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KORERIMA SMALL SCALE PRODUCTION IN ETHIOPIA: the case of GEWATA WOREDA, KAFFA ZONE

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Abtract

The study evaluates the determinants of korerima production and economic efficiency in Ethiopian agriculture using data from 234 smallholder producers. The determinants include age, sex, family size, education, livestock holding, credit utilization, experience, land ownership, total cultivated land, and organic fertilizer utilization. The study suggests that policymakers and development practitioners should address these factors to improve the well-being of korerima producers by using best practices and setting targets for improvement.

Keywords: economic efficiency, stochastic frontier model, censored Tobit model, korerima production, small scale production, Ethiopia, Gewata Woreda, Kaffa zone

JEL Classification: Q12, Q18, Q01, Q10, Q19

INTRODUCTION

1.1 Background of the study

The diverse agro ecology in Ethiopia supports growing a wide variety of crops in general and spice crops in particular. With 18 major agro-ecological zones and various agro-ecological subzones, Ethiopia has a suitable climate for growing more than 146 types of crops and has been producing a number of spices for some time.

Out of 109 spices, herbs, and aromatic plants shortlisted by the International Organizations for Standardization (ISO), the country produces as many as 50, out of which 23 are traded as export items. Ethiopia mainly produces Korerima (*Aframomum Korerima*), ginger, turmeric, black cumin, rosemary, cardamom, capsicum, fenugreek, coriander, timiz, black pepper, hot pepper, long red pepper, white cumin/bishops weed, rue, celery, coriander, fenugreek, sage, cinnamon, and thyme (Ethiopian Investment Commission, 2019).

According to Eyob *et al.* (2009), Korerima (*A. korerima*) is a native crop to Ethiopia and is well known for its widespread utilization in Ethiopian dishes. The growing and cultivation of the plant are mainly practiced in the forests of the south and south-western parts of Ethiopia, such as Gamo Gofa, Debub Omo, Kaffa, Iluababor, Sidama, and Wollega, among others, and it is also the major type of spice produced in Kaffa and Sheka Zone.

Korerima provides a variety of benefits to Ethiopian communities. Some of these include importance in food preparation; dried fruits are used in most Ethiopians' daily meals; medicinal values; and highly significant economic importance for local and export commodities in terms of economic benefit (Getasetegn and Tefera, 2016).

Korerima, a crop native to southwestern Ethiopia, is cultivated in natural forest canopy, smallholder farms, and natural habitats. It produces 500–800 kg per hectare without fertilizer and 100–120 kg with fertilizer (FAO, 2007). Smallholder and subsistence farmers produce 98% of Ethiopia's agricultural output. Seyoum et al. (2011). H (ADB, 2010). However, increasing productivity through modern technologies or improving efficiency is critical. Although major crop output has grown, further expansion is difficult due to technological constraints and farm land pressures (Endashaw, 2007; Mulatu & Gadisa, 2020).

According to the Gewata Woreda Agriculture and Natural Resource Office (GWANRO, 2024), the total area covered by Korerima was is 1890 hectares held by 3761 smallholder producers, with the average holding 0.5 hectares. The total annual production of the korerima in the 2019–20 production year was 385,000 kg. But the productivity of 189 kg in the 2019–20 production years is very low and far from the national productivity per hectare from propagation by seed (2180 kg per hectare) and by clumps (1520 kg per hectare) in the Tepi Agricultural Research Center (Edossa, 2014).

1.2 Statement of the problem

Ethiopian agriculture is characterized by low productivity due to technical, allocative and socio-economic factors. Most of the time, farmers produce different yields per hectare with the same resources due to management of efficient inputs, limited use of modern agricultural technologies and outdated agricultural techniques (FAO, 2012). One of the basic strategies of the Ethiopian government to improve agricultural productivity is the introduction of new technologies and the use of modern inputs (David et al., 2011). Meaton et al. (2015) and Fissiha et al. (2016) reported that farming practices and techniques rely heavily on indigenous knowledge passed down from generation to generation and that production levels are low, fertilizer supplies are inadequate, planting material is insufficient, access to credit is poor, competition with wildlife and price setting are inadequate. Size or demand are the main factors that negatively impact korerima production.

Low productivity is largely attributed to inefficiencies. The heavy reliance on outdated agricultural techniques and poor complementary services such as extension, credit and infrastructure resulted in the production, productivity and efficiency status of Korerima productivity being below the national average (GWANRO, 2024). The level of korerima production and productivity can be increased by either introducing modern technologies or by improving the efficiency of inputs with existing technologies. These two are not mutually exclusive because the introduction of modern technology might not lead to the expected shift in production frontiers when existing efficiency levels are low. This implies the need to integrate modern technologies with improved efficiency (Kinde, 2005).

Therefore, a proper analysis of farmers' economic efficiency requires the estimation of both technical and allocative efficiency. Measuring economic efficiency remains an important area of research, particularly in developing countries where resources are scarce and opportunities for development through the invention or adoption of better technologies are decreasing (Bedasa and Krishnamurthy, 1997). The modeling and evaluation of both technical and allocative efficiency of agricultural production is often motivated by the need for a more comprehensive representation of farmers' economic efficiency implied by economic production theory (Arega and Rashid, 2005).

Various studies have been conducted to assess the productivity of different sectors in Ethiopia. These studies have examined the technical efficiency of spice production (Lindara M. et al., 2004), coffee production (Temesgen and Getachew, 2018), major crops in Ethiopia (Solomon, 2014), black cumin (Abebe et al., 2020), teff production (Yimer, 2017), as well as the economic efficiency of coffee production (Mustefa et al., 2017), maize production (Kifle et al., 2017), and tomato production (Kifle et al., 2020). However, none of these researchers have specifically focused on the economic efficiency of Korerima production.

The majority of these studies primarily focused on technical efficiency, neglecting the consideration of economic efficiency, which encompasses allocative efficiency as well. In terms of methodology, three variables were taken into account: the experience of smallholder producers in Korerima production as an input variable for the stochastic production Frontier model, technology, and organic fertilizer for the identification of determinants of economic efficiency. Previous studies did not include these variables, and the researcher attempted to incorporate them as potential variables for this study. The purpose of this study was to address these gaps. To the best of the researcher's knowledge, there has not been a comprehensive analysis of input efficiency in Korerima production in the study area.

Consequently, this investigation plays a significant role in shaping relevant policies and acquiring research insights to mitigate factors affecting Korerima production and economic inefficiency. The primary goals involve examining the determinants of Korerima production and the technical and allocative efficiencies of small-scale producers in the study area through the exploration of specific research questions. The general objective of this study was to evaluate the determinants of korerima production and economic efficiency in Gewata WoredaKaffa zone.

- To identify the determinants of korerima production and economic efficiencies in Korerima production of smallholder producers in Gewata woreda Kaffa zone
- To determine the level of technical efficiency of Korerima production of smallholder farmers in the study area
- To determine the level of allocative efficiency of Korerima production of smallholder farmersin the study area

REVIEW OF RELATED LITERATURE

2.1 Theoretical literature review

Ethiopian agriculture is defined by low productivity attributed to the use of outdated technology and agronomic practices. In comparison to other countries globally and within the country itself, the sector's production, productivity, and efficiency levels are notably low across most African nations, including Ethiopia. Therefore, in order to accurately assess the economic efficiency of farmers, it is essential to calculate both technical and allocative efficiencies as emphasized by Bedasa and Krishnamurthy in 1997.

