



WERABE UNIVERSITY
COLLEGE OF AGRICULTURE AND NATURAL
RESOURCES DEPARTMENT OF AGRICULTURAL
ECONOMICS POSTGRADUATE PROGRAM

ECONOMIC EFFICIENCY OF SMALLHOLDER FARMERS IN WHEAT
PRODUCTION: SILTI WOREDA CENTRAL ETHIOPIA REGION
ETHIOPIA

M.Sc. Thesis

BY:

SHEMSIA HELIL

ADVISOR: NEGUSSIE ZERAY (PhD)

CO-ADVISOR: Mr. ABAY AMANA (MSc)

MARCH, 2026

WERABE, ETHIOPIA

**WERABE UNIVERSITY
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SHEMSIYA HELIL

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DECLARATION

I, the under signed student of Werabe University, Post Graduate Program in Agricultural Economics, declared that this Master Thesis is my original work and it has not been presented in any MSc/PhD thesis or any other purpose at any University.

Shemsiya Helil

Student Name

Signature

Date

APPROVAL SHEET

This is to certify that the thesis entitled "**Economic Efficiency of Smallholder Farmers In Wheat Production: The Case of Silti Woreda Siltie Zone Central Ethiopia Regional**" submitted in partial fulfilment of the requirements for the degree of **Master's** with specialization in **Agricultural Economics**, the Graduate Program of the Department/School of **Agricultural Economics**, and has been carried out by Shemsiya Helil Id. No 016/15 **weekend**, during the period 2015-2018(E.C). under my/our supervision. Therefore I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Negussie Zeray

Name of major advisor



Signature

03/01/2026

Date

Abay Amana

Name of co-advisor

Signature

Date

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COLLEGE OF AGRICULTURE AND NATURAL RESOURCE,
POST GRADUATE PROGRAM
DEPARTMENT OF ARGICULTURAL ECONOMICS
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As members of the Board of Examiners of the final Master's degree open defense, we certify that we have read and evaluated the thesis prepared by SHEMSIA HELIL under the title **Economic Efficiency of Smallholder Farmers In Wheat Production: The Case of Silti Woreda Siltie Zone Central Ethiopia Regional** and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in Agricultural Economics with Specialization in Agricultural Economics.

_____ Name of the Chairperson Nesre Kedir	_____ Signature	_____ Date
_____ Name of Internal Examiner	_____ Signature	_____ Date
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ACRONYMS AND ABBREVIATIONS

ADB	African Development Bank
AE	Allocative Efficiency
ATA	Agricultural Transformation Agency
CSA	Central statistical Agency of Ethiopia
DEA	Data Envelopment Analysis
EE	Economic Efficiency
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
IFPRI	International Food Policy Research Institute
MD	Man-day
ML	Maximum Likelihood
MoA	Ministry of Agriculture
NGO	Non-governmental Organization
OLS	Ordinary Least Squares
SFA	Stochastic Frontier Analysis
SPF	Stochastic Production Frontier
SWAO	Silti Woreda Agriculture Office
TE	Technical Efficiency
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor
WB	World Bank
WFP	World Food Programme

ABSTRACT

Due to a massive yield gap, Ethiopia, the largest wheat producer in Africa, is still a net importer. This dilemma is most evident in Silti Woreda, where smallholder yields remain stagnant at 1.5 t/ha. The purpose of this study was to evaluate the technical (TE), allocative (AE), and economic efficiency (EE) levels of smallholder wheat growers in Silti Woreda and to pinpoint the main institutional and socioeconomic elements that account for efficiency disparities. Both primary and secondary data sources were used. In order to select a representative sample, three stage sampling procedure was used, 196 randomly chosen wheat-growing households provided a cross-sectional dataset. Stochastic production frontier approach was employed. The stochastic production frontier model reveals that wheat production is influenced by labor, oxen, land, and DAP. The inefficiency coefficient is 0.74, highlighting diminishing returns in stage II production while suggesting opportunities for growth despite inefficiencies. The stochastic frontier technique reveals significant differential efficiencies: mean technical (69.7%), allocative (48.95%), and economic (40.12%) efficiencies show that farmers may use their current resources to reduce expenses by 59.88% or raise output by 30.3%. Tobit regression revealed important factors, such as the beneficial benefits of market information, off-farm income, and extension contact; however, loan availability had a significant detrimental impact on allocative and economic efficiency, indicating that money is squandered without supervision. In order to increase productivity, lessen reliance on imports, and improve food security, the results highlight that inefficient use rather than input scarcity is the main obstacle. This calls for a policy shift toward interventions that combine credit with technical training, reorient extension to cost-minimizing allocation, and encourage practices like row planting.

Keywords: Cobb-Douglas, Economic Efficiency, Stochastic Frontier Analysis, Technical Efficiency, Allocative Efficiency, Wheat, Smallholders, Silti, Ethiopia

1. INTRODUCTION

1.1. Background of the study

Agriculture is at the heart of Ethiopia's economy. It makes up 46.6% of the country's GDP and employs 85% of the population (World Bank, 2024), with cereals dominating what people eat. Wheat, which is the fourth most widely grown crop (covering 1.6 million hectares), delivers about 14% of the calories in local diets and is second only to maize as a food source (Yirga and Berhanu, 2023). Even though Ethiopia is the biggest wheat producer in Sub-Saharan Africa (3.9 million tons each year, CSA 2024), the country still imports wheat spending over \$600 million annually to fill the gap (Guido, 2024; Abate et al., 2023). That's a pretty striking contradiction, and the roots of it lie in chronic inefficiencies. Around 4.7 million smallholder farmers across Ethiopia average just 2.54 tons per hectare—far below the research potential of 48 t/ha (IFPRI, 2020) and even less than the global average (2.93 t/ha). In Silti Woreda, Central Ethiopia, where each smallholder owns only about 0.34 ha, yields are just 1.5 t/ha (SWAO, 2024), which is 50% lower than the region's average (0.19 ha per household, CSA 2024). This shortfall pushes rural poverty and makes food insecurity worse.

Closing these yield gaps means making better use of resources, especially when land is limited and the climate is unpredictable. There's plenty of evidence showing big efficiency deficits in Ethiopia's wheat sector. For example, Mufti (2019) found an efficiency rate of 31.65% in Robe (Arsi Zone), while Milkessa et al. (2019) in East Arsi reported 35.26%, both linked to low input use and poor management. Improving economic efficiency—which combines technical efficiency (getting the most output), allocative efficiency (using inputs at the lowest cost), and scale efficiency—could really help. Kebebew et al. (2021) found that 59.88% of possible output gains in Debra Libanos could come just from increasing efficiency. Silti Woreda faces similar hurdles: holdings are small and fragmented, rainfall is unpredictable (912–1,160 mm/year), and only about a third of farmers use yield-boosting methods like row planting (32.65%).

Previous research mostly looked at inefficiencies in more promising areas: Abate and Walelign (2023) recorded 67% efficiency in Gedeb, Oromia; Adugna et al. (2023) saw 37.31% in Womberma, Amhara. But no one has studied the Siltie Zone in Central Ethiopia a rainfed region with its own set of socio-ecological challenges. This study steps in to: (1) use a stochastic frontier method to measure technical, allocative, and economic efficiency among

Silti's wheat farmers, and (2) figure out what's behind the inefficiencies, like input allocation or access to institutions. The findings aim to help design interventions that boost productivity without expensive new technology, supporting Ethiopia's move toward substituting imports (ATA, 2020). So, the purpose of this study was to gather cross-sectional data from smallholder wheat producers in the Silti district of southern Ethiopia in order to quantify overall efficiency and identify its determinant elements.

Moreover, the sector is dominated by smallholder farmers that are characterized by subsistence production with low input use and low productivity, and dependency on traditional farming and rainfall. The smallholder farmers, who are providing the major share of the agricultural output in the country, commonly employ less modern production technologies and limited external inputs (World Bank, 2007). Therefore, being agriculture dependent country with a food deficit gap, increasing crop production and productivity is not a matter of choice rather a must to attain food selfsufficiency.

1.2. Statements of the Problem

Ethiopia depends heavily on wheat imports, even though it devotes 1.6 million hectares to growing the wheat crop. That signals a major problem with inefficiency. Smallholder farmers produce 90% of the country's wheat, but their average yield is just 2.54 t/ha (CSA, 2024) way below the achievable 4 to 8 t/ha (IFPRI, 2020). The result? The economy spends more than \$600 million a year on wheat imports (Guido, 2024). In Silti Woreda, Central Ethiopia, the situation is worse. Yields sit at 1.5 t/ha (SWAO, 2024), which is half the regional average, even though the area has the right conditions for wheat. Studies trace these gaps to systemic inefficiencies. Mufti (2019) in Arsi (EE: 31.65%) and Milkessa et al. (2019) in East Arsi (EE: 35.26%) point to not using modern farming inputs, mismatched input-output prices, and problems with scaling up.

