by Kinyua (2019), was used to confirm that the error term in this study was normal. The test's p-value, which was 0.0625,

is higher than the significance level of 0.05. At a 95 percent significance level, this shows that the data has a normal distribution and that the study does not reject the null hypothesis.

#### 4.4. The Empirical Results from the Stochastic Frontier Analysis

The results of econometric study of the stochastic frontier of Cobb-Douglas functional form are presented and illustrated in this section. Table 31 presents the empirical findings of the function estimation.

	Coefficient	t Ratio
(Constant)	0.295	0.772
labour	0.426	0.488
concentrate	0.595	0.638
Acres-fodder	0.209	0.198
fodder	0.538	0.641
Expenditure -health	-0.472	-0.138
R-Squared	0.145	0.270
log likelihood function	-0.101	
Gamma ( $\gamma_m$ )	0.782	-0.153

Table 31: Maximum Likelihood Estimates of the Stochastic Frontier for Production Function  
Source: Calculations by Author

From the estimates, the estimated R Squared for the stochastic production function for the smallholder dairy farmers was 0.145 and was statistically significant at the 5% threshold, indicating that the estimated stochastic production function was indeed notable at the same level of significance. According to the results, smallholder dairy cattle in the Kinangop sub-county were not functioning effectively, which suggests that their performance was below the frontier level. This suggests that inefficiencies rather than random variation are the cause of the differences between the frontier (potential output) and observed (actual levels). The range of the Gamma ( $\gamma_m$ ) parameter is zero to one. One indicates significant and non-random inefficiency, whereas zero indicates that there are no inefficiency effects in the model.

From the estimates, all variables were insignificant at 5%. However, only expenditure on animal health had a negative coefficient. Labour hired in Kinangop had no impact on TE due to the non-intensive nature of the sector, unlike in Mukurue-ini, where (Maina et al. (2020) found labour to be negatively influencing TE. Large land availability and the region's frequent rainfall help to explain why the number of acres used for fodder production was negligible. This is in contrast to Ngeno & Chumo (2021), who discovered that milk production in the three agro-ecological zones increased in returns to scale, suggesting that SDFs are still likely to reach their maximum potential despite operating in the first stage of the classical production function. The size of the fodder production did not matter in Kinangop.

Range (%)	Frequency	Percentage	Cumulative Downwards	Cumulative Upwards
0-10	0	0	0	100
11.-20	0	0	0	100
21-30	2	2	2	100
31-40	0	0	2	98
41-50	3	3	5	98
51-60	7	7	12	95
61-70	26	26	38	88
71-80	45	45	83	62
81-90	17	17	100	17
91-100	0	0	100	0
Minimum	22.82%			
Maximum	88.80%			
Mean	71.10%			

Table 32: Frequency Distribution of Technical Efficiency in Dairy Farming  
Source: Calculations by Author

According to the findings presented in table 32, the technical efficiency of smallholder dairy cattle farmers exhibits a broad distribution. The observed out among these farmers ranged from 0 liters to 120 liters, with an average mean technical score of 71.1% percent. Notably, no farmer achieved a frontier level of 100%. Only approximately 5% of the smallholder dairy farmers operated at below 50% technical efficiency levels, while the vast majority, 95%, operated above this threshold, with 83% operating above 70% technical efficiency levels. The average technical efficiency score falling at 71.10% below the frontier underscores the urgent need to enhance the technical efficiency of smallholder dairy farmers in

Kinangop sub-county by approximately 28.9%. This improvement could be achieved by optimizing input utilization, leveraging available extension services, and increasing society membership to enhance productivity through improved input access. The underutilization of inputs like concentrates and feed, restricted access to extension services, land constraints, low levels of education, and the high cost of inputs, including labor and other resources, can all be blamed for the lower levels of technical efficiency.

#### 4.5. Technical Efficiency Distribution and Farmer Characteristics

The study further sought to analyze the technical efficiency scores by the farmer's characteristics, including the level of education, land ownership, employment status, and level of mechanization, level of hiring machinery, provider of extension services, provider of credit services, and the cattle breeds reared. Table 33 presents the results.