2.1.1 Concepts of Technical, Allocative and Economic Efficiencies

According to Coelli et al. (2005), allocative efficiency in input refers to the selection of input combinations, such as labor and capital, that can produce a specified amount of output at the lowest possible cost based on prevailing input prices. The combination of allocative and technical efficiency provides an overall measure of economic efficiency. Technical efficiency is the firm's ability to maximize output using a specific set of inputs (input-oriented measures) or to achieve a certain level of output using the least number of inputs (output-oriented measures). Allocative efficiency, on the other hand, is the firm's ability to utilize inputs in the optimal ratio considering their prices and the technology of production. Economic efficiency (EE) is calculated as the multiplication of technical efficiency (TE) and allocative efficiency (AE), representing the firm's capability to produce a predetermined quantity of output at the lowest cost given the level of technology. This concept has been defined by Farrell (1957) and further elaborated by Khan and Saeed (2011). Efficiency, productivity, technology growth, and economic growth are commonly used but not interchangeable in economics. Efficiency is measured by the production function, productivity by output to input ratio, and efficiency by output value to input cost ratio (Khan and Saeed, 2011).

2.1.2 Concepts of Productivity and Efficiency

In the field of economics, terms such as efficiency, productivity, technology growth, and economic growth are frequently utilized and, at times, used interchangeably. Despite similarities and connections among them, they are not synonymous. Efficiency is conceptualized and measured based on the specification of a production function, which showcases the maximum output achievable from a specific level of inputs. Productivity, on the other hand, is described as the proportion of output generated by the resources utilized. However, efficiency is determined as the proportion of the value of output created to the expense of inputs employed (Khan and Saeed, 2011).

2.1.3 Elasticity's and Returns to scale of production function

The estimates of parameters in a Cobb-Douglas production function represent the elasticity's, and their sum determines the return to scale. These estimates highlight the significance of factor inputs in production. An increasing return to scale is indicated when the sum of all elasticity's is greater than one; a decreasing return to scale when it is less than one; and a constant return to scale when it equals one. The cost function, being dependent on input prices, has coefficients that show the cost elasticity of production. The scale effect (SE) is defined as the inverse of the sum of all cost elasticity with respect to all outputs in the regression. The estimation of cost function parameters, particularly the coefficients of output in the Cobb-Douglas model, suggests the presence of scale effects in production. Positive economies of scale (ESp) exist when SE is above 1, indicating a reduction in the cost of production while maintaining input prices constant. Conversely, diseconomies of scale (DS) occur when SE is below 1. The concepts of return-to-scale and scale effects are equivalent only when the product is homothetic, a condition inherent in Cobb-Douglas function structures.

As mentioned by Baloyi (2012), if costs increase proportionately with output, there are no economies of scale, signifying a constant return to scale. If costs increase by a larger margin than output, there are diseconomies of scale, representing a decreasing return-to-scale. On the other hand, if costs increase at a lower rate than output, positive economies of scale are observed, also known as economies of scale, implying an increasing return-to-scale.

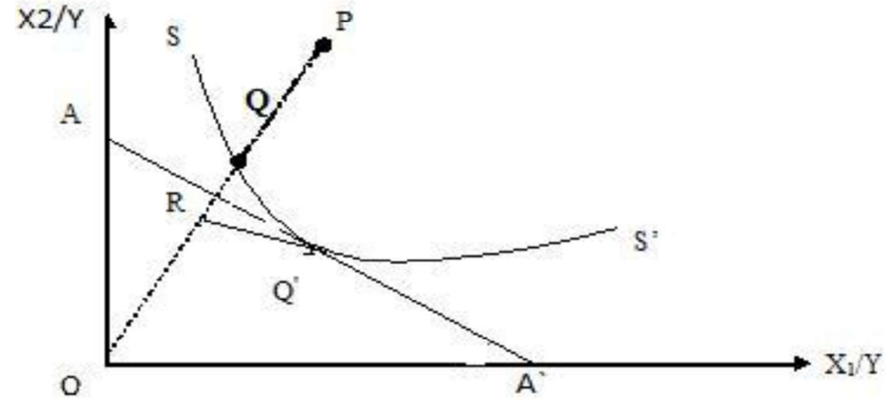
2.1.4 Approaches of Measuring Efficiency

Coelli and Battese (2005) suggest that efficiency can be calculated using two different approaches: input-oriented and output-oriented. The output-oriented method focuses on increasing output from a set level of inputs, while the input-oriented approach looks at reducing input quantities while keeping output constant. These two measures of efficiency will coincide under constant returns to scale but may differ in other technological scenarios.

Input oriented measure

Farrell (1957) proposed the notion of quantifying efficiency through a graphical representation. In this representation, SS' denotes input combinations that are technically efficient and AA' represents a cost curve. In order to optimize profits, companies should produce at point Q', which corresponds to the minimum cost combination, known as the point of economic efficiency.

Figure - 2.1: Input oriented measures of technical efficiency.



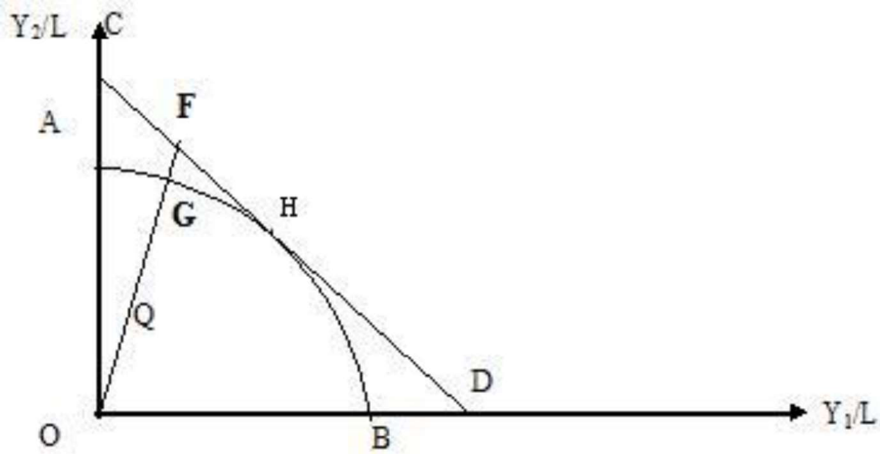
Source: Adapted from Solomon, 2014

Figure 1 illustrates that achieving a non-technically efficient production at point P is unattainable, as fewer inputs are required at point Q on isoquant SS'. Nevertheless, all farmers operating along the is quant are considered to be fully technically efficient, as their level of technical efficiency is directly proportional to the maximum inputs that can be theoretically obtained.

Output oriented measure

Farrell (1957) posited that output-oriented measures can be exemplified when production involves two outputs (Y1 and Y2) and a single input (L). Efficiency from an output-oriented perspective is assessed while maintaining inputs at a consistent level. When the input quantity remains constant at a specific level, the technology can be depicted by a two-dimensional production possibility curve.

Figure – 2.2: Output oriented measures for technical efficiency.



Source: Adapted from Solomon, 2014

The production possibility curve shown as curve AB in Figure 2 illustrates the optimal combinations of output production for Y1/L and Y2/L. If the same quantity of input (L) is used, production at point Q is considered to be inefficient. Technical efficiency (TE) for a firm situated at point Q can be calculated as the ratio OQ/OG. In contrast, all farmers operating on the production possibility curve demonstrate 100 percent technical efficiency.

2.1.5 Efficiency Models

Farrell's empirical study in 1957 resulted in the creation of different techniques for estimating frontiers and calculating efficiency scores. These techniques predominantly employ frontier methodologies, concentrating on firms with concentrated output or those that are well-structured. Productive inefficiency can be accessed through two primary methodologies: econometric and non-parametric approaches.

Efficiency techniques are predicated on the assumption that the production function of a thoroughly organized firm is unequivocally understood, although this is not universally applicable. In this research, a parametric methodology is employed to juxtapose deterministic and stochastic frontier models. The deterministic model posits that deviation from the frontier can be attributed to inefficiency, whereas the stochastic framework accommodates for statistical variations (Coelli et al., 1998).