Although data shows ongoing allocative and economic inefficiencies, the government's encouragement of "import substitution" through ATA extension packages (2020) thinks technology adoption alone suffices. Due to poor mechanization, scattered holdings (0.34 ha/hh), and irregular rainfall (912–1,160 mm/year), farmers in Silti find it difficult to maximize resources. Only 32.65% of farmers use row planting, a technique that has been shown to increase output (Tolosa et al., 2014). Meanwhile, cost inefficiencies are made worse by restricted access to loans and extension (Kebebew et al., 2021).

Several recent studies on the technical efficiency (TE) of crop production for wheat indicated the existence of a yield gap. This gap refers to the difference in productivity between best

practice farms and other farms that operate with comparable available resources under similar circumstances (Daniel *et al* 2020). The presence of shortfalls in efficiency indicates that output can be increased with given inputs and existing technologies. If this is the case, then empirical estimations of efficiency are important to determine the gain that could be obtained by improving the performance in production with existing technology. It also helps to find out whether the yield variability is due to random influences beyond the control of the farmers or to the factors under the control of the farm

Importantly, whereas nearby zones like Gedeb (EE: 67%; Abate and Walelign, 2023) and Womberma (EE: 37.31%; Adugna et al., 2023) demonstrate location-specific limitations, no study has measured economic efficiency (TE, AE, EE) or identified its causes in Silti. Targeted interventions are hampered by this gap. Policies run the risk of misallocating resources and sustaining food insecurity and import dependency if they do not comprehend how input allocation, socio-institutional factors, and scale efficiency limit productivity. Therefore, this study poses the following questions: What are the technical, allocative, and economic efficiency levels in Silti's wheat systems, and which institutional and socioeconomic factors account for variances in efficiency among smallholders?

1.3. Research Questions

1. What are the levels of technical, allocative and economic efficiencies of smallholder wheat producers in the study area?
2. What are the factors that affect technical, allocative and economic efficiencies of smallholder wheat producers in the study area?

1.4. Objectives of the Study

1.4.1. General objective

The general objective of this study was assessment of economic efficiency of smallholder wheat producers in Silti woreda Silte.

1.4.2. Specific objectives

1. To measure the levels of technical, allocative and economic efficiencies of smallholder wheat producers in the study area.

2. To identify factors that affect technical, allocative and economic efficiencies of smallholder wheat producers in the study area.

1.5. Scope and Limitations of the Study

This study assesses technical (TE), allocative (AE), and economic efficiency (EE) of smallholder wheat farmers in Silti Woreda during the 2023/24 production season. Using a Cobb-Douglas stochastic frontier model, it quantifies efficiency levels and diagnoses socio-institutional drivers (e.g., credit access, extension contact), while excluding other crops to maintain analytical focus on wheat production systems.

Methodologically, efficiency scores are relative to the sample's best performers and Cobb-Douglas's fixed elasticity assumptions may oversimplify production responses. Cross-sectional data cannot capture interannual climate adaptations (e.g., rainfall variability in Silti's 912–1,160 mm zone), while self-reported inputs/outputs risk recall bias from unrecorded operations. Findings are primarily generalizable to rainfed wheat systems; efficiency drivers may differ for irrigated contexts.

1.6. Significance of the Study

This study delivers actionable insights for policymakers by identifying efficiency levers (e.g., row planting adoption) to align with Ethiopia's import substitution strategy, potentially reducing wheat imports by 59.88% through optimized resource use; for farmers by revealing pathways to increase yields by 22.32% (TE) and reduce costs by 50.74% (AE) without new technology, enhancing incomes; for development agencies, including SWAO and NGOs, through evidence to redesign extension programs (e.g., cost-minimizing input allocation training) and credit-risk tools; and for academic research while advancing theory on smallholder efficiency in fragmented land systems.

1.7. Organization of the Thesis

The study comprises five sections: the introduction (including background, problem statement, objectives, significance, scope, and limitations), a literature review on efficiencies worldwide, a description of the study region and data methodologies, results and discussions on models, and a concluding chapter summarizing findings and suggestions.

2. LITERATURE REVIEW

In this chapter, definition of basic terms, methods of measuring production efficiency performance of agriculture in Ethiopia, wheat production and its advantages, and empirical studies on technical, allocative and economic efficiencies have been reviewed.

2.1. Basic Concepts of Production Efficiency

Technical Efficiency ("Doing things right"): This refers to producing the maximum possible output from a given set of inputs, or using the minimum inputs necessary to produce a given output, thereby avoiding waste. It is concerned with the physical relationship between inputs and outputs.

Allocative Efficiency ("Doing the right things") This occurs when resources are distributed according to consumer preferences, where the price consumers are willing to pay equals the marginal cost of production. It ensures resources are directed toward goods and services that provide the highest value.

Economic (or Total) Efficiency: This is the combination of both technical and allocative efficiency. A firm or economy is economically efficient if it uses the best input combination (allocative) to produce goods at the lowest cost (technical)

In economics, efficiency is the most commonly used concept. It is described as accomplishing a goal with little to no resource waste. It has to do with assessing how well a farm business converts inputs into outputs. (Negese and sanait, 2023) distinguished between three types of efficiency: technical, allocative, and economic. The ability of any decision-making unit to provide the greatest potential result from a set of inputs at a specific technological level is measured by technical efficiency. It is the physical output-to-production ratio on the production border line. He claims that the ability of a decision-making unit to generate a specific level of output at the least expensive input combination is measured by allocative efficiency. It is the physical output-to-production ratio on the production border line. He claims that the ability of a decision-making unit to generate a specific level of output at the least expensive input combination is measured by allocative efficiency. When more output can be produced from a given amount of input simply by lowering the amount of resource from other uses, it is considered to have been accomplished. The combination of inputs that achieve personal or societal goals is known as economic efficiency.

In economics, terms such as efficiency, productivity, technology growth and economic growth are very widely used and sometimes interchangeably. However, although there are

similarities and linkages among them, they are not equivalent. The conceptualization and measurement of efficiency relies on the specification of a production function. The production function represents the maximum output attainable from the use of a given level of inputs. The production function describes production performance and productivity is the measure of it. Algebraically, productivity is defined as the ratio of the amount of output produced to the amount of resources used. However, efficiency is the ratio of the value of output produced to the cost of inputs used (Shanmugam and Atheenda, 2018).

Following the pioneer work by (Meshesha, 2025) efficiency of a firm consists of two components: Technical Efficiency (TE) and Price efficiency. TE is defined by comparing between observed and optimal values of output and inputs of a production unit (Raul *et al.*, 2023). It refers to the ability of a producing unit (firm) to obtain maximum (optimal) output from a given set of inputs and technology. Stated differently, technical inefficiencies reflect the failure of attaining the highest possible level of output given inputs and technology, it is using more inputs than is necessary. Formally, the level of TE is measured by the distance of firm production from the optimal production frontier, a firm that sits on the production frontier is said to be technically efficient.

According to (Meshesha, 2025) technical and allocative efficiency in production together comprises the economic efficiency. Technical efficiency relates the physical input with the optimum level of output that can be produced at a given level of technology; whereas allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. Allocative efficiency shows a firm's ability to maximize profits by equating the marginal revenue product of the factors of production to their respective marginal costs.

2.2. Measurement of Production Efficiency

The conventional micro-economic theory, which examines how businesses behave, assumes perfect information, unfettered resource mobility, and the complete and effective use of resources. Nonetheless, several empirical investigations have shown that both wealthy and developing nations have economic inefficiencies in a variety of sectors.

2.2.1. Approaches of measuring production efficiency

There are two approaches of measuring production efficiency: output-oriented approach (primal approach) and input-oriented approach (dual approach).

2.2.1.1. Input-oriented measure

The original concept of depicting technology through a convex iso-quant serves as an input-oriented measure of efficiency. In 1957, Farrell demonstrated this notion of input-oriented efficiency with a straightforward example involving a firm that utilizes two production factors: capital (K) and labor (L) to generate a single output (Y). This firm operates under the production function $y = F(K, L)$, assuming constant returns to scale. This assumption allows for a clear representation of all relevant information on a basic iso-quant. The input-oriented approach seeks to answer the question of how much a production unit can be proportionally adjusted, specifically regarding the quantities of inputs required to achieve a specified level of output (Sarojrani, 2021).