Characteristic	Category	Mean	Std. Dev.	Frequency	p-Value
Level of Education	No Formal education	0.673	0.1150	2	0.0027***
	Primary	0.681	0.1180	37	
	Secondary	0.687	0.1180	30	
	Certificate/diploma	0.773	0.0740	25	
	Bachelor's degree	0.759	0.4960	5	
	Post graduate	0.837	0.0000	1	
Land Ownership	Rent	0.686	0.0900	9	0.8868
	Both	0.725	0.0950	32	
	Own	0.707	0.1230	59	
Employed or in Business	Farming only	0.691	0.1378	39	0.3664
	Business	0.706	0.0904	30	
	Employed	0.741	0.0896	30	
	Business and Employed	0.756	0.0000	1	
Level of Mechanization	Low	0.710	0.1025	57	0.6757
	Intermediate	0.720	0.1214	39	
	Intensive	0.638	0.1448	4	
Level of Hiring Machineries	Low	0.714	0.1038	58	0.7830
	Intermediate	0.720	0.1214	39	
	Intensive	0.696	0.1060	3	
Provider of Extension Services	No access	0.681	0.1197	11	0.2725
	Government	0.639	0.1638	9	
	Cooperative society	0.770	0.0527	22	
	Private hired officers	0.705	0.1114	55	
	Farmers	0.711	0.0833	3	
Credit Provider	No access	0.682	0.1110	43	0.0127**
	Others	0.610	0.1968	7	
	Cooperative society	0.746	0.0779	44	
	Commercial banks	0.783	0.0805	6	
Cattle Breeds Reared	Mixed	0.705	0.1225	27	0.9865
	Ayrshire	0.722	0.1000	6	
	Holstein/Freshian	0.712	0.1104	66	
	Jersey	0.756	0.0000	1	

Table 33: Summary of Technical Efficiency by Household Characteristic

Source: Calculations by Author

Significant at \*10%, \*\*5%, \*\*\*1%

From the outcome in table 33, the education level of respondents and credit providers was statistically significant, suggesting that these variables made significant contributions to the technical efficiency of the smallholder dairy farmers under study. Conversely, variables such as level of mechanization, cattle breed reared, hiring machinery, and extension service providers were statistically insignificant at the 99% and 95% significance levels. This implies that these variables may contribute to the technical efficiency of smallholder dairy farmers, though their contributions are insignificant.

Farmer technical efficiency declines with increasing technical inefficiency in production. The education level of dairy farmers plays a significant role in determining their technical efficiency, as it influences the skills acquired related to dairy farming. Kinyua (2019) further suggested that higher levels of education have positive effects on technical efficiency. Moreover, Kinyua's (2019) findings indicated that factors such as access to extension services postulated a negative impact on technical efficiency, which is not the case in this study.

#### 4.6. Factors Influencing Technical Efficiency in Smallholder Dairy Farmers

The study's second objective aimed to pinpoint the factors influencing technical effectiveness in dairy cattle production in Kinangop sub-county. The factors examined included gender of the farmer, age, education level, experience in farming, land ownership, access to irrigation water, access to extension services, access to credit services, grazing method, cattle breeds reared, dairy farming as the only source of income and society membership. An OLS efficiency model was applied to assess the impact of these factors on technical effectiveness in dairy cattle production in Kinangop sub-county, with detailed findings presented in table 34.

Variable	Coefficient	t-ratio
const	0.623458***	10.62
GENDER	0.0400476	1.627
AGE	-0.000585626	-0.3925
LEVEL OF EDUCATION	0.0317079***	3.212
HOUSEHOLD SIZE	-0.00622485	-1.061
EXPERIENCE IN FARMING	0.00126994	0.9551
LAND OWNERSHIP	0.00284695	0.1646
GRAZING METHOD	-0.00955922	-0.4375
ACCESS TO EXTENSION SERVICE	0.0296661	0.8594
CREDIT	-0.0186569	-0.5565
IRRIGATION	-0.0482917	-1.057
CATTLE BREEDS	-0.00242593	-0.2024
DAIRY -SOURCE OF INCOME	-0.0205831	-0.9971
SOCIETY MEMBERSHIP	0.0770605**	2.399