Non- stochastic/deterministic

Coelli (1995) states that the model under consideration does not take into account the possible effects of measurement inaccuracies and other disruptions on the form and position of the estimated frontier. In this model, any deviation from the frontier is viewed as inefficiency. Techniques such as linear programming or econometric methods like corrected ordinary least squares (COLS) can be used to compute the non-random or deterministic production frontier. The application of this model, especially in circumstances where there is a considerable probability of measurement ambiguity, is expected to result in inefficiency estimates that are overstated when compared to models that magnify the error term by a factor of two. Aigner and Chu (1968) stated a non-stochastic or deterministic frontier model of Cobb Douglas production function for a sample of N firms as:

$$\text{Ln}\,(Y_i) = F\,(Xi; \beta i) - Ui \quad , i = 1,2,...N \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: Yi is the output of the i^{th} firm;

Xi is the vector of input quantities used by the i^{th} firm;

β is a vector of unknown parameters to be estimated;

F (***Xi*; *βi***) denotes an appropriate function (Cobb Douglas); and

Ui is a non-negative variable representing the inefficiency in production.

Stochastic frontier production function

In order to overcome the limitations of the deterministic solution proposed by Aigner and Chu (1968), Timmer (1971) suggested a method that involved expanding the number of firms closest to the frontier of value and reevaluating the frontier using the collected sample. However, the probabilistic nature of selecting certain observations to exclude, as noted by Coelli (1995), has hindered the widespread adoption of Timmer's probabilistic approach. When addressing outliers, such as high-performing business units or farmers, they may also be considered outliers to prevent inflated levels of inefficiency. The SPF function was initially introduced by Kumbhakar and Lovell (2000) in two separate articles that were published nearly simultaneously by two distinct research groups - one in Europe and the other in the United States, one in the field of science and the other in nature. Meeusen and Van den. The article by Broeck (1977) was released in June, theorentische and.

2.1.6 Empirical Literature from Africa

A study carried out by Ali and his team in 2012 aimed to determine the energy efficiencies of wheat and faba bean cultivation in Northern Sudan using the Single-Parameter Production Function (SFPF) and Constant-Factor (CF) methods. The researchers selected 120 farmers from Dongola and Ed-abba localities in the winter season of 2004/05 using a randomized, multi-stage stratified-sampling technique. Using the SFPF and CF methods, the researchers estimated the energy efficiency for these farmers. For wheat cultivation, the average technical efficiency was 0.75 in Dongola and 0.66 in Ed-abba, while for faba bean cultivation, it was 0.65 in Dongola and 0.71 in Ed-abba. The overall allocative efficiency for both areas was 0.72 for wheat and 0.86 for faba beans. The mean energy efficiency of wheat in Dongola was calculated to be 0.41, compared to 0.45 in Ed-abba. On the other hand, the mean energy efficiency values for faba beans were approximately 0.57 in Dongola and 0.62 in Ed-abba. This indicates that cultivating faba beans has higher energy efficiency compared to growing wheat.

Essilfie and colleagues (2011) conducted a study to assess the levels of technical efficiency in small-scale maize farming in the Mfantseman Municipality of Ghana using the stochastic frontier approach. The research also aimed to identify certain socio-economic factors and management strategies that influence technical efficiency in maize cultivation. They further calculated the marginal physical products, average physical products, relative efficiency of resource utilization, and returns to scale of input usage. The findings showed that the average technical efficiency of small-scale maize production in the area under study was 58%, with a range from 17% to 99%. The study also determined a return to scale of 1.49, indicating increasing returns to scale in maize farming within the study region.

2.1.7 Empirical Literatures from Ethiopia

Kifle et al. (2020) and Tsegaye et al. (2019) conducted studies on the technical, allocative, and economic efficiencies of tomato growers in the Oromiya region and Guraferda, Ethiopia. They used Cobb-Douglas stochastic frontier and Tobit models to estimate efficiency levels. The study found that labor, land fertilizer, and seed significantly impacted tomato production, with a return to scale of 1.96. Factors such as sex, frequency of extension visits, and training also impacted efficiency. The study suggests that increasing rice production without extra inputs and reducing input costs could increase efficiency by 21.5%.

Mustefa and his colleagues (2017), along with Kifle and his team (2017), investigated the effectiveness of coffee and maize production in Ethiopia from an economic standpoint. They employed the Cobb-Douglas stochastic frontier production model and its dual cost functions to gauge technical, allocation, and economic efficiency. The research indicated that a boost in labor inputs could spike production by 28.29% and slash input costs by 85.87%. Nonetheless, a notable level of inefficiency was noted among maize farmers. Various factors influencing these efficiencies were identified, including age, engagement in off-farm or non-farm activities, gender, land ownership, and attitudes towards agricultural policy.

Solomon (2012) conducted research on wheat seed production efficiency (TE), average efficiency (AE), and economic efficiency (EE) in Womberma Woreda, West Gojam Zone. The findings of the study revealed notable inefficiency, with the average TE, AE, and EE of households standing at 79.9%, 47.7%, and 37.3%, respectively. Various factors influencing efficiency were identified, such as interest in the wheat seed industry, total income, level of education, ownership of livestock, and land ownership. Nejuma (2012) studied the efficiency of potato-producing farmers in West Arsi Zone, focusing on factors affecting their efficiency (EE). The study found that age, access to credit, and training positively impact EE, while socioeconomic and institutional factors like age and credit also played a role.

2.2 Summary of Related Literature and Research Gaps

This study focuses on efficiency in Ethiopian korerima production using the stochastic frontier approach and the Censored Tobit model. It uses the SPF method to estimate efficiency and identify determinants in Gewata woreda. Previous studies mainly focused on technical efficiency, neglecting economic efficiency, allocative efficiency, and three variables: experience, technology adoption, and organic fertilizer utilization.

Table - 2.1: Summary of Research gaps.

Authors	Focus of the research	Findings	Research gaps
Lindara M. *et al.* (2004)	Technical efficiency in spice production	The average technical efficiency of spice-based agro forestry systems was 84.32%. According to the inefficiency model, farm visits by extension officers, participation in farmer training, less sloping lands, more experience, and greater agricultural system variety all resulted in significant increases in efficiency.	The study only focused on technical efficiency and ignored the element of allocative efficiency. This study fills the gap by including this component.
Solomon , 2014,	Technical efficiency of Major crops production in Ethiopia	According to the findings of this study, land and seed were significant determinants of maize production in Ethiopia. In general, all significant input variables had a positive effect on output, which was expected. Furthermore, the model output showed that the average level of TE for major crops, teff, wheat, and maize production, was 63.56, 67.26, 84.16, and 91.41 percent, respectively.	The study only focused on the technical efficiency of major crops. This study fills the gap by evaluating the economic efficiency of korerima production.
Abebe,Tadie and Bethlehem (2020)	Estimation of technical efficiency of black cumin	The actual yield, potential yield, and yield gap averaged 3.131, 5.832, and 2.701 quintals, respectively. Furthermore, the results of the stochastic frontier model, along with the inefficiency parameters, revealed that the market price of black cumin and access to extension services were significant variables that positively influenced black cumin producers' productivity levels. .	The study included farmer efficacy variation variables but excluded the most promising ones, such as technology and organic fertilizer. This study closes the methodology gap by including these variables.