The two input factors utilized by a firm can be illustrated within a two-dimensional input-input framework. The iso-quant SS' (refer to Figure 1) depicts the various combinations of these two input variables that a firm may employ to achieve a unit of output. This iso-quant delineates the input-output ratios that correspond to the most efficient utilization of inputs for the specified output. SS' is also referred to as the best practice production frontier. Conversely, the line AA' represents an isocost line, indicating all possible combinations of inputs that maintain a constant total cost across all points. For a firm aiming to maximize profits, production should occur at point Q' , where the iso-quant and isocost line are tangent. This point signifies the least-cost combination of inputs for producing output Q , indicating that the producer operates with economic efficiency.

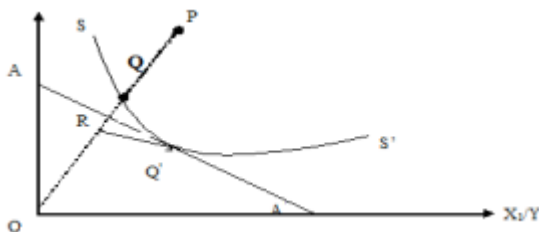


Figure 1. Input-oriented measure of technical and allocative efficiencies

Source: Coelli (1995).

The same figure is employed to measure the technical, allocative and economic efficiency. Suppose a farmer is producing his output depicted by iso-quant SS' with input combination level of production at input, combination of point (P) is not technically efficient because the level of inputs needed to produce the same quantity is Q on iso-quant SS' . In other words, the farmer can produce at any point on SS' with fewer inputs (and), in this case at Q in an input-

input space. The degree of TE of such a farm is measured as OQ/OP , which is proportional in all inputs that could theoretically be achieved without reducing the output. In Figure 1, AA' represents input price ratio or iso-cost line which gives the minimum expenditure for which a firm intending to maximize profit should adopt. The same firm using (and) to produce output with input combination at point P would be allocatively inefficient in relation to R. Its level of AE is represented by OR/OQ , since the distance RQ represents the reduction in production costs if the farmer using the combination of input (and) was to produce at any point on AA' , particularly at point R instead of P. The economic efficiency is measured as the product of OQ/OP and OR/OQ , which is OR/OP . All three measures of efficiency are bounded between zero and one. This follows from interpretation of distance RP as the reduction in costs if a technically and allocatively inefficient producer at P were to become efficient (both technically and allocatively) at Q' (Coelli, 1995).

2.2.1.2. Output-oriented measure

The input-oriented approach addresses the question of how much input usage can be minimized without compromising output levels. Conversely, the output-oriented approach seeks to determine how much output can be enhanced without increasing input usage (Mubeshir, 2023). From this viewpoint, efficiency is assessed while keeping inputs constant. Understanding the fully efficient production possibility curve and the isorevenue line enables the measurement and interpretation of the level of efficiency. Output-oriented measures can be exemplified by examining a scenario where production involves two outputs and a single input (L). When the input quantity is maintained at a specific level, the technology can be depicted through a two-dimensional production possibility curve as follows:

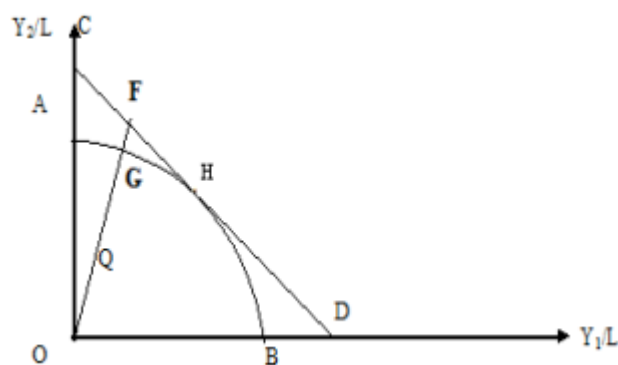


Figure 2. Output-oriented measures for technical and allocative efficiencies

Source: Coelli *et al.* (1998)

The production possibility curve is illustrated by curve AB in Figure 2, depicting the technically efficient combinations of outputs $Y1/L$ and $Y2/L$. The point of economic efficiency is identified as H, where the marginal rate of product transformation aligns with the slope of the iso-revenue line CD. For a firm located at point Q, its economic efficiency is represented by the ratio OQ/OF .

TE is represented by OQ/OG and the AE is OG/OF . The point of tangency between the isorevenue line CD and the production possibility curve AB (at point H) represents the economically efficient point of production, which is 100% technically and allocatively efficient.

2.3. Models for Measuring Efficiency

The assessment of inefficiency within the agricultural sectors of both developing and developed nations has garnered significant interest from researchers since the late 1980s, particularly as frontier methods for measuring efficiency have become more popular. The production frontier method for evaluating technical inefficiency allows for a clear differentiation between technological advancements and progress towards the optimal practice frontier. By estimating the best practice production function, which is not directly observable, this method determines technical efficiency by measuring the gap between the frontier and the actual output.

Two different groups of technique have been used to measure technical efficiency under the frontier approach, which differ in the assumptions imposed on the data; non-parametric linear programming technique (Data Envelopment Analysis, DEA), and the Parametric Stochastic Frontier Approach (SFA).

2.3.1. Non-parametric frontier model

The non-parametric approach has been traditionally assimilated into Data Envelopment Analysis (DEA); a mathematical programming model applied to observed data that provides away for the construction of production frontiers as well as for the calculus of efficiency scores relatives to those constructed frontiers. Data Envelopment Analysis (DEA) is a non-parametric method and can easily handle multiple input and output relation. Moreover, in DEA, application inputs and output can have very different units of measurement without requiring any a priori trade off or any input and output prices. DEA does not impose any

assumptions about functional form; hence it is less prone to misspecification. Further, DEA does not take it in to account random error. It is not subject to the problems of assuming on underlying distribution about the error term. However, since DEA cannot take account of such statistical noise, the efficiency estimates may be biased if the production process is largely characterized by stochastic elements. Thus, it is only for the literature review purposes.

2.3.2. Parametric frontier model

Parametric methods can be categorized into two main types: deterministic and stochastic models. The first often referred to as "full frontier" models, encompass all data points and measure the gap between actual production and the optimal production level, which is determined by the frontier and existing technology, as a form of technical inefficiency. In deterministic models, any divergence from the frontier is attributed solely to inefficiency. In contrast, stochastic models account for random statistical variations.

The deterministic frontier functions can be solved either by using mathematical programming or by means of econometric techniques. The stochastic specifications are estimated by means of econometric techniques only (Mubeshir, 2023) recommended that SPF is more appropriate than DEA and deterministic models in agricultural applications, especially in developing countries, where the data are heavily influenced by measurement errors, and the effect of weather, disease, etc plays a significant role.

2.3.3. Deterministic model

The parametric deterministic models used for measuring technical efficiency. We assume that production can be modeled as:

$$y_i = \alpha + \beta x_i - u_i \quad (1)$$

Where 0 represents inefficiency and all variables are specified in logarithms.

$$u_i \geq -DF_i \exp\{-u_i\} \quad (2)$$

The Debreu-Farrell measure of technical efficiency does not require the production function to be limited to the Cobb-Douglas form. This particular functional form is selected for its alignment with the work of (Daniel, 2023) for ease of use. Alternatively, one may opt for the flexible translog production function, which is linear concerning its parameters. This approach is deemed deterministic, as the stochastic element is entirely attributed to

inefficiency, with measurement error being disregarded. In accordance with Bravo and Rieger (2021), the deterministic model can be estimated using Ordinary Least Squares (OLS). While the slope parameters are consistently estimated in this scenario, the intercept is subject to bias. Greene demonstrates that a consistent estimate of the intercept can be achieved by adjusting the OLS line upward.

To ensure that the largest adjusted residual equals zero, if the actual error term consists of a normally distributed noise component and a non-negative inefficiency component, ordinary least squares (OLS) does not represent maximum likelihood estimation; however, it still yields unbiased and consistent estimates of the slope parameters. Consequently, the estimated slope parameters derived from stochastic frontier and OLS regressions will exhibit only slight variations. Adjusting the intercept from an OLS regression is merely one deterministic method. Adugnaw and Dagninet. (2020), proposed alternatives using linear and quadratic programming techniques.

The deterministic specification assumes that all deviations from the efficient frontier are attributed to factors beyond the agent's control/constant, which can lead to suboptimal performance of units. Elements such as regulatory and competitive environments, weather conditions, chance, socio-economic and demographic influences, and uncertainty should not be regarded as indicators of technical efficiency. Nevertheless, the deterministic approach treats them as such (Raul *et al.*, 2023)

Additionally, any issues related to specification are considered as inefficiencies when assessed through the lens of deterministic methods. In contrast, stochastic frontier approaches account for both specification errors and uncontrollable variables separately from the technical inefficiency aspect by incorporating a two-sided random error into the frontier model's specification.

2.4. Approaches to Identify Efficiency Factors

The literature suggests two methodological approaches for analyzing the sources of efficiency based on stochastic production functions. Those are two-stage estimation approach and one stage estimation approach.