Table 34: Estimates of the Technical Efficiency of Smallholder Dairy Farmers

Significant at \*10%, \*\*5%, \*\*\*1%

Source: Calculations by Author

From the results, the variables analyzed, including the level of education, gender, access to extension services, experience in farming membership to society and land ownership, had positive coefficients. In the efficiency model, these positive coefficients signify a beneficial impact on the efficiency level. Conversely, a negative coefficient indicates a detrimental effect on the efficiency levels of the dairy farmers under study. It is important to note that as technical inefficiency in production increases, the farmer's technical efficiency decreases.

This study established that the level of education of the farmer was significant at a 1% level and had a positive impact on TE. The education level of dairy farmers plays a significant role in determining their ability to produce the most from the least available resources. Education determines the skills acquired by the farmers in relation to dairy farming. The results are in tandem with the findings of Kinyua (2019), which indicated that the highest access to education had positive significant effects on technical efficiency.

Age and gender were both insignificant. Age had a negative coefficient; therefore, TE score decreased with age. Gender had a positive coefficient, meaning being male increased one's technical efficiency score. These results agree with Nyagaka et al. (2009), who found no statistically significant relationship between age and gender on economic efficiency.

Farming experience was statistically insignificant with a positive coefficient. Age and farming experience were highly correlated. Experience in farming increased with age. An increase in age negatively affected the efficiency level of the farmers. These results agree with (Kinyua, 2019), who found experience in farming to be statistically insignificant, though with a negative coefficient, meaning that young farmers were more technically efficient, unlike otherwise. Older farmers had low levels of education. TE rises as more young farmers adopt improved varieties (methods) and have greater access to financial resources, ultimately raising production for the young farmers. However, this is different in this study since the level of education may not have caused age to be significant because of urban-rural migration and consequently, farming experience.

This research found that access to credit had a negative impact on TE, though statistically insignificant. This was because of the high cost of loans from commercial banks, where the majority of respondents borrowed. These results are in tandem with (Maina et al., 2020), who found acquired loans to have a negative impact on both the economic and technical efficiency of farmers in mukurue-ini and statistically insignificant.

Society membership had a positive significant impact due to the many benefits members earned. Membership in society was significant at 5%. This study found that society members accessed cheaper loans, unlike non-members. Extension services offered by societies were at a fair price, thus giving them an edge over non-members. These results agree with Maina et al. (2020), who found that society members accessed cheaper loans and were more technically efficient.

Access to extension service had a positive coefficient, though insignificant. Access to more extension services improved the knowledge of the farmers, which positively improved their TE. Extension services ensured the farmer's health cost was the lowest due to prior knowledge and preventive measures employed by extension officers. The results, however, do not concur with the findings of Kinyua (2019), which indicated that factors including entry to extension services had a negative insignificant impact on technical efficiency.

Dairy farming as the only source of income was found to be insignificant. These results agree with Etich (2013), who found income from other farm activities to be insignificant statistically. This was attributed to the inability of such farmers to acquire additional financing for farming, unlike employed farmers and businesspersons. Access to irrigation had a negative insignificant impact on TE. However, Kinyua (2019) found irrigation access to be significant. This was not the case in this study because of the vastness of land required to grow fodder, unlike bananas. The current cost of acquiring irrigation kits also contributed to the worsening of the TE scores for farmers who practised irrigation.

The grazing method negatively influenced TE. Farmers who practised zero grazing were inefficient. This was a result of the intensive nature of the zero-grazing method. Zero grazing heavily relied on concentrates. The results concur with the findings of Aweer et al. (2020), indicating that concentrate feeds were fed most frequently, consequently having a negative insignificant impact on TE. Household size had a negative insignificant impact on technical efficiency. These results corroborate with Kamau et al. (2016), who found household size to be detrimental to TE scores for coffee farmers. Bigger households allocated more land to other crops other than coffee for food production despite providing labor.