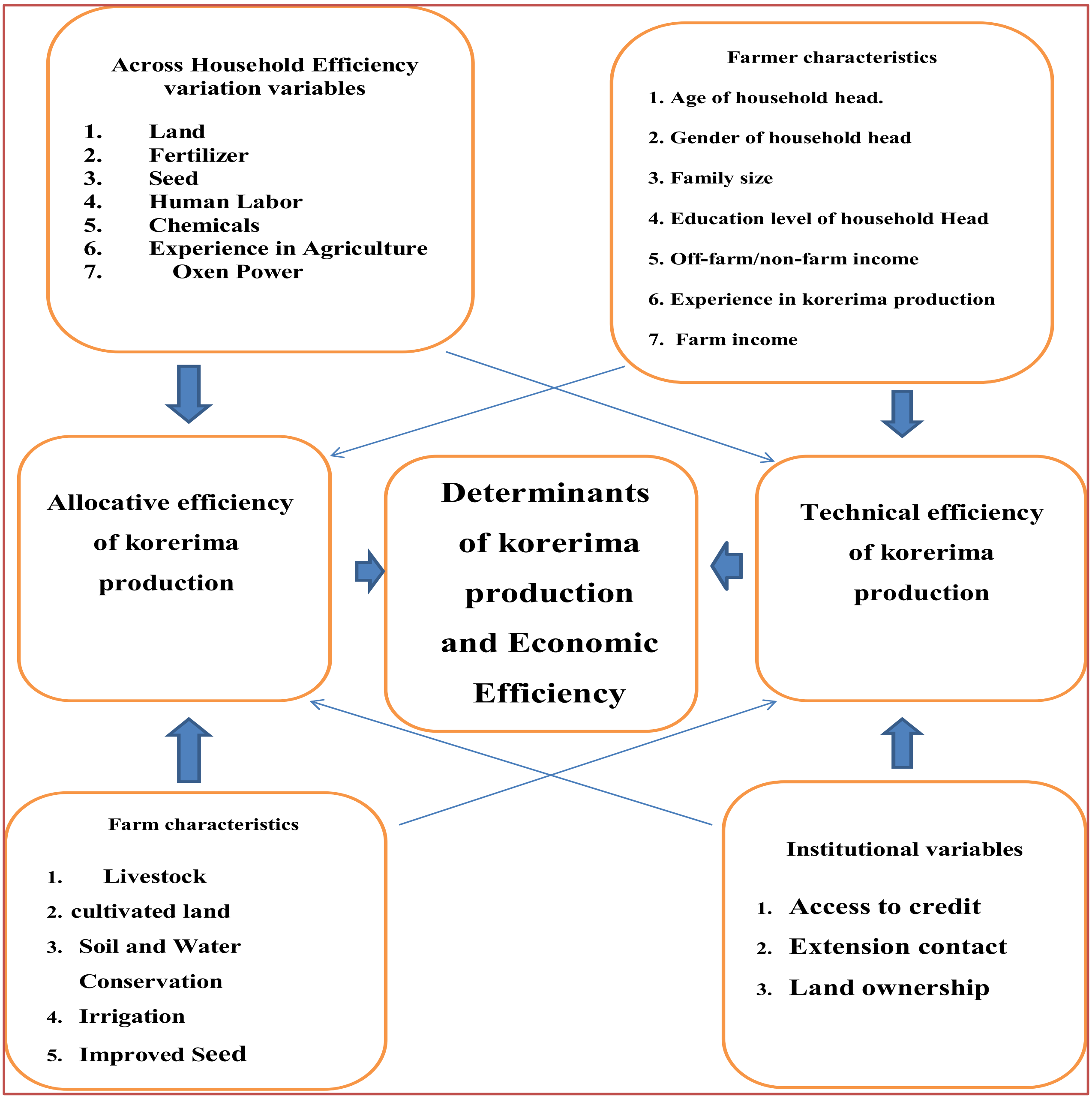
Source: Researcher's design, 2024

2.3 Conceptual frame work of the study

The conceptual framework presented below illustrates the factors influencing Korerima production and economic efficiency through three main categories: smallholder farmer characteristics, farm characteristics, and institutional determinants. Characteristics of smallholder farmers, such as their level of education, gender, age, family size, experience, farm income, and off-farm income, play a vital role in determining resource utilization efficiency in korerima production and influencing their managerial capacity. According to Kwabena et al. (2014), farmers with higher levels of education are more inclined to adopt new technologies. Education level and farming experience are crucial factors in determining efficiency, which can be integrated into agricultural policies to encourage adoption of new technologies by farmers with higher education levels, more land, and better access to farm tools. Additionally, family size, farm income, and non-farm income are positively associated with efficiency (Ajibefun, 2002). I'm sorry, but it seems like you forgot to provide the text that needs to be paraphrased. Please provide the text so I can help you with paraphrasing it.

"Characteristics of farms such as the size of cultivated land, soil and water conservation methods, and livestock holdings, as well as irrigation practices and the use of improved seeds, are important factors in farming systems that often experience variations. (Ruth, 2011). It is believed that factors related to the characteristics of smallholder farmers and their farms have an impact on the production of korerima and the technical and allocative efficiency of korerima production for smallholder farmers. Therefore, these factors are included in the analysis." Factors within institutions, such as credit availability, land ownership, and extension contact, can greatly impact the efficiency of resource use in Korerima production. According to Tchale (2009), extension contact and credit accessibility serve as crucial policy and institutional factors that have a positive influence on efficiency. The availability of credit provides both motivation and the means to adopt improved crop technologies by enhancing the liquidity of smallholder farmers and making the necessary inputs more affordable. Therefore, institutional structures that focus on facilitating access to credit, improving infrastructure (such as irrigation), and ensuring access to education are key variables that can significantly affect resource use efficiency, allocative efficiency, and productivity.

Table - 2.3: Conceptual frame work of the study.



Source: Adapted from Tarekegn (2017)

Method and material

3.1 Research Design

A cross-sectional study design with quantitative and qualitative approach of research was employed on data from Smallholder korerima producers in Gewata woreda Kaffa zone in 2019/20 production Year.

3.2 Data type and sources

In this study, primary data was collected from various sources. The main primary data collection methods were semi-structured questionnaires and key informant's interviews. The semi- structured questionnaire schedule was administered by five skilled enumerators selected from five kebele and in the same fashion key informants interview was held by these enumerators. In addition to this filed observation were held by the researcher to triangulate the information obtained from respondents by the enumerators. Moreover, to enrichthe investigation secondary data was obtained from various sources. The key informant's interview and questionnaire schedule which consists of semi-structured questions were prepared in English and translated into Amharic language to collect information on farm characteristics, farmer characteristics and institutional characteristics of korerima producer households. Furthermore, the questionnaire was pre-tested using pilot survey, and the necessary amendment was made before the actual survey. Finally, semi-structured questionnaire was administered by enumerators for 234 korerima producers.

3.3 Target population and sampling

3.3.1 Target population

The study has 3,761 smallholder korerima producers as total population and the target population due to their best practice in producing korerima was 1250 smallholder producers from 5 rural kebele in Gewata Woreda, especially 352 smallholder farmers in Kasha, 203 in Gawamecha, 245 in Bera, 250 in Yesha and 200 in Tura Kebele(GWANRO, 2020).

3.3.2 Sampling Design

The researcher employed a mix of non-probability and probability sampling methods, specifically purposive sampling, two-stage sampling, and simple random sampling, to choose the final sample units. Through two-stage probability sampling techniques, 234 Korerima producers were chosen as the sample. Initially, five main korerima producer kebeles (Kasha, Gawamecha, Bera, Yesha, and Tura) were selected in the first stage using purposive sampling based on their expertise in korerima production. In the second stage, 234 korerima producers were randomly selected (66 from Kasha, 38 from Gawamecha, 46 from Bera, 47 from Yesha, and 37 from Tura), with proportions maintained according to the total number of smallholder farmers in each kebele.

3.3.3 Sample size Determination

There are several ways to calculate the sample size of respondents from a finite population. The sample size for this study was determined using Kothari's (2004) formula, with a 5% level of significance.

$$\mathbf{n} = \frac{z^2pqN}{e^2(N-1)+z^2pq}$$

e = = the level of acceptable error of 5%, which shows the value will be assigned as 0.05, and p and q are estimates of the proportion of the population to be sampled, which is p = 0.75 and q = 1 - p and z is the value of the standard variance at a given level of significance and to be worked out from the table showing the area under the normal curve, which is shown as Z = 1.96.

Based on the above formula the sample size of this study is calculated as follows:

$$\mathbf{n} = \frac{\mathbf{1.96^2(0.75)(0.25)(1250)}}{\mathbf{0.05^2(1250-1)+1.96^2(0.75)(0.25)}}$$

$$\mathbf{n} = \frac{\mathbf{900.375}}{\mathbf{3.8428}}$$

$$\mathbf{n = 234}$$

The data analysis process involved both descriptive and empirical analysis. The variables included in the research have been analyzed using descriptive statistics such as mean, standard deviation, percentage, and range. The stochastic production frontier model was used to estimate the elasticity of the production function and the level of efficiency using a Cobb-Douglas production function and the maximum likelihood estimation model, while the censored Tobit model was used to identify the determinants of economic efficiency.