2.4.1. Two stage estimation approach

The initial method involves a two-stage estimation process. In the first stage, the stochastic production function is estimated, leading to the calculation of efficiency scores. In the second

stage, these efficiency scores are regressed against explanatory variables utilizing ordinary least squares or Tobit regression techniques.

This approach has been criticized on grounds that the firm's knowledge of its level of technical inefficiency affects its input choices; hence inefficiency may be dependent of the explanatory variables. The inefficiency effects would only be identically distributed if the coefficients of the farm specific factors are simultaneously equal to zero. It is possible to overcome this problem by the use of a single stage maximum likelihood approach (Adugna *et al.*, 2023).

2.4.2. Single stage simultaneous approach

The second approach advocates a one stage simultaneous estimation approach as in Battese and Coelli (1995), in which the inefficiency effects are expressed as an explicit function of a vector of farm-specific variables. In the Battese and Coelli (1995) approach, the technical inefficiency effects are specified in the stochastic frontier model and assumed to be independently but not identically distributed non- negative random variables. The technical inefficiency effects are expressed as:

$$\delta u_j = z_j \quad (3)$$

Several factors including socio-economic and demographic factors, plot-level characteristics, environmental influences and non-physical factors are likely to affect the efficiency of smallholder farmers. This research employed a one-stage simultaneous method to assess technical efficiency.

2.4.3. Stochastic frontier procedures model

The theoretical literature on productive efficiency, which began in the 1950s through the contributions of Koopmans (1951) and Debreu (1951), significantly shaped the development of stochastic frontier analysis (SFA). Koopmans established a definition of technical efficiency, stating that a producer is considered technically efficient if it is impossible to increase the output of one product without either decreasing the output of another product or utilizing additional input. Debreu introduced distance functions to model technologies with multiple outputs, which, from our viewpoint, serves as a crucial method for assessing the radial distance of a producer from the efficiency frontier, particularly in the context of output expansion. The stochastic frontier production function is characterized by:

$$y = f(x_i; \beta) \exp(v_i - u_i) \quad i = 1, 2, \dots, N \quad (4)$$

This was developed by Aigner *et al.*(1977), Meeusen and van den Broeck (1977) and Battese and Corra (1977) simultaneously to incorporate the efficiency term

capture the effects of exogenous shocks beyond the control of the analyzed units. Moreover, this type of model also covers errors in the observations and in the measurement of outputs. For the Cobb-Douglas case, and in logarithmic terms, the single-output stochastic frontier can be represented as

$$\ln y_i = \beta_0 + \sum_{n=1}^N \beta_n \ln x_{ni} + v_i - u_i \quad (5)$$

Where y_i is the maximum output obtainable from x_i , a vector of (non-stochastic) inputs, and β is an unknown parameter vector to be estimated.

v_i is a random error having zero mean, which is associated with random factors (e.g., measurement errors in production, weather, industrial action, etc.). These are factors outside the control of the smallholder farmers. The model is such that the possible production, y_i is bounded above by the stochastic quantity, $f(x_i; \beta) \exp(v_i)$; hence the term stochastic frontier. The random errors

v_i , $i = 1, 2, \dots, N$, were assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ random variables, independent of the u_i 's which were assumed to be nonnegative random variables which are independently and identically distributed as $N(0, \sigma_u^2)$

distribution (i.e., half-normal distribution) or have exponential distribution which reflect technical inefficiency to the frontier production of wheat which is the ratio of observed output to maximum feasible output of the i^{th} plot. The distribution of u_i is half normal with mean

u_i and variance. Given the assumptions of the stochastic frontier (5) model, inference about the parameters of the model can be based on the maximum-likelihood estimators because the standard regularity conditions hold. Aigner *et al.* (1977) suggested that the maximum likelihood estimates of the parameters of the model be obtained in terms of the parameterization, $\sigma_v^2 + \sigma_u^2 = \sigma^2$ and $\sigma_u / \sigma_v = \lambda$. Rather than use the non-negative parameter, λ (i.e., the ratio of the standard deviation of the $N(0, \sigma_u^2)$ distribution involved in specifying the distribution of the non-negative u_i 's to the standard of symmetric errors, v_i), Battese and Corra (1977) considered the parameter; $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ which is bounded between one and zero.

As it could be envisaged, the parameter λ is an indicator of the relative variability of the two sources of variations. If λ is closer to zero the symmetric error term dominates the variation between the frontier/ maximum attainable level of output and the observed level of output. Or put differently, a value of λ close to zero implies that the discrepancy between the observed and the maximum attainable levels of output is dominated by random factors outside the control of the producer. Otherwise, the more λ is greater than one the more the production is dominated by variability emanating from inefficiency.

Thus the technical efficiency of firm i th in the context of the stochastic frontier production function is the same expression as for the deterministic frontier model, namely:

$$TE_i = y_i / y_i^*$$

$$TE_i = f(x_i; \beta) \exp(v_i - u_i) / f(x_i; \beta) \exp(v_i) \quad (6)$$

$$TE_i = \exp(-u_i)$$

Where y_i is the observed wheat output and y_i^* is the maximum possible wheat output using the given level of inputs and the other variables are defined as mentioned earlier. For a given set of data, the estimated technical efficiencies obtained by fitting a deterministic frontier will be less than those obtained by fitting a stochastic frontier, because the deterministic frontier will be estimated so that no output values will exceed it. The prediction of the technical efficiencies of individual firms associated with the stochastic frontier production function, defined by, $TE_i = \exp(-u_i)$ $i = 1, 2, \dots, N$ was considered impossible until appearance of Jondrow *et al.* (1982). u_i , given that the random variable, $\varepsilon_i = v_i = u_i$, was observable.

They suggested that u_i would be predicted by the conditional expectation of u_i , given the value of random variable, $\varepsilon_i = v_i = u_i$. This expectation was derived for the cases that u_i had half-normal and exponential distributions. They used $1 - \sum(u_i / v_i - u_i)$ to predict the technical inefficiency of the i th firm. However, given the multiplicative production frontier model Coelli and Battese (1998) pointed out that the technical efficiency of the i th firm,

$TE_i = \exp(-u_i)$, is best predicted by using the conditional expectation of $\exp(u_i)$ given the value of the random variable, $\varepsilon_i = v_i = u_i$ (Coelli and Battese, 1998). They proposed the best predication of firm level efficiency and expressed as

$$\sum [\exp(-u_{it}) / \varepsilon_i] = \frac{1 - \phi(\delta^* + (\gamma \varepsilon_i / \delta^*))}{1 - \phi(\gamma \varepsilon_i / \delta^*)} \cdot \exp(\gamma \varepsilon_i + (\delta^2 / 2)) \quad (7)$$

Where $\delta^* = \delta_u \delta_v / \delta$ and $\gamma = \delta_u^2 / \delta^2$

Most of the literature related to the measurement of economic efficiency have based their analysis either on any of the above parametric or on non-parametric methods. The choice of estimation method has been an issue of debate, with some researchers preferring the parametric others the nonparametric approach.

The main disadvantage of non-parametric approaches is their deterministic nature. Data Envelopment Analysis, for instance, does not distinguish between technical inefficiency and statistical noise effects. On the other hand, parametric frontier functions require the definition of a specific functional form for the technology and for the inefficiency error term. The functional form requirement causes both specification and estimation problems. This study had used SFA due to the stochastic and random nature of agricultural production.

2.5. Review of Empirical Studies on Efficiency Abroad

Zitzmannetal *et al.*, (2022) used the stochastic parametric technique to determine the technical, allocative and economic efficiencies of plantain (*Musa spp.*) farmers in Ondo State, Nigeria. Their findings showed that the mean TE, AE and EE indices were 61%, 57% and 35% respectively. Their results indicated that age was significant and positively correlated to TE and EE, while extension services contributed significantly to TE. Their results suggest that experience in plantain farming and increased investment in extension services could jointly contribute to an improvement in efficiency of plantain farmers in Ondo State of Nigeria.

Kamanu and Geoffrey (2020), assessed technical efficiency in resource use from smallholder Irish potato farmers from Nyandarua North District, Kenya. They used a dual stochastic parametric decomposition technique to derive technical efficiency indices while a two-limit Tobit model was to examine the effects of socio-economic characteristics and institutional factors on the derived technical efficiency indices. Their results showed that resource use was subject to decreasing returns to scale while the mean TE was 67%. Education, access to extension, access to credit and membership in farmers' association and innovations positively and significantly influence TE.

Kaur *et al.* (2021) conducted their study on technical efficiency of wheat production in Punjab state, India. They used stochastic frontier production to estimate the technical efficiency of wheat production and they found that the mean technical efficiency of wheat production as 87 per cent, 94 per cent, 86 per cent and 87 per cent in semi-hilly, central, south-western and Punjab state as a whole, respectively. The result of their model showed that the technical efficiencies are positively and significantly related to age, education and experience of a farmer and percentage area under the crop.