## 5. Summary, Conclusions and Recommendations

### 5.1. Introduction

The chapter brings together research findings, presenting them in a manner that is both logical and coherent. Consequently, the conclusion of this assessment is summarized within this section. Here, not only is there a concise summary of the results provided, but also conclusions and recommendations derived from the principal findings concerning technical efficiency levels and the factors influencing them are presented. Moreover, suggestions for further research are outlined, thereby laying the groundwork for future exploration in the field. This comprehensive approach ensures that the insights gained from the study are effectively communicated and serves as a valuable resource for both practitioners and researchers in the field of dairy cattle production efficiency.

### 5.2. Summary

Dairy cattle are mainly reared for the production of milk, though some other breeds are reared for beef and milk as well. Around 150 million people depend on milk and dairy products as vital food sources and sources of income in the global supply and value-adding chains. 81% of the world's milk comes from cattle, 15% from buffalo, 4% from goats, and the remainder comes from sheep and camels. In comparison to other major agricultural commodities, milk output is expected to expand at a quicker rate over the next ten years, reaching 1060 Mt by 2031. While yields in high-income countries are predicted to improve by only 0.5% per year, the highest growth is anticipated in Southeast Asia and North Africa, where the yield growth average is around 1% per year. It is anticipated that yield growth would enhance production more than herd growth in practically every part of the planet.

Dairy cattle farming in Africa has been characterized by low output per cow due to frequent drought and poor breeds. Kenya produces more than 60% of its milk from improved breeds, only 25% from indigenous cows, and the remaining from goats and camels. Kenya ranks 5th as countries with the most cattle herd in Africa and the 2nd highest milk-producing country after Ethiopia, which produces 3 billion liters a day. Dairy farming is a major economic activity in Kenya, incorporating 1.8 million smallholder farmers. Dairy output accounts for 14% of Kenya's agricultural GDP, in addition to creating employment. Nyandarua is the eighth biggest contributor to Kenya's GDP. In the dairy sector, Nyandarua is the second-highest producer nationwide after Kiambu County. Dairy farming employs 80% of Nyandarua households. The County has a total dairy herd of 349,300 cows, with the majority of farms ranging two to three dairy cows. The county produces roughly 296 million liters of milk. With an average price of Ksh. 32 per liter in 2019, the sector generated around Ksh. 13 billion to Nyandarua's domestic product. 60% of milk produced is traded in informal markets, with 40% sold in legal markets. Home consumption accounts for 20% of total milk production. The annual per capita milk intake is 114 liters, compared to the national average of 125 liters in Nyandarua and the World Health Organization's optimum amount is 209 liters.

The study aimed to assess the technical efficiency among smallholder farmers in Kinangop Sub County, Nyandarua County, and to identify the factors influencing this efficiency among dairy farmers. A total of 100 respondents participated in the study, and the variables examined included farming experience, land ownership, grazing techniques, access to extension services, financial services, irrigation, land acreage, employment status, number of hours of hired labor, access to credit facilities, and the type of dairy cattle reared. Stochastic Frontier Analysis (SFA) was utilized to estimate the stochastic production function and determine efficiency levels. The findings revealed that the average technical efficiency for smallholder farmers was 71.1 percent. This means that approximately all farmers are 28.9% technically inefficient. The regression coefficients indicated that only membership in society and level of education were positive and statistically significant. In addition, gender, experience in farming, access to extension services and land ownership were positive but statistically insignificant. However, other factors were identified that influenced the technical efficiency of the dairy farmers, including access to irrigation water, household size, age of the farmer, method of grazing and cattle breeds reared.

### 5.3. Conclusions

The conclusion of this study is that dairy farmers' production falls short of the frontier output. This study revealed that the average technical efficiency of dairy farming was above average. However, there is a prospect for improving production by raising the level of education of farmers and increasing membership in a cooperative society. The results of the technical efficiency analysis indicated that there existed technical inefficiency effects on dairy production, as depicted

by the efficiency model. Additionally, the ML estimates of the production model show that the amount of labor hired, the area under fodder production, and the amount of fodder and concentrates per animal per day had a positive influence on dairy farming, whilst expenditure on animal health had an insignificant negative influence on dairy farming.