4.1.1.1 Model specification

Coelli and Battese (1995) suggest that the stochastic production frontier model is most suitable due to its unique features, which include a disturbance term composed of both symmetric and one-sided components. Therefore, efficiency measures derived from stochastic frontiers are expected to accurately reflect a farmer's true ability given their available resources.

The basic stochastic frontier model was originally proposed by Meeusen and Van Den Broeck (1977) for efficiency measurement. The efficient frontier can be viewed as either the maximum output achievable with a given set of inputs (output orientation) or the minimum input required to produce a specific output level (input orientation) according to Tingley et al. (2005). A single-stage approach, as suggested by Reifschneider and Stevenson (1991), incorporates explanatory variables directly into the inefficiency error component. In this method, the variance of the efficiency error component is assumed to be influenced by firm-specific factors.

Moreover, the commonly used production functional model, such as the Cobb-Douglas function, was employed to determine the physical relationship between production inputs and output. Compared to the transcendental logarithmic (translog) function, the Cobb-Douglas production function is considered simpler, less prone to issues of multicollinearity among explanatory variables, and provides coefficients that are of reasonable magnitude and sign as stated by O'Neill et al. (1999). Additionally, the Cobb-Douglas model has been widely utilized in numerous empirical studies, particularly those focusing on developing countries, for analyzing farm efficiency according to Bravo-Ureta and Pinheiro (1997).

The general form of Cobb–Douglas production function:

$Y = F(Xi\beta) \exp(\boldsymbol{vi} - \boldsymbol{ui})$, where i = 1, 2, 3 ……….234……… (2)

For the investigation of the technical, allocative and economic efficiencies of Korerima production, separate SPFF of the following form was estimated by using Maximum likelihood Estimation Model:

$$\ln(\text{output}) = \beta0 + \beta1(\text{lnland}) + \beta2(\text{lnDap}) + \beta3(\text{lnUrea}) + \beta4(\text{lnseed}) + \beta5(\text{lnlabor}) + \beta6(\text{lnchems}) + \beta7(\text{lnexperik}) + \beta8(\text{lnoxenp}) + vi - ui \quad \ldots\ldots (3)$$

Where: Output**:** denoted total physical quantity of korerima output of the i^{th} farm (Kg); *land:* denotes the total land allotted to korerima production in hectare; Urea and DAP, most commonly used fertilizers in Ethiopia, are an important inputs for production applied on plot of land Kg per hectare is used in this study. *Seed* denotes the total quantity of seed used in kg per hectare, *Human Labor* (labor): This input captures family, shared and hired labor used for different agronomic practices of korerima production. But the differences in sex and age among labor will be expected. Hence to make a homogeneous group of labor to be added, the individual labor will be changed in to Man Days (MDs) using the standard (Storck, 1991). Therefore, the human labor input is expressed in terms of total MDs employed to perform land preparation, planting, input application, cultivation and harvesting. *Chemicals* (chems): denotes quantity of chemicals (pesticides) used for korerima production liters per hectare, Experience in korerima production (experik): This refers to the experience of farmer in years in the production of output,and Oxen Power (*Oxenp) :* denotes the total own oxen, exchange oxen and hired oxen was used in Oxen-days; and;βi denotes vector of unknown parameters to be estimated; vi denotes a disturbance term which accounts for factors outside the control of the farmer and ui denotes non-negative random variable which captures the economic inefficiency in production.

The farm-specific technical efficiency (TE) is also defined in terms of observed output (Yi) to the corresponding frontier output (Yi*) using the available technology to be estimated.

$$TEi = \frac{Yi}{Yi*} = \frac{Actual\,Yield}{Potential\,Yield} \quad \text{(4)}$$

Technical efficiency takes value on interval (0, 1), where 1 indicates a fully efficient farm.

The farm-specific minimum cost (economic efficiency) of production defined as the ratio of minimum total production cost (Ci*) to actual observed total production cost (Ci).

$$\text{EEi} = \frac{Ci*}{Ci} = \frac{\text{minimum total production cost}}{\text{actual observed total production cost}} \quad \text{(5)}$$

Following Farrell (1975), the AE index will be derived from equation (5) and (4) as follows:

$$\text{AEi} = \frac{EEi}{TEi} \quad \text{(6)}$$

In this study TE, AE and EE estimates from SPFF were regressed using a censored Tobit model on farmer specific explanatory variables that explaining variation in efficiency across farmers. As the distribution of the estimated efficiencies is censored from above at the value 1, Tobit model (Tobin, 1958) is specified as:

$$\text{Ei} = \sum_{j=0}^{n} \text{Bj}\, xj + v \quad \text{(7)}$$

Ei=1 if Ei*> 1 and Ei = Ei* if Ei*< 1

Where, Ei is an efficiency score representing TE, AE and EE; V~N (0, δ^2);

βj are vector parameters to be estimated;

Xj represent various farmer-specific variables and

Ei* is latent variable with E [Ei*/Xi] equals Xiβ.

Table - 3.1: Summary of Variable Descriptions of stochastic production frontier model.

S/N	Variable	Code	Nature of the variable	Description	Expected Sign
1	Land	Land	Continuous	Plot of land allotted for korerima production in hectare	-
2	Dap	Dap	Continuous	DAP applied on plot of land in Kg per hectare	+
3	Urea	Urea	Continuous	Urea applied on plot of land in Kg per hectare	+
4	Seed	Seed	Continuous	total amount of seed in clumps (vegetative method) in Kg per hectare	+
5	Human Labor	Labor	Continuous	Family shared and hired labor used for different agronomic practices of korerima production in Man Days (MDs).	+
6	Chemicals	Chems	Continuous	Quantity of chemicals (pesticides) used for korerima production liter per hectare	-
7	Experience in korerima production	Experik	Continuous	Experience of farmer in years in the production of output.	+
8	Oxen Power	Oxenp	Continuous	Total own oxen, exchange oxen and hired oxen used in Oxen-days	+

4.1.1.2 Estimation of the Determinants of Economic efficiency

Determinants of efficiency: These farm characteristics, farmer characteristics, demographic and institutional variables chosen in reference to former studies and logical reasoning are used in identifying the determinants of efficiency. Most literatures used to analyze determinants of efficiency rather than inefficiency. However, the .only difference between them is only on the interpretation. These determinants are age of the household head, Sex of household head, Family size, educational level of the household head, Soil and Water Conservation, Extension contact, Irrigation, Off-farm income, farm income, livestock size of the household, total land cultivated, Organic fertilizer and adopted improved seed.

The most common procedure is to examine determinants of efficiency, in that the inefficiency or efficiency index was taken as a dependent variable and was then regressed against a number of other explanatory variables that were expected to affect efficiency levels (Bravo-Ureta and Rieger, 1991; Sharma *et al.*, 1999).

Technical, allocative and economic efficiency estimates derived from Stochastic Production Frontier (SPF) was regressed, using a censored Tobit model on the following farm-specific explanatory variables that explains variations in production efficiencies across farms. The rationale behind using the Tobit model is that there were a number of farms for which efficiency was one and the bounded nature of efficiency between zero and one (Jackson and Fethi, 2000).