Tilak *et al.* (2024) conducted their study on economic efficiency of wheat and faba bean production for small-scale farmers in northern state, Sudan. They used stochastic frontier production and cost functions to estimate the economic efficiency of farmers. Their results showed that the mean technical efficiencies of wheat were 75 and 66% in Dongola and Ed-abba, respectively, while for faba bean they were 65 and 71%, the overall mean allocative efficiencies of wheat in the two localities were 72 and 68%, whereas, they were 86 and 84% for faba bean. The predicated overall mean economic efficiencies estimated as inverse of their cost efficiencies of wheat were 41 and 45 percent in the two localities, while in faba bean production they were 57 and 62 percent in Dongola and Ed-abba, respectively. That means farmers who cultivated faba bean were more economically efficient than farmers who cultivated wheat in the two localities and their allocative efficiencies were sources of gain.

Mohamed (2012) carried out his study on economic efficiency of wheat production in Gezira scheme, Sudan. He used stochastic production frontier model to achieve the study objectives. His test result indicated that there was inefficiency in the production of wheat in the study area. Accordingly, the mean economic efficiency of wheat production is 63% which means that economically efficient farmer could produce 37% additional wheat. The main socio-economic factors determining the farmer's economic efficiency appeared to be: the timing of the different agricultural operations, irrigation and land ownership.

A study done by Rafael *et al.*, (2021) on the technical efficiency of sorghum production and its determinants used stochastic frontier production function which incorporates a model of inefficiency effects. He used farm level data collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state. According to his study, land, seed, and 12 fertilizers were the major factors that influence changes in sorghum output and education, extension contact and household size were major explanatory variables that had significant

effects on the technical inefficiency among the sorghum producers. The TE of farmers varied from 15.62 to 92.14% with a mean TE of 72.62%.

In order to identify the determinants of technical efficiency, Adugna *et al.*, (2023) used the Cobb Douglas functional form for rice producers in the Philippines. The results showed that fuel, fertilizer, land rent, planting season and land area were factors that affect the production and technical efficiency of rice production. They found an average technical efficiency score of 0.54. A similar study was made by Mohammed *et al.*, (2024) on rice production in South Korea. It was apparent from their study that it was possible to increase the production efficiency and the effect of the location on the production yield was significant.

2.6. Empirical Evidence on Efficiency in Ethiopia

Abate and Walelign (2023) analyzed of wheat production efficiency, the case of small-scale farmers in Gedeb-hasasa district, West Arsi Zone of Oromia regional state for cross-sectional data in 2009/2010 production year. He used the stochastic Cobb-Douglas frontier functional form to decompose wheat production efficiency into TE, EE and AE estimates. His results indicated that the mean of TE, EE and AE estimates were 89%, 67% and 76%, respectively. His results also showed that livestock ownership, extension contact and slope were positively related to efficiency. On the other hand, off/non-farm income, proximity, market distance, land size and age were negatively related to efficiency.

Adugna *et al.*, (2023) analyzed the efficiency of crop-livestock production and assessing their potential for improvement in North-East Ethiopian highlands. They had used cross-sectional data to analyze the economic efficiency of mixed crop and livestock production system and identify its determinants factors. The parametric method stochastic frontier approach was employed to measure economic efficiency. Their results indicated that most farmers in the study area were not efficient with the mean technical, allocative and economic efficiencies of the household were 62%, 51% and 29%, respectively. Their results also showed that improved agricultural technology adoption significantly improved production efficiency of households.

Adugna *et al.*, (2023) carried out his study on economic efficiency of wheat seed production in Womberma district of west Gojam zone, Ethiopia. He used stochastic production frontier the production of wheat seed in the study area. Accordingly, the mean TE, AE and EE of wheat production is 79.94%, 47.71% and 37.31% respectively which means that efficient farmer could produce 20.06%, 52.29% and 62.69% additional wheat. The main socio-

economic factors determining the farmer's economic efficiency appeared to be: level of education and livestock ownership, family size and total cultivated land.

Kebebew (2021) conducted his study on technical efficiency of malt barley production in South Eastern Ethiopia. He used stochastic production frontier approach to achieve the study objectives. His estimated stochastic production frontiers model indicates farm size of malt barley, DAP, urea, seed, labour and oxen labour are significant inputs that determine production level of malt barley in the areas. His test result indicated that there was inefficiency in the production of malt barley in the study areas. Accordingly, the mean technical efficiency of the farmers of malt barley is 72.5%. His estimated stochastic frontier production model together with the inefficiency parameters shows that education level, number of workable labour force in the households, cooperative membership, number of plots, number of contact with extension agents, access to credit and farming experience of malt barley, number of plots are significant factors that determine efficiency/inefficiency level of malt barley farmers.

Mufti (2019) carried out his study on economic efficiency of rain-fed wheat producer farmers in the case of Robe district, Arsi zone, Oromia national regional state, Ethiopia. He used stochastic production frontier model to achieve the study objectives. His test result indicated that there was inefficiency in the production of wheat in the study area. Accordingly, the mean TE, AE and EE of wheat production are 72.49 %, 42.7 % and 31.65 % respectively which means that efficient farmer could produce 27.51%, 57.3% and 68.35% additional wheat. The main socio-economic factors determining the farmer's economic efficiency appeared to be: sex of the household heads, land fragmentation, fertility status of land, slope, credit use, and training obtained and oxen numbers contributed significantly and positively to TE, while it has inverse related with farm size. The allocative and economic efficiency of the farm household was positively and significantly affected by sex of the household heads, frequency of extension use, oxen number, family size, distance of wheat crop from residence, slope and training shows that these variables.

Milkessa *et al* (2019), out his study on economic efficiency of barley production in Chole District, East Arsi Zone, Oromia National Regional State, Ethiopia. He used stochastic production frontier model to achieve the study objectives. His test result indicated that there was inefficiency in the production of barley in the study area. Accordingly, the mean TE, AE and EE of wheat production are 78.2%, 46.05% and 35.26% respectively which means that

efficient farmer could produce 21.8%, 53.95% and 64.74% additional barley. The main socio-economic factors determining the farmer's economic efficiency appeared to be: level of education total cultivated land extension contact, training, crop rotation and number of livestock.

In summary, different studies conducted by different researchers using different models were reviewed to see the efficiency of farmers and the influence of different agro-climatic and socioeconomic conditions on farmers' efficiency indicated the existence of efficiency differentials among small-scale farmers. Therefore, undertaking studies on farm households' efficiencies in different localities help the policy makers and other development workers to design and implement an appropriate policy intervention.

2.7. Wheat Production in Ethiopia

According to the Agricultural Sample Survey of 2024, there are 4.7 million wheat farmers in Ethiopia. Of these, more than three-quarters (78 percent) live in Oromia and Amhara. CE accounts for 11 percent and Tigray for 8 percent. Less than 3 percent of wheat farmers live in other regions of Ethiopia. The average wheat area per farm is largest in Oromia, where farmers plant an average of 0.43 hectares/hh. This is partly the result of the large farms in Bale, Arsi, and West Arsi, the main wheat growing zones of the country. In contrast, the smallest areas cultivated with wheat are found in CE, where the average is just 0.19 ha/hh. The average wheat area in Amhara, Tigray, and other regions is between 0.28 and 0.39 ha/hh.

Table 11. Number of wheat grower farmers and average wheat area by region

Region	Average wheat area(1000ha)	No of wheat producers(1000s)	(%)	Av. wheat area(ha/hh)
Tigray	113	399	8	0.28
Amhara	530	1,742	37	0.30
Oromia	837	1,949	443	0.43
CE	68	532	11	0.19
Other	50	356	3	0.39

Source: CSA, (2024)

Although small-scale farmers dominate Ethiopian wheat production (and Ethiopian agriculture in general), there are some large-scale commercial farms growing wheat. Large scale wheat production covers about 50-80 thousand hectares of land and produces 150-200 thousand tons of wheat annually.

According to CSA (2020) estimates, Ethiopia produced 3.9 million tons of wheat, making it the largest wheat producer in Africa south of the Sahara by a considerable margin. The

second largest producer is South Africa with 1.7 million tons, followed by Kenya with just 0.5 million tons. On the other hand, Ethiopian production is relatively small by global standards. Its production is surpassed by two North African countries, Egypt, and Morocco, with more than 7 million tons each, and 27 other countries. Ethiopia represents just 0.6 percent of the 713 million tons produced globally grown significantly in the country, rising from around 1.1 million tons in 1995 - 96 to 3.9 million tons in 2013. This represents an average annual growth of 7.5 percent. Despite this rapid growth, there is significant annual fluctuation in production, primarily due to variation in rainfall. The coefficient of variation of wheat production over this period is 44 percent, but the Cuddy-Della-Valle (CDV) index, which measures variability around the trend, is 12 percent. By this measure, the variability of wheat production is substantially lower than that of maize and sorghum production, somewhat lower than that of *teff*, and marginally higher than that of barley production.