The study concludes that the smallholder dairy cattle farmers in Kinangop sub-county are 28.9% technically inefficient. The study results indicated that the technical efficiency of the dairy farmers was above average, whereas all of the farmers were technically inefficient. The regression coefficients indicated that only society membership and level of education were positive and statistically significant. However, gender, experience in farming, and land ownership were positive but statistically insignificant.

#### 5.4. Recommendations

The study recommends that the smallholder dairy farmers in Kinangop sub county ought to strive to be technically efficient by joining the various societies that may be critical in providing credit, extension services among other services, and reducing expenditure on animal health by practicing animal husbandry. The study further recommends that the county government of Nyandarua come up with policies that would aid the citizens in accessing extension services, enable farmers to join cooperative societies and improve access to higher levels of education, providing incentives.

#### 5.5. Areas for Further Studies

The study's recommendations extend beyond the immediate context of Kinangop sub-county, Nyandarua, advocating for broader research endeavors that encompass all 47 counties in Kenya. Such comprehensive studies would offer a panoramic view of the diverse factors influencing dairy farming practices and outcomes across different regions, facilitating the development of more targeted and effective policy interventions. Additionally, exploring additional variables beyond those considered in this study would enrich our understanding of the intricate dynamics at play within the dairy farming sector. By addressing the limitations of the current study and incorporating a broader range of variables, future research can provide deeper insights into the drivers of technical efficiency and financial performance among smallholder dairy cattle farmers, thus informing more robust strategies for enhancing productivity and sustainability.

Furthermore, future research endeavors should adopt a multidisciplinary approach that integrates both qualitative and quantitative methodologies. This holistic approach would enable researchers to capture the complexities and nuances of smallholder dairy farming, considering not only economic factors but also socio-cultural, environmental, and institutional dimensions. Investigating the socio-economic impacts of dairy farming on local communities would shed light on the broader implications of dairy production beyond economic metrics, fostering a more holistic understanding of its role in livelihoods and rural development. Moreover, exploring sustainable farming practices and innovative technologies can contribute to enhancing the resilience and environmental sustainability of the dairy sector, ensuring its long-term viability in the face of evolving challenges such as climate change and resource scarcity.

## 6. Dedications

I dedicate this research to my beloved wife, Jayne, whose unwavering support and encouragement have been my anchor throughout this journey. To our precious baby Joy, your presence brings boundless joy and inspiration to my life, motivating me to strive for excellence in all endeavors. And to my dear parents, Mr. and Mrs. Rev Joshua, your love, guidance, and sacrifices have shaped me into the person I am today. This research is a testament to the profound impact of your love and support on my academic and personal growth.

## 7. Acknowledgments

I extend my heartfelt gratitude to the Almighty, acknowledging that my progress thus far is solely attributable to His benevolence. His grace has been the cornerstone of my achievements, and I offer Him profound praise and worship.

I am deeply thankful to my beloved spouse, Jayne, whose constant and resolute encouragement played a pivotal role in my success. Throughout nights filled with restlessness, she stood by my side unwaveringly. Even in moments when I was preoccupied, my patient and understanding daughter, Joy, demonstrated exceptional support. I commit to never letting you down.

Special acknowledgment goes to my mentor, Dr. Paul Mwangi Gachanja, whose valuable guidance, constructive critique, and insightful suggestions significantly influenced the development of this research. I am truly grateful for his generosity in sparing time amidst his busy schedule.

I commend my colleagues at the Land Settlement Fund for their collaborative efforts, enriching the quality of my investigation. I particularly want to express sincere thanks to Mr. Kiarie Ndung'u and Mrs. Ann Njoroge for their assistance and inspiration. I am thankful to Kenyatta University for providing me with the opportunity to pursue further studies.