The determinants of technical, allocative and economic efficiencies are explained by:

$$
\begin{aligned}
Ui = \alpha o &+ \alpha 1\ (Age) + \alpha 2\ (Age)^2 + \alpha 3\ (Sex) + \alpha 4\ (Family) + \alpha 5\ (Educ) \\
&+ \alpha 6\ (SWC) + \alpha 7\ (Extfreq) + \alpha 8\ (Irrig) + \alpha 9\ (Offincom) \\
&+ \alpha 10\ (TLU) + \alpha 11\ (Impseed) + \alpha 12\ (Acscdt) \\
&+ \alpha 13\ (Experik) + \alpha 14\ (Landowner) + \alpha 15\ (Totfincom) \\
&+ \alpha 16\ (Totcultlnd) + \alpha 17\ (Orgfert) + wi \ \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)
\end{aligned}
$$

Where: for farm i, α is a vector of unknown parameters. Thus, the parameters of the frontier production function are simultaneously estimated with those of an efficiency model, in which the efficiency effects are specified as a function of other variables. U represents efficiency effects measured in efficiency scored from SPF and it is continues variable; αo represents the intercept.

Post estimation Tests

Before conducting analysis and drawing conclusions, it is crucial to assess the suitability of the model and the explanatory variables included in the model. Given the nature of the cross-sectional data, various tests were carried out to check for multicollinearity, hetroscedasticity, normality, and endogeneity issues. Multicollinearity, which occurs when there is a high correlation among explanatory variables in a multiple regression, was examined using variance inflation factors (VIF). The VIF mean value was found to be 3.39, indicating no evidence of multicollinearity, with VIF values for all variables ranging from 1.07 to 6.71. Economic efficiency estimation requires that efficiency effects are stochastic with a specific distributional specification. Assumptions were made regarding the distribution of efficiency components to ensure consistent estimators. Skewness and kurtosis tests were employed to confirm the assumed distribution. Heteroscedasticity, a common issue in cross-sectional data, was addressed by considering sources of heteroscedasticity using specific options. Neglecting heteroscedasticity may result in biased efficiency estimates, as shown by previous research.

Endogeneity problems in stochastic frontier models can lead to inconsistent parameter estimates. It is essential to properly address endogeneity to ensure accurate results. In this study, independent variables were not fully explained within the stochastic frontier models. The Ramsey RESET test was used to check for omitted variable bias.

RESULTS AND DISCUSSIONS

4.1 Background Information of the study participants

Table - 4.1: Background Information of Sample Households.

Variable Description	Minimum	Maximum	Mean	Std. Deviation
Age of Household Head	18	75	42.50	12.60
Family size	2	16	5.96	2.19
Educational status of Household Head	0	11	4.0	3.21

Source: Field Survey, 2024

Table 4.1 shows that the average household size in the study area is higher than the national average of 5.2 people per household. The average age of the sample households is 42.50 years, with an average of 4 years of schooling. Education is crucial for improving decision-making skills and adopting new technologies, and combined with increased experience, it can guide households in better managing their farm activities.

Table - 4.2: Sex Category of Sample Households.

Variable Description	**Category**	**Frequency**	**Percentage**	**Cumulative percentage**
Sex	Male	183	78.2	78.2
	Female	51	21.8	100
	Total	234	100	

Source: Field Survey, 2024

As shown in Table 4.2, approximately 78.2% of the sample households were headed by men, with the remaining 21.8% headed by women. It was discovered that female-headed households in rural Ethiopia face greater challenges in agricultural production and marketing than their male-headed counterparts. This is consistent with SMU (2012), who stated that the low participation trend in agricultural production among female-headed households is due to cultural thinking as well as their busy schedules due to domestic, reproductive, and community responsibilities.

4.1.1 Descriptive results

Table - 4.3: Summary statistics of variables used in the models (SPFF).

Variable	Measurement	minimum	Maximum	Mean	Std. Deviation
Output	Qt/ Hr.	0.11	5.90	1.56	113.02
Land	Hectare	0.03	1	0.31	0.21
Labor	Man days	0.8	7.3	3.76	1.09
Oxen power	Oxen days	0.33	2.97	0.86	0.45
Dap	Quintal	0.012	1	0.27	0.19
Urea	Quintal	0.003	0.625	0.14	0.11
Seed	Quintal	0.156	5	1.55	1.05
Chemicals	Litters	0.25	1	0.31	0.213
Experience in korerima production	In Years	1	39	7.32	6.05

Source: Field Survey, 2024

The production function for this study was estimated with eight input variables. Sample households produced an average of 1.56 qt of korerima, representing the dependent variable in the production function. The land allotted to korerima production by sample households during the survey ranged from 0.03 to 1 ha, with an average of 0.31 ha. On average, households used 1.55 kg of seed. Labor and oxen power were significant inputs in the study area's traditional farming system, alongside other factors. During the 2019–20 production year, households produced korerima with an average of 3.76 adult equivalent units of labor and 0.86 oxen days. In the study area, households used Dap and urea for korerima production, which is estimated to

Table - 4.4: Summary statistics of variables used to estimate cost function.

Variable	Measurement	minimum	Maximum	Mean	Std. Deviation
Output	Qt/Hr.	0.11	5.90	1.56	113.022
Cost of Land	Birr	1562	156000	32343.9	33769.5

Cost of labor	Birr	2144	25450	10136.1	3077.37
Cost of Oxen power	Birr	9800	95998	42273.4	21900.3
Cost of Dap	Birr	32	2650	695.08	508.12
Cost of Urea	Birr	20	1231	286.36	220.243
Cost of Seed	Birr	15.76	505	57.06	106.566
Cost of Chemicals	Birr	8	264	81.4077	55.5666

Source: Field Survey, 2024

As we have seen above in production function, the mean and standard deviation of each variable used in the cost function along with their contribution to the total cost of cultivation are presented in Table 4.4. Among the various factors of production, the average cost of land, labor, oxen power, Dap Urea, urea and chemicals were 32343.9, 10136.1, 42273.4, 695.08, 286.36, 157.06 and 81.40 ETB respectively.

4.1.2 Econometric results

4.1.2.1 Estimation of the Cobb-Douglas frontier production function

Table - 4.5: Estimation of the Cobb-Douglas frontier production function.

Variables	Parameters	Coefficients	Std. Err.	P – value
Constant	β0	5.978***	0.693	0.000
ln(land)	β1	0.789***	0.127	0.000
ln(DAP)	β2	0.014**	0.0057	0.015
ln(urea)	β3	0.181	0.033	0.580
ln(seed)	β4	0.096***	0.009	0.000
ln(labor)	β5	0.028*	0.015	0.057
Ln(chems)	β6	0.090	0.116	0.437
Ln(experik)	β7	-0.017	0.0186	0.558
ln(oxen)	β8	0.0184**	0.0075	0.014
$Sigma^2$ –v		-2.2507*	0.0925	0.075
$Sigma^2$ – u		-11.8382***	174.95	0.000
Sigma square	(σ2)	-14.089	0.00977	
Gamma	(γ)	0.84		
Log likelihood function		71.64		

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

Source: Field survey, 2024

The dual cost function which was derived analytically from the stochastic production function is given as follows basis for computing allocative and economic efficiency:

$$\ln C_{ki} = 4.35+0.335\ln_{wland}+0.36\ln_{wseed}+0.35\ln_{wdap}+0.029\ln_{wurea} +0.24\ln_{woxen}+0.052\ln_{wchemicals}+0.32\ln_{wlabor}+0.86\ln Y^*$$

Where: $\boldsymbol{lnC_{kp\ i}}$ is minimum cost of korerima production; w_1 is cost of land perha; $w_2$refers to the price of seed per kg, w_3 is cost of Dap per kg; w_4 is cost of urea per kg;w_5 is cost of oxen per day; w_6 is price of chemicals per liter,w_7 is cost of labor per day, $\boldsymbol{Y}$ $*$is output adjusted for any statistical noise; ith refers to the ith sample household.

The STATA 11 software was utilized to compute maximum-likelihood estimates of SPFF parameters. According to Table 4.5, the impact of each input on korerima production and their interaction effects are displayed. The analysis revealed that five input variables in the production function (ln(land), ln(dap), ln(seed), ln(labor), and ln(oxenp)) had a positive and significant influence on Korerima production. Consequently, increasing these inputs is expected to lead to a significant increase in korerima production. Specifically, a 1% increase in land size, DAP, seed, labor, and oxen power would result in a 0.789%, 0.014, 0.096%, 0.028%, and 0.0184% increase in korerima production, respectively.