In more instinctive terms, wheat production deviates from the trend growth by an average of positive or negative 11 percent. Tilak *et al.* (2024) Wheat is currently grown on 1.6 million hectares in Ethiopia, which makes wheat the fourth most widely grown crop in the country, after *teff*, maize, and sorghum. The wheat area has risen to this level from 900 thousand hectares in 1995-96, representing an annual growth of 3.4 percent despite the rapid growth in wheat area; the importance of wheat among cereals does not appear to have changed significantly. According to data from the Agricultural sample survey, the proportion of cereal area cultivated with wheat has fluctuated between 15 and 18 percent over the past ten years with no discernable trend. This implies that other cereals have expanded their cultivated areas at similar rates over the past 20 years (Adugnaw and Dagninet, 2020).

However, the aggregate and farm level productivity and efficiency of the crop remain in question for the country as a whole and Damot Gale district in particular.

2.8. Conceptual Framework of the Study

Raising agricultural productivity depends critically on improvement of efficiency in production, development and dissemination of cost effective productivity-enhancing technologies, which leads to directly by raising production levels and indirectly by, for example, reducing poverty through raising incomes of farm households, raising employment, lowering the price of food and there by affecting the food security and wellbeing status of rural households. Therefore, agricultural productivity affects food security directly by increasing the available supply of food, particularly for subsistence households, and

indirectly by reducing the shortage of finance of farmers that can be used for the adoption of improved agricultural technologies, increasing production inputs and enhancing efficiency in resource utilization processes.

Efficiency in production is assumed to be affected by a wide range of factors. Efficiency of production was determined by the host of socio-economic and institutional factors (Bealu 2021). These factors directly/indirectly affect the quality of management of the farm's operator and, therefore, are believed to have effect on the level of technical inefficiencies of farms.

From the extensive reviews, the various factors were grouped into the following three broad categories: (1) Demographic (2) Socio-economic and (3) Institutional factors. The factors related to demographic include age and family size. The factors related to the socio-economic include total expenditure, livestock holding, and time of sowing, row planting, and proximity homestead. The institutional factors include use of education, credit and extension service.

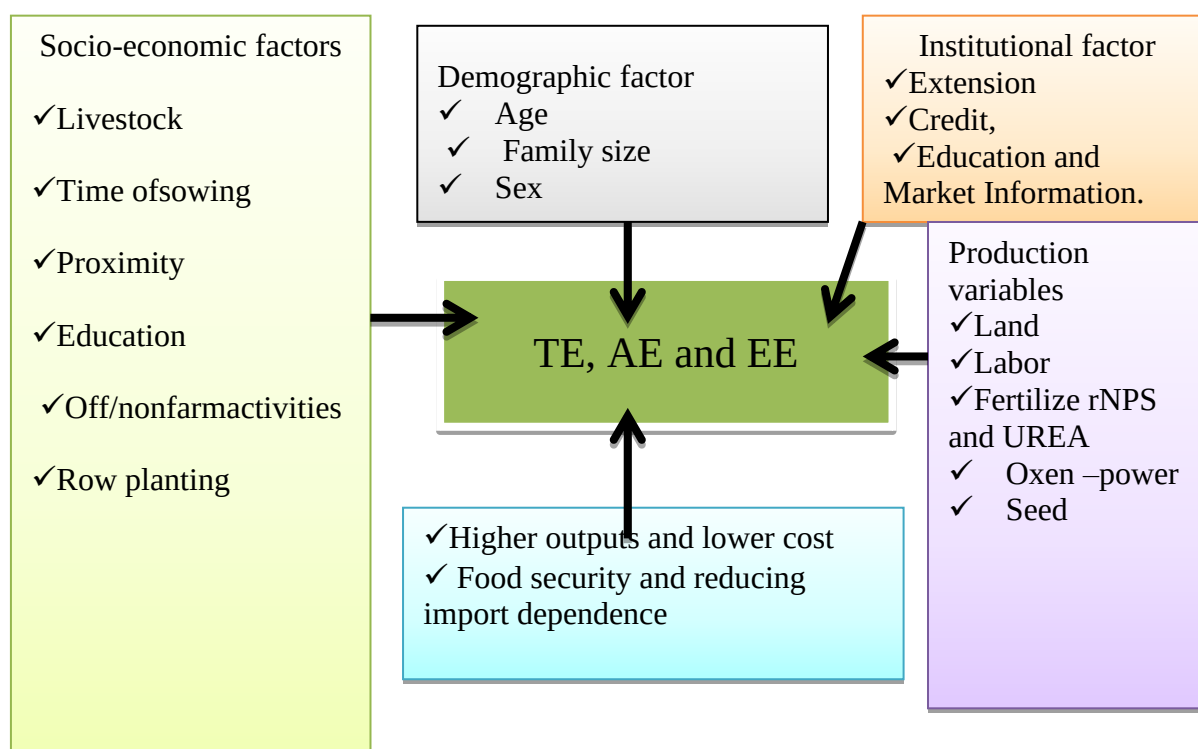


Figure 3. Conceptual framework of overall efficiency in wheat production

Source: Own conceptualization based on literatures (Fategn et al., 2017, Getachew et al., 2018 and Musa et al., 2015)

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, types and sources of data, sampling method and sample size, methods of data collection, methods of data analysis and definitions of variables hypothesized were presented.

3.1. Description of the Study Area

Silti Woreda (7°53'–8°07'N, 38°12'–38°28'E) in Central Ethiopia's Siltie Zone spans 33,140.34 hectares (ha), with elevations ranging from 1,750 to 3,003 meters above sea level (masl). Agro-ecologically, 91% is classified as Weyna Dega (mid-altitude, 1,900–2,500 masl), characterized by undulating terrain (40%), flatlands (54.3%), and hills (5.4%), while 9% is Kola (lowland, 1,701–1,700 masl) (SWAO, 2024). The area receives bimodal rainfall averaging 912–1,160 mm annually, with mean temperatures of 18–30°C, creating favorable conditions for wheat but exposing crops to drought risks during irregular rains (SWAO, 2024; CSA, 2024).

Socio-economically, Silti's 168,751 residents practice mixed crop-livestock farming on fragmented holdings (avg. 0.34 ha/household). Wheat dominates cereal systems, occupying 26.1% of cultivated land (21,567.28 ha) yet yielding only 1.5 t/ha less than half of the national potential (4–8 t/ha) due to low adoption of yield-enhancing practices (e.g., row planting: 32.65%) and limited mechanization (SWAO, 2024; IFPRI, 2020). Farmers integrate wheat with maize, teff, haricot beans, and livestock (cattle, sheep, poultry), using a "cut-and-carry" system due to grazing land shortages. Livestock serve as draft power and income buffers. This synergy underscores the need to analyze efficiency within Silti's unique agro-socioeconomic context.