My appreciation knows no bounds for my parents, Rev. Joshua Mwaura and Mrs. Miriam Nyambura Mwaura. Their unwavering dedication has been instrumental, and I now realize the immense privilege of having committed parents. Gratitude also extends to my Uncle Jesse Waithaka, younger brothers, and sister for their consistent financial support.

## 8. Abbreviations

AI — Artificial Insemination

CAIS — Central Artificial Insemination Station

ECDPM — European Centre for Development Policy Management

FAO — Food and Agriculture Organization of the United Nations

GDP — Gross Domestic product

ILRI — International Livestock Research Institute

JKUAT — Jomo Kenyatta University of Agriculture and Technology

KARI — Kenya Agricultural Research Institute

KALRO — Kenya Agricultural Livestock Research Organization

KIPPRA — Kenya Institute of Public Policy Research and Analysis

KDPA — Kenya Dairy Processor Association

KNBS — Kenya National Bureau of Statistics

MoALFC — Ministry of Agriculture, Livestock, Fisheries and Cooperatives-State Department of Livestock

MOLD — Ministry of Livestock Development

OECD — Organization for Economic Co-operation and Development

SFA — Stochastic frontier analysis

DEA — Data envelopment analysis

TE — Technical Efficiency

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## Appendices

### Appendix I: Introductory Letter and Authority

Dear Respondent,

I trust this message finds you well. My name is Eric Kimani Mwaura. I am a Master of Economics (Policy and Management) student at Kenyatta University (KU). As part of the requirements for my degree, I am conducting a study on technical efficiency among smallholder dairy cattle farmers in Kinangop Sub-county.

The primary aim of my research is to establish the level of technical efficiency and identify its determinants among Kinangop dairy farmers. The insights gathered will contribute to policy formulation by providing valuable information to the government. To achieve this, I am utilizing questionnaires as a data collection method. I kindly request your assistance in providing reliable information related to the technical efficiency of smallholder dairy farming in Kinangop. Your insights and experiences will significantly contribute to the success of this research.

Please be assured that any information you provide will be treated with the utmost confidentiality and used exclusively for the purpose of this research. Upon completion of the study, I would be happy to share the final document with you upon request.

Your cooperation in this matter is highly appreciated, and your valuable input will contribute to the success of this research endeavor. If you have any concerns or questions, please feel free to contact me.


Thank you for considering my request, and I look forward to your support.

Yours Sincerely,

K102/CTY/26157/2018

Eric Kimani Mwaura

Master of Economics (Policy and Management) Student Kenyatta University (KU)

  
KENYATTA UNIVERSITY  
GRADUATE SCHOOL

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Website: [www.ku.ac.ke](http://www.ku.ac.ke) NAIROBI, KENYA  
Tel. 810901 Ext. 4150

Internal Memo

FROM: Executive Dean, Graduate School DATE: 9<sup>th</sup> September, 2024

TO: Eric Kimani Mwaura REF: KI02/CTY/26157/2018  
C/o Economic Theory Dept.

SUBJECT: APPROVAL OF RESEARCH PROPOSAL


We acknowledge receipt of your revised Research Proposal as per our recommendations raised by the Graduate School Board of 14<sup>th</sup> August, 2024 Entitled "Technical Efficiency among Smallholders' Dairy Cattle Farmers in Nyandarua County, Kenya."

You may now proceed with your Data Collection, Subject to Clearance with Director General, National Commission for Science, Technology and Innovation.

As you embark on your data collection, please note that you will be required to submit to Graduate School completed Supervision Tracking and Progress Report Forms per semester. The Forms are available at the University's Website under Graduate School webpage downloads.

Also, please ensure that you publish article(s) from your project before submitting it to Graduate School for examination as per the Commission for University Education and Kenyatta University guidelines.


Thank you.