The σ2 value for the frontier of Korerima output was -14.089, significantly different from zero. The significant value indicates that the composite error term distribution meets the specified assumption (Okoye et al., 2007). The estimated value of gamma was 0.84, indicating that 84% of the total variation in Korerima farm output was caused by technical, allocative, and economic inefficiencies. Table- 4.6:Elasticities and returns to scale of the parameters of stochastic frontier production function.

Variables	Elasticities
ln(land)	0.789
ln(DAP)	0.014
ln(urea)	0.180
ln(seed)	0.096
ln(labor)	0.028
Ln(chems)	0.09

Ln(experik)	-0.017
ln(oxen)	0.0184
Returns to scale	1.036

Source: Own computation, 2024

The returns-to-scale analysis coefficients were found to be 1.03%, indicating an increase in returns-to-scale. This implies that Korerima producers had the potential to continue expanding their production. A proportional increase in all inputs would boost total production by 1.03%. The findings were consistent with Fekadu and Bezabih (2009), who estimated the return to scale at 1.09% in a study of the TE of wheat production in Ethiopia.

4.1.2.2 Efficiency Scores

Table – 4.7: Frequency distribution and summary statistics of korerima production.

Range	TE		AE		EE	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
00 – 10	0.0	0.00	0.0	0.00	0.0	0.00
11 – 20	0.0	0.00	0.0	0.00	4.0	1.71
21 – 30	2.0	0.85	0.0	0.00	23.0	9.83
31 – 40	4.0	1.71	5.0	2.14	23.0	9.83
41 – 50	10.0	4.27	14.0	5.98	6.0	2.56
51 – 60	22.0	9.40	14.0	5.98	46.0	19.66
61 – 70	33.0	14.10	81.0	34.62	122.0	52.14
71 – 80	52.0	22.22	59.0	25.21	7.0	2.99
81 – 90	55.0	23.50	40.0	17.09	2.0	0.85
91 – 100	56.0	23.93	21.0	8.97	1.0	0.43
Minimum	26.0		31.0		12.0	
Maximum	99.0		98.0		95.0	
Mean	76.8		72.0		55.0	
Std. Deviation	16.0		13.5		14.6	

Source: Field survey, 2024

Table 4.5 displays the frequency distributions and summary statistics of efficiency measures for Korerima production. The average TE, AE, and EE of the households in the sample were 76.8%, 72.0%, and 55.0%, respectively, suggesting inefficiency in korerima production. The mean TE suggests that if the sample households operated at full efficiency, they could increase their output by 23.2% with the current resources and technology. In essence, the sample households, on average, reduce their inputs by 23.2% to achieve the current output. This finding is consistent with the research of Kifle et al. (2020), Tsegaye et al. (2020), and Mustefa et al. (2017). The average AE score shows that, on average, the sample households could improve korerima output by 28% if they used the correct inputs and produced the right output considering input costs and output price. The most allocatively efficient farmer would see an efficiency gain of 67% calculated as (0.98-0.31/1)*100 to reach the efficiency level of the most technically efficient household. This finding aligns with the studies of Kifle et al. (2020), Tsegaye et al. (2020), and Mustefa et al. (2017).

4.1.2.3 Determinants of efficiency in korerima Production

Table – 4.8: Determinants of efficiency in korerima production among sample households.

Variables	TE		AE		EE	
	Coefficents	Std. Err.	Coefficents	Std. Err.	Coefficents	Std. Err.
age	0.026***	0.003	0.028***	0.002	0.021***	0.002
Age2	-0.003***	0.0001	0.0002***	0.0001	0.0001***	0.0001
Sex	0.004	0.027	0.367*	0.025	-0.048*	0.002
Family	0.031*	0.005	-0.034	0.005	-0.062	0.0001
Educ	0.014***	0.003	0.027*	0.003	0.007**	0.003
Swc	-0.018	0.026	-0.034	0.024	-0.029	0.023
Extfreq	0.016**	0.007	-0.035	0.007	0.095*	0.007
Irrig	-0.026	0.024	-0.009	0.022	-0.022*	0.0001
Offincom	0.000	0.000	0.0003**	0.0001	0.0001	0.0005
Tlu	0.027*	0.003	0.036*	0.003	0.018**	0.003
Impseed	0.066	0.395	-0.909	0.362	-0.448	0.350
Acscdt	0.272**	0.023	-0.046*	0.002	0.303*	0.021
Experik	0.042**	0.002	-0.001	0.002	0.020*	0.002
Landowner	0.076**	0.031	0.081***	0.029	0.057**	0.028
Totfarminc	0.0001	0.0002	0.0003	0.0002	0.0005	0.0006
Totcultlnd	-0.384	1.831	-4.469***	1.678	-2.276*	1.062
Tech	0.040	0.030	0.025	0.028	0.404	0.027
Orgfert	0.003*	0.001	-0.001	0.001	-0.037	0.000

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

The TE, AE, and EE estimates derived from the model were regressed on demographic, socioeconomic, and institutional variables that explain variations in efficiency across farm households using a censored Tobit regression model.

Age of the household head: The estimated coefficient of age for TE, AE, and EE is positively significant at the 1% significance level. This suggests that age had a positive impact on TE, AE, and EE, possibly due to the accumulated farming experiences over the years. As the age of the producers increases each year, their technical and allocative efficiency also increase by 0.026% and 0.028%, respectively, holding other factors constant. This result is consistent with a study by Kifle et al. (2017). Older producers are likely to have more experience and be more active, enabling them to make informed decisions in farming, leading to higher efficiency in korerima production. This finding was corroborated by responses from key informants. It indicates that as the age of the decision-maker advances, allocative and economic efficiency also increase. This outcome aligns with recent studies (Tsegaye et al., 2020; Solomon, 2012; Kifle et al., 2018; Rebecca, 2011).

Sex of household head: The gender of the household head was found to have a significant negative impact on energy efficiency at a 10% level of significance. This corresponds with the findings of Aynalem (2006) and Kifle et al. (2014), who also found a negative relationship between female-headed households and their involvement in domestic activities. The results from interviews with key informants further strengthen this conclusion, indicating that female-headed households are primarily focused on home responsibilities. I'm sorry, but it seems like there is no text provided for paraphrasing. Please provide the text that you would like me to paraphrase.

Family size: The impact of family size on total efficiency (TE) is found to be positive and statistically significant at a 10% significance level. This is because family labor plays a crucial role in korerima production, and a farmer with a larger family size may be able to effectively manage additional crop plots and utilize appropriate input combinations by utilizing their own labor on the korerima plot. With each increase in family size by one, the TE of a korerima producer is observed to increase by 0.03%, assuming all other factors remain constant. These findings align with previous research conducted by Mustefa et al. (2015) and Kifle et al. (2020).

Level of Education: The education level of farmers's had a significant a significant positive relationship with economic efficiencies at 1%, 10%, and 5% levels for TE, AE, and EE, respectively. The number of years of schooling increases by one year, and the TE and AE of the Korerima production increase by 0.014% and 0.027%, respectively. According to key informants, the production process of korerima requires labor, and they get labor from family members. Those households with a larger number of family-sized employees have more labor for their agronomic activities and get the production process easier than others. This result is in line with the results found by Giang (2013) and Tsegaye *et al. (*2020).

Extension Frequency: As expected, the coefficient of estimation was positive and significantly affected the level of economic efficiency at the 5% level of significance for TE and the 10% level of significance for EE. This might be due to the fact that the high frequency of better information obtained from extension workers had a strong power to increase the awareness and know-how of farmers towards technologies and efficient utilization of the existing resources to increase their efficiency and decrease wastage of resource use. As extension workers frequently visit and follow up with farmers, more and more farmers may obtain important and influential information to increase their economic efficiency level by 0.016% and 0.095%, keeping other variables constant. As indicated by the key informant's extension workers, they visit their farm regularly, which helps them increase their Korerima production and production efficiency. This finding was in agreement with the findings of Nejuma (2011) and Mustefa (2017).