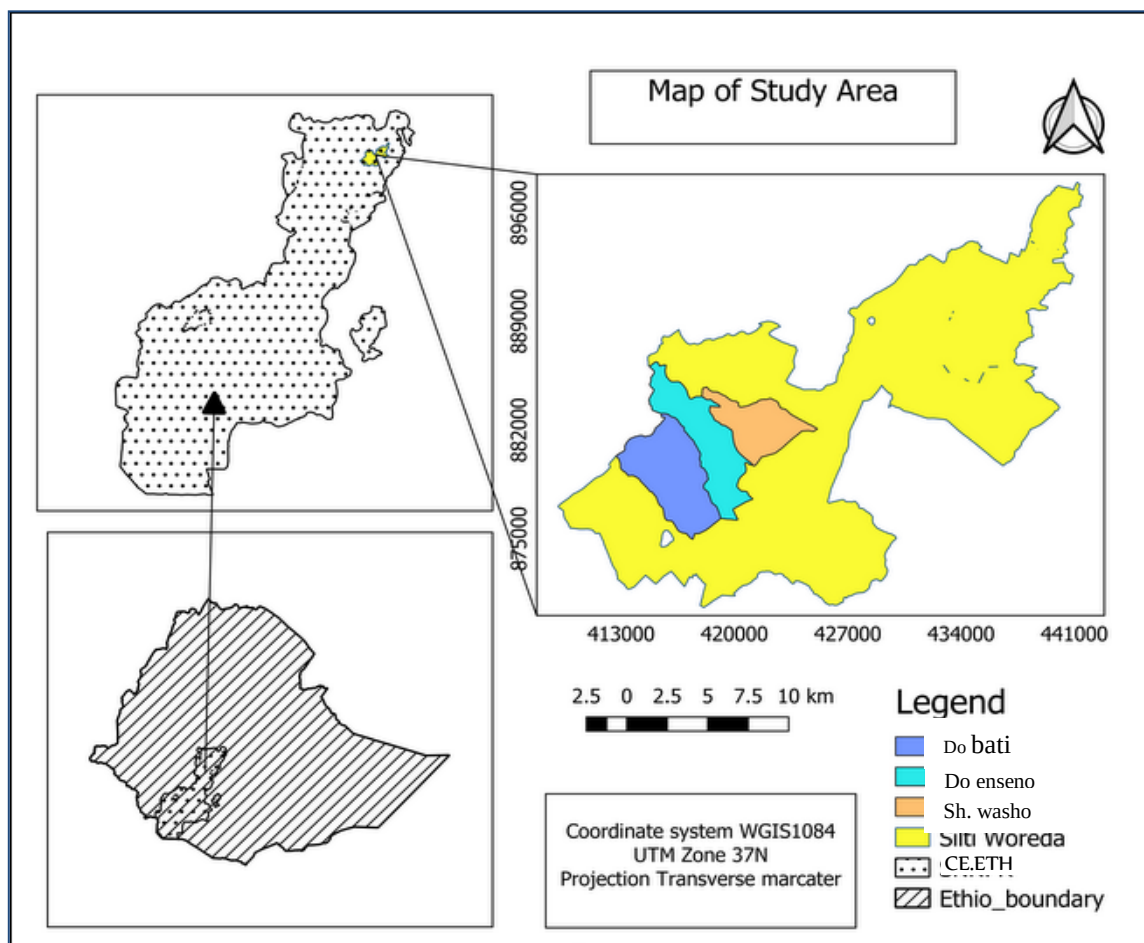


Figure 4. Map of the study area
Source (Nesrie, 2024)

3.2. Data Types, Sources and Methods of Data Collection

Primary data collection employed a structured questionnaire designed around an efficiency measurement framework, covering (1) socioeconomics (landholding size, labor allocation), (2) production metrics (input-output ratios), and (3) institutional drivers (extension frequency). The instrument was pretested in Asano Kebele (non-sampled) to refine clarity and logic, achieving internal consistency guidelines. Enumerators received 1-day training on survey ethics (confidentiality, informed consent), data recording protocols, and local unit conversions (timad to hectares), followed by random back-checks (10% of samples) and focus group discussions (one per kebele) to contextualize quantitative findings.

Primary data was collected using a structured questionnaire built around an efficiency measurement framework. It covered socioeconomic factors like landholding size and labor allocation, production metrics such as input-output ratios, and institutional influences like how often extension services reached farmers. Before rolling it out, we pretested the

questionnaire in Asano Kebele (which wasn't part of the main sample). This helped us fix any unclear or illogical questions and make sure it met internal consistency standards. Our enumerators went through a one-day training that covered survey ethics like confidentiality and informed consent, good data recording habits, and converting local units (timad to hectares). After training, we did random back-checks on 10% of the samples, and held focus group discussions one in each kebele to give context to the quantitative results.

Both qualitative and quantitative data were used. Data was obtained from both primary and secondary data sources. The primary data were collected using structured questionnaire that was administered by the trained enumerators.

3.3. Sampling Method and Sample Size Determination

In order to select a representative sample, three stage sampling procedure was used. In the first stage, Silti woreda was selected purposely due to its potantia in wheat. In the second stage, three kebeles out of the 25 wheat producing kebeles in the district were randomly selected. In the third stage, 196 sample farmers were selected using simple random sampling technique based on probability proportional to the size of wheat producers in each of the three selected kebeles. To obtain a representative sample size, the study employed the sample size determination formula given by **Yamane (1967)** Eq. (8)

$$n = \frac{N}{1+N(e^2)} \quad (8)$$

Where: n –Denotes sample size;

N' –Denotes total number of wheat producing household heads in the district (4,940)

e –Denotes the desired level of precision (taking 7%)

Thus, total sample size of 196 households were selected for the study from three selected *kebeles* and assuming a 95% confidence level and $\pm 7\%$ precision.

Table 22. Selected kebeles and their sample size

Kebele	Household head size	Sample size
Shelewasho	1920	76
Dobena Enseno	1480	59
Dobena Bati	1540	61
Total	4940	196

Source: Own computation (2024)

3.4. Methods of Data Analysis

The study employed both Descriptive and Econometric analysis were used to analyze the data. Descriptive statistics were employed to describe the demographic, socio-economic and institutional characteristics of the wheat farmers. Technical efficiency measurements are basically carried out using frontier methodologies, which shift the average response functions to the maximum output or to the efficient farm. A stochastic frontier model (SFM) was employed to derive efficiency scores for the wheat producers and to determine technical, allocative and economic inefficiency factors respectively.

3.4.1. Descriptive statistics

The data collected on socio-economic, institutional and demographic characteristics of the sample households, are analyzed by using descriptive statistics such as mean, standard deviation, frequency and percentage.

3.4.2. Econometric model

An econometric estimation analysis was initially conducted by defining the production frontier through the Cobb-Douglas stochastic model. This model has provided estimates for the parameters of the production frontier, the efficiency levels, and the significance of various factors contributing to farmers' inefficiency. The null hypotheses concerning the parameters in both the production frontier function and the inefficiency model were evaluated using the likelihood ratio test (LR) as proposed by Coelli (1998).

3.4.2.1. Specification of stochastic frontier model

Crop production in the study area under investigation relies on rainfall, making it vulnerable to unpredictable events like drought and irregular precipitation. Farmers may stray from optimal performance not only due to measurement inaccuracies, statistical fluctuations, or

other external factors but also as a result of inefficiencies. The effects of these random disturbances are distinctly noticeable. To evaluate these circumstances, a stochastic frontier model was employed to analyze the efficiency of wheat production in the area studied.

A stochastic frontier model is favored due to its ability to account for measurement errors and other statistical disturbances that can influence the shape and location of the production frontier. The stochastic frontier production model introduced by Battese and Coelli (1995), which aligns with the foundational models developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977), was utilized to examine efficiency using cross-sectional data.

The stochastic frontier production function of Cobb-Douglas type is defined in logarithmic forms as:

$$\ln(y_i) = \beta_0 + \beta_1 \ln(AREA) + \beta_2 \ln(LAB) + \beta_3 \ln(OX) + \beta_4 \ln(FER) + \beta_5 \ln(SEED) + \exp \varepsilon_i \quad (9)$$

$$i = 1, 2, \dots, N$$

$$\varepsilon_i = v_i - u_i \quad (10)$$

Where, $\ln$ represents natural logarithms,

y represents the wheat output level of sample farmer,

$AREA$ represents the size of land for wheat operation in hectares,

LAB is the quantity of labor power used by the farmer in man-days,

OX is the quantity of oxen power used by the farmer in oxenday,

FER is the quantity of fertilizers used in kilogram and

$SEED$ represents the quantity of seed used in kilogram; e is production coefficient (unknown parameters) to be estimated.

u_i is an error term made up of two components; v_i is random error having zero mean, $N(0, \delta^2 v)$ which is associated with random factors such as measurement error in production and weather which are not control of the farmers and assumed to be independently and identically distributed. u_i is $N(0, \delta^2 u)$ with a random error that is independent of v_i . η_i is the non-negative efficiency measured relative to the stochastic frontier that is firm not attaining maximum efficiency of production and ranges between 0 and 1, which is also assumed to be independently and

identically distributed as half-normal at zero mean or truncated half-normal at mean μ , $N[\mu, \delta^2 u]$ or according to Greene (1990) with two parameter gamma distributions. N represents the number of farmers involved in the survey of the farms.

The variance parameters are:

$$\sigma^2 = \sigma^2 + \sigma^2 v_i \quad (11)$$

And

$$\gamma = \sigma^2 u_i / \sigma \quad (12)$$

The parameter γ must lie between 0 and 1. The maximum likelihood estimation of equation (8) provides consistent estimators for the β , γ and σ^2 parameter, where, σ^2 explains the total variation in the dependent variable due to technical inefficiency (u_i , σ^2) and random shocks (v_i , σ^2) together. Hence, equation (10) and (11) provide estimates for and after replacing σ^2 and γ by their estimates.

The technical efficiency of the farmers can be estimated by using the expectation of conditional on the random variables as shown by Battese and Coelli (1995). The TE of an individual farmer is defined in terms of the observed to the corresponding frontier output given the level of inputs can be calculated as:

$$TE_i = \frac{y_i}{y^*} = \frac{\exp(x_i \beta + v_i - u_i)}{\exp(x_i \beta + v_i)} \quad (13)$$

$$TE_i = \exp(-u_i)$$

Following Bravo-Ureta and Rieger (1991) for a given level of yield of output, the technically efficient input vector of the farmer, is derived by solving (8) and the observed input ratio simultaneously. Assuming that the production function in equation (11) is self-dual (e.g., Cobb-Douglas), the dual cost frontier is derived algebraically and written in the following way:

$$C_i = C(W_i, Y_i^*, \alpha) \quad (14)$$

Where c_i is the minimum cost of the farm associated with the adjusted yield of output Y_i^* and α is a vector of parameters to be estimated. The economically efficient input vector of the farm is derived by applying Sheppard's Lemma and substituting the firm's input prices and adjusted yield of output level into the resulting system of input demand equations.

(15)

$$\partial C_i / \partial W_k = X_{ik} (W_i Y_i^* \psi)$$

Where k represents the total number of inputs used. The observed, technically and economically efficient costs of production of the farm are then equal to and , respectively. According to Sharma *et al.* (1999) these cost measures are used to compute technical efficiency (TE):

$$TE_i = W_i' X_{it} / W_i' X_i \quad (16)$$

Economic efficiency (EE):

$$EE = W_i' X_{ie} / W_i' X_i \quad (17)$$

These cost measures are used to compute TE and AE indices of the farm.

Following Ferrell (1957) allocative efficiency (AE) can be derived from equation (15) and (16) as,

$$AE = W_i' X_{ie} / W_i' X_{it} \quad (18)$$

The production frontier was estimated using frontier model whereas the cost frontier will be derived analytically from production assuming self-dual.

Aigner *et al.* (1977) proposed the log likelihood function for the model in equation (9) assuming half normal distribution for the technical inefficiency effects (u_i). They expressed the likelihood function using λ parameterization, where λ is the ratio of the standard errors of the non-symmetric to symmetric error term (i.e. $\lambda = \sigma u / \sigma v$). However, there is an association between γ and λ . The reason is that λ could be any non-negative value while γ ranges from zero to one and better measures the distance between the frontier output and the observed level of output resulting from technical inefficiency. According to Bravo and Pinheiro (1997) gamma (γ) can be formulated as:

(19)

$$\gamma = \left[\frac{\lambda^2}{(1 + \lambda^2)} \right]$$

The parameter γ quantifies the difference between the frontier output and the actual observed output, reflecting the total variation in output from the frontier that is due to technical

inefficiency. Its value ranges from zero to one. A value of zero signifies that the non-negative random variable, u_i , is not present in the model, while a value of one indicates that there is no statistical “noise” or external “shocks” affecting the model, resulting in a lower level of production for the farm compared to the optimal output achieved by other farms, which is entirely attributed to specific inefficiencies of the farm. Additionally, the significance of σ^2 determines whether the traditional average production function is an adequate representation of the data.

In numerous investigations into technical efficiency, the findings are utilized to assess the impact of different factors on inefficiency. These effects can be estimated through either a one-stage or a two-stage approach. According to Coelli et al. (2006), a significant issue with the two-stage method is the inconsistency in the assumptions regarding the distribution of inefficiencies.

In the first stage, inefficiencies are assumed to be independently and identically distributed in order to estimate their values. However, in the second stage, estimated inefficiencies are assumed to be a function of a number of firm-specific factors, and hence are not identically distributed (Coelli *et al.*, 1998).

Therefore, one-stage estimation procedure of the inefficiency effects model together with the production frontier function was implemented in this study for technical efficiency. This is due to not only inconsistency problem but also γ which shows variation due to inefficiency is better represented by single stage as compared to R^2 of OLS.

Given the absence of boundary efficiency values (i.e., no observations at 0 or 1) in the dataset indicating no fully efficient or fully inefficient farmers—allocative (AE) and economic efficiency (EE) determinants were analyzed using Ordinary Least Squares (OLS) regression. OLS was deemed appropriate over censored regression models (e.g., Tobit) due to the uncensored nature of the efficiency scores and better suitability of the dataset for linear estimation. Furthermore, a generalized likelihood ratio (LR) test was conducted to select the optimal functional form. The LR statistic tested the null hypothesis $H_0: \beta_{ij}=0$ (all interaction and squared terms equal zero), calculated as:

$$LR = -2(LC - LT) \quad (19)$$

where L denotes the log-likelihood value under each specification."

Where: LR= Generalized log-likelihood ratio;

LC = Log-likelihood value of Cobb-Douglas frontier; and

LT = Log-likelihood value of Translog frontier.

This value is then compared with the upper 5% point for the χ^2 distribution and the decision was made based up on the model result. If the computed value of the test is bigger than the critical value, the null hypothesis will be rejected and the Translog frontier production function would better represent the production technology of farmers.

3.5. Variables Definition and Hypothesis

3.5.1. Production function variables

These are the dependent and independent variables measured in physical terms. These variables were used in determining the stochastic frontier production function of wheat in the study area and are specified as follows

Output (OUTPUT): It is output of wheat produced by sample households in quintals in the year 2023/24 production season, which is the dependent variable in the estimation of production functions

Inputs: This refers to explanatory variables used in the estimation of production functions.

In this study, a total of four production functions were fitted, independently. The variable definitions are same for all functions.

Land (LAND): This refers to the physical unit of land area under wheat cultivation expressed in hectare (ha). A study conducted by Hossain (2016), Araya *et al.* (2019) and Dagineh and Endrias (2020) found that land size will be positively affecting technical efficiency of pepper production. Hence, a household with large land size was hypothesized to be more technically efficient than household with less land size. Basically, positive coefficient was expected.

Human labor (LABOR): Represents the total human labor employed in the wheat production process. The type of person participated in the given activity by categorizing as children, men and women. Labor inputs used for major agronomic activities were converted into man equivalent. The man-equivalent was computed by taking into account the age and sex of the labor used following standard conversion factor developed by Araya *et al.*, (2019). Therefore, the human labor input was expressed in terms of total man-equivalent employed to

perform land preparation, planting, input application, cultivation, pre-harvesting and threshing of wheat production.

Oxen power: Given small scale farmers and less mechanized farming exercise in the study area, oxen power are among major inputs of production. In the study area, task of ploughing are often done using oxen. Hence, oxen power was measured using the total amount of oxen days allocated for ploughing activities of wheat production. It was measured in oxen-days (one oxenday is equivalent to eight working hours).

Seed (SEED): It refers to the quantity of wheat seed used in kilogram by the household. Thus, seed used measured in kilograms was used for analysis. The estimated coefficient of seed shows the effect of change in seed on red pepper output. According to studies conducted by Hossain (2016) Fatima and Araya *et al.* (2019) investigated that utilization of improved seed have been important inputs for pepper cropping system production and technical efficiency among smallholder farmers. The estimated coefficient was expected to have a positive effect on technical efficiency.

Chemical fertilizer (FERT): It is an important input for production. Unlike the old days, there is an increased demand and use of chemical fertilizers in Ethiopia (Hossain, 2016; Araya *et al.*, 2019). Hence, Urea and DAP applied by sample households measured in Kg was used in this study.

3.5.2. Cost function variables

These include variables used in the dual frontier cost function derived from the stochastic Cobb Douglas production function. These variables indicate the monetary values of inputs used for a given physical quantity of wheat output. Thus, the relative measures of cost minimization and resource allocation are depicted by the levels of cost and allocative efficiencies for sample households in the study area. These variables were assumed to be positively related to the total variable costs of wheat production.

Price of land (PLAND): It is the annual cost of land (i.e. payments for tax) expressed in Birr was used as a price of land.

Price of labor (PLAB): It is the average wage of 300 Birr/man-day for hired labor used in wheat production process.

Price of oxen (POX): It is the average payment of 250Birr/oxen-day for oxen used in wheat production process.

Price of fertilizer (PFERT): This refers to the payment of 60 Birr/kg for DAP and 55Birr/kg for urea applied by each farmer in wheat production in the study area.

Price of seed (PSEED): It is the price of seed 70 Birr/kg used for wheat production in the study area.

Output(Y*): It is the observed wheat yield adjusted for noise and expressed in quintals for the households in the study area.

3.5.3. Definition of inefficiency variables and hypothesis

From several review of previous studies on production efficiency and factors affecting efficiency of production, the following variables were hypothesized to affect efficiency of wheat production.

1. **Sex of household head (SEX):** It is dummy variables whether participants in wheat production activity (ploughing, harvesting and etc) is male (1) or female (0). Male farmers are more likely to attend meetings, frequent follow-ups and supervisions of their farms than females. The assumption is that, firstly, women in the area do not carry on plowing by themselves. The practice is either they rent out their land for sharecropper or look for someone who does the plowing operation, which affect 51 timely operation. It was hypothesized as male participants were more Technically