  
JOHN ODONGI  
FOR: EXECUTIVE DEAN, GRADUATE SCHOOL


C.c. Chairman, Department of Economic Theory

Supervisor:

- Dr. Paul Gachanja  
C/o Department of Economic Theory  
Kenyatta University

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Tel. 8710901 Ext. 57530

Our Ref: KI02/CTY/26157/2018 DATE: 9<sup>th</sup> September, 2024

Director General,  
National Commission for Science, Technology  
and Innovation  
P.O. Box 30623-00100  
\*NAIROBI

Dear Sir/Madam,


**RE: RESEARCH AUTHORIZATION FOR ERIC KIMANI MWAURA REG. NO. KI02/CTY/26157/2018**


I write to introduce Eric Kimani Mwaura who is a Postgraduate Student of this University. The student is registered for M.ECON degree programme in the Department of Economic Theory.

Eric intends to conduct research for a M.ECON Project Proposal entitled, "Technical Efficiency among Smallholders' Dairy Cattle Farmers in Nyandarua County, Kenya."

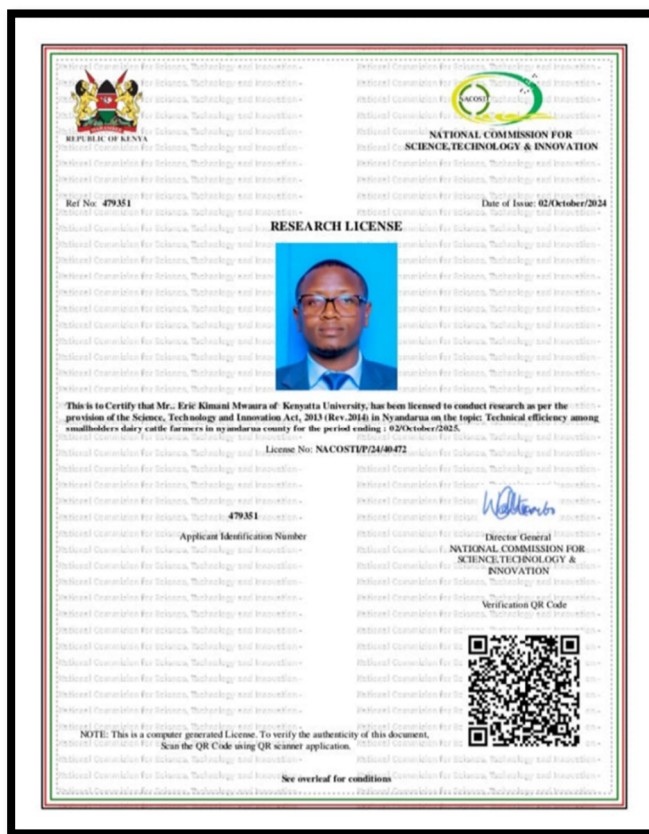
Any assistance given will be highly appreciated.

Yours faithfully,

  
PROF. ELUD NJAGI  
EXECUTIVE DEAN, GRADUATE SCHOOL

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Appendix II: Questionnaires

Part A: General information of respondents

1. Name of Region

-----

2. Farmer's Gender

-----

3. Years of Experience

- a. 0-5 [ ]
- b. 6-10 [ ]
- c. 11+ [ ]

Part B: Specific Questionnaires

Indicate the degree of disagreement or agreement by marking the table below in their respective columns. The ratings range from 1 to 5 as follows:

- 5: Strongly Agree
- 4: Agree
- 3: Undecided
- 2: Disagree
- 1: Strongly Disagree

Level of Technical Efficiency	5	4	3	2	1
We allocate a lot of time to feeding dairy cattle					
We pay attention to the requirement of fodder concentrates					
We ensure proper feeding of dairy by using stipulated fodder per cow per day					
We carry out proper calculation of monthly expenditures					
We ensure efficiency in dairy production to minimize wastage					

In your own opinion, how does technical efficiency improve dairy farmers' production among smallholder dairy cattle farmers?

.....

Determinants of Technical Efficiency

1. Farmer Demographics:

i. Gender:

- a. Male
- b. Female
- ii. Education Level:
  - a. No Formal Education
  - b. Primary
  - c. Secondary
  - d. Tertiary
  - e. University
- iii. Household Information:
  - a. Size of Household: \_\_\_\_\_
- iv. Primary Source of Income:
  - a.  Farming
  - b. Other (Specify) \_\_\_\_\_
- v. Farming Experience:
  - a. Years of Farming Experience: \_\_\_\_\_
- vi. Land Ownership:
  - a. Owned
  - b. Not Owned
- vii. Grazing Techniques:
  - a. Free-range
  - b. Stall-feeding
  - c. Other (Specify) \_\_\_\_\_
- viii. Access to Services:
  - a. Access to Extension Services:  Yes  No
  - b. Access to Financial Services:  Yes  No
  - c. Access to Irrigation:  Yes  No
- ix. Primary Source of Income: \_\_\_\_\_
- x. Main Source of Income:
  - a.  Dairy Farming
  - b.  Other (Specify) \_\_\_\_\_

These statements aim to gather information on various factors that may influence the technical efficiency of dairy farming production. Respondents are asked to provide details related to their demographics, farming experience, household characteristics, grazing techniques, and access to essential services.

2. Do you own or rent land? \*

Mark only one.

- a. Own
- b. Rent
- c. Both

3. How many acres of land do you own? \*

4. How many acres of land do you rent? \*

5. How many acres of land have you allocated to animal grazing? \*

6. How many acres of land have you allocated to fodder production? \*

7. Do you practise irrigation farming? \*

- a. Yes
- b. No

### **Animal Production**

In this section, data on dairy animal production shall be entered.

1. Is dairy farming the only source of income you have? \*

Mark only one.

- a. Yes
- b. No

2. If no, are you formally employed or in business? \*

Mark only one.

- a. Employed
- b. Business

- c. Crop Farming [ ]
- d. Other [ ]

3. Do you hire labor? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

4. If yes, how many hours of labor do you hire in a day? \*

If no, indicate 0.

- a. 0 – 5 hours [ ]
- b. 5 – 8 hours [ ]
- c. Over 8 hours [ ]

5. How much do you spend on hired labor per day? \*

If you don't hire, indicate 0.

6. Are you a member to a cooperative society? \*

- a. Yes [ ]
- b. No [ ]

7. Do you access extension services? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

8. If yes, who offered the services (vet or agricultural Officers)? \*

Mark only one.

- a. Government [ ]
- b. Private Hired Officers [ ]
- c. Farmer to Farmer [ ]
- d. Cooperative Society [ ]

9. Have you ever accessed credit for dairy farming purposes? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

10. If yes, who offered you the loan? \*

Mark only one.

- a. Cooperative Society [ ]
- b. Commercial Bank [ ]
- c. Other [ ]

11. If yes, were you able to service the loan from dairy proceeds only? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

12. Do you practice zero grazing as the main method of grazing? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

13. Do you use concentrates? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

14. At what price do you acquire a 90kg bag? \*

15. How many kgs of concentrate do you feed a cow per day on average? \*

16. Which cattle breeds do you rear? \*

Mark only one.

- a. Ayrshire [ ]
- b. Holstein/Freshian [ ]
- c. Jersey [ ]
- d. Guernsey [ ]
- e. Mixed [ ]

17. How many kgs of fodder do you feed per day per animal? \*

18. What is the amount of concentrates used per day per animal? \*

(KES)

19. Do you preserve silage? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

20. Do you preserve hay (dry fodder)? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

21. Do you buy fodder? \*

Mark only one oval.

- a. Yes [ ]
- b. No [ ]

22. If yes, how much did you spend on purchase of fodder? (KES) \*

23. Do you feed animals on farm residuals? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

24. Do you use AI? \*

Mark only one.

- a. Yes [ ]
- b. No [ ]

25. What was your expenditure on animal health last month? (KES) \*

26. How many liters of milk do you produce daily? \*

27. How many liters do you sell in a day? \*

28. At what price did you sell milk? (KES) \*

29. Would you be willing to participate in follow-up interviews or discussions related to this study? \*

Mark only one.

- a. Yes
- b. No

30. If yes, please provide your preferred contact method (Phone/Email): \*