Irrigation: Irrigation is a dummy variable that indicates whether the farmer uses small irrigation canals on Korerima plots or not. It was hypothesized that farmers who used irrigation would be more efficient than their counterparts because it helps to increase output by recycling and restoring nutrients needed for Korerima production, potentially lowering costs. Interestingly, it has a negative sign and is statistically significant for economic efficiency at the 10% level. The results support Musa's (2017) argument.

Off-farm income earning: Unexpectedly, the coefficient of off/non-farm activities has a positive and significant impact on AE because the income generated by such activities can be used to purchase agricultural inputs and supplement the financing of household expenditures that are entirely dependent on agriculture. The findings are consistent with Hassen (2011) and Kifle et al. (2017).

Livestock holding (TLU): The coefficient for livestock holding had a positive and significant impact on TE, AE, and EE, which confirms the considerable contribution of livestock in the Korerima production system. It affected economic efficiencies positively at the 10%, 10%, and 5% level of significance for TE, AE, and EE, respectively. This means that farmers who increased their number of livestock holdings by one TLU could increase their technical, allocative, and economic efficiency by 2.7%, 3.6%, and 1.8%, respectively. The result also disclosed that farmers with the largest number of livestock holdings help to avoid cash constraints. This finding was consistent with the results obtained from Wassie (2012) and Kifle *et al.* (2017).

Access to credit: Credit utilization had a positive and significant impact on TE and EE, implying that, on average, households that use more credit are more efficient. The findings are consistent with those of Hasan (2006) and Nejuma (2012).

Experience in korerima production: Farmers' farming experience on korerima production had a significant positive impact on their economic efficiencies at the 5 and 10% levels of significance for TE and EE, respectively. Its positive sign could be attributed to the fact that farmers with more experience are more likely to respond to modern input combinations that reduce costs. So, as farming experience increased by one year, farmers' economic efficiencies increased by 2%, while other factors remained constant. This result is consistent with that found by Adeyemo et al. (2010).

Land ownership: Land ownership is a dummy variable that indicates whether the farmer uses his own land or not. Farmers who use their own land are expected to be more efficient than their counterparts because it increases output by reducing technical, allocative, and economic inefficiency while also having a positive and significant impact on TE, AE, and EE. Households producing korerima on their own land have higher levels of TE, AE, and EE. This implies that farmers who produce on their own land use inputs properly and prioritize sharecropped land management during agronomic practice periods. The results are consistent with Fekadu and Bezabih (2009) and Solomon (2012).

Total cultivated land: Total cultivated was found to have a significant and negative impact on AE at the 1% significance level and EE at the 10% significance level. The result implies that farm size increases technical inefficiency. Perhaps timely and appropriate agricultural operations on larger land with traditional technology may not be effective, which leads to a higher level of inefficiency. Larger plot sizes may also mean the expansion of agricultural lands to marginal areas, which makes efficient crop production difficult. As a result, efficiency and productivity can be negatively affected when the plot size is large, given the current level of technology. The result is in agreement with Kifle *et al.* (2017).

Organic fertilizer utilization: Organic fertilizer is essential in Korerima production because it increases yields regardless of farm size. Small-scale farmers often struggle to obtain fertilizer due to a lack of funds. At the 10% significance level, there is a positive relationship between organic fertilizer use and technical efficiency among small-scale Korerima producers. Organic fertilizer is widely used to increase productivity and agricultural production in general. This finding is consistent with Solomon (2012).

5.1 Summary

The study aimed to estimate technical, allocative, and economic efficiencies among smallholder Korerima producer households in Gewata, Kaffa zone, Ethiopia. It analyzed the determinants of economic efficiency and analyzed the technical, allocative, and economic efficiencies among these farmers. The research used cross-sectional data, quantitative and qualitative approaches, and a combination of non-probability and probability sampling. The study used the stochastic production frontier model to estimate production and cost functions and identify determinants explaining efficiency variation. The TE, AE, and EE estimates were regressed on farm characteristics, farmer characteristics, demographic, socioeconomic, and institutional variables.

The study found that households operating at full efficiency could increase their korerima output by 23.2% using existing resources and technology. The average AE score was 72.0%, indicating that households could increase korerima output by 28.0% if they used the right inputs and produced the right output relative to input costs and output price. Factors such as age, sex, family size, education level, extension frequency, livestock holding, credit usage, farming experience of smallholder farmers, land ownership, and organic fertilizer utilization all had positive impacts on korerima production. The study suggests that utilizing the right inputs and producing the right output can lead to increased economic efficiency in korerima production.

The study found that factors such as age, education level, off/non-farm activities, livestock holding, land ownership, and total cultivated or farm land significantly impact agricultural efficiency (AE). Farmers who use their own land for korerima production have a higher level of AE, as they use inputs properly and prioritize farming periods. The SPFF model suggests that increasing input use can improve production efficiency, and if agricultural technologies are introduced and disseminated alongside existing efficiency, there can be significant gains in production levels or reduced costs.

5.2 Conclusion

The research utilized a method called stochastic production frontier function to assess the technical, allocative, and economic efficiency of smallholder korerima producers in Gewata woreda using data from a farm-level survey conducted in 2019/20. The findings indicated that there is potential for enhancing the efficiency of smallholder korerima producers. The study determined that the average levels of technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) for the households surveyed were 76.8%, 72.0%, and 55.0%, respectively. Various factors were identified as influencing efficiency, including the age and gender of the household head, family size, level of education, frequency of extension services, livestock holdings, access to credit, experience in korerima production, land ownership, and use of organic fertilizers. Allocative efficiency, which pertains to the ability to utilize inputs in a cost-effective manner to produce a specific output, was influenced by factors such as age, education level, engagement in off-farm activities, ownership of livestock and land, as well as the total agricultural land cultivated. The presence of irrigation was shown to have a statistically significant and detrimental impact on the economic efficiency of smallholder farmers.

5.3 Recommendations

Recommendations are given to government officials, policymakers, and stakeholders in the agriculture sector in order to enhance korerima production and economic efficiency in the study area. The study found that female-headed households were less efficient compared to male-headed households, possibly due to their domestic responsibilities. Introducing technologies that reduce the domestic burden on female household heads could improve their technical efficiency in korerima production. Age was found to have a positive impact on efficiency, suggesting that mechanisms should be put in place to encourage collaboration between experienced and inexperienced farmers. Education also played a significant role in technical, allocative, and economic efficiency, highlighting the importance of providing basic training opportunities for farmers.

Extension services were found to positively affect technical and economic efficiencies, indicating the need for adequate support from government bodies for korerima producers. Off-farm activities were linked to improved allocative efficiency, emphasizing the importance of strategies that promote non-farm employment opportunities. Farmers with a large number of livestock showed higher efficiency levels, underscoring the need for technologies that support livestock production. Credit utilization was also found to positively impact efficiency, suggesting the importance of microfinance institutions in supporting korerima producers. Farmers who cultivated korerima on their own farms were more efficient than those using share cropping arrangements, indicating the need for increased support for smallholder share cropping producers. The use of organic fertilizers was positively associated with technical efficiency, highlighting the need for government support and training for producers. Overall, there is a high level of inefficiency in korerima production that requires attention from policymakers and development practitioners. Learning from efficient farmers and promoting resource allocation decision-making can help improve efficiency levels through initiatives such as field days, cross-visits, and experience-sharing forums.

5.4 Suggestions for further Researches

The results of this research suggest some suggestions for future studies. Firstly, additional research is required to enhance understanding of various factors affecting economic efficiency, such as agro-ecological variables like rainfall, consumption, market information, and planting techniques. Secondly, it is important to analyze the spatial efficiency of Korerima production to identify potential misallocation of resources between different Kebeles. Lastly, this study did not examine how marketing challenges may affect the efficiency of Korean producers. Therefore, further research should focus on investigating this aspect.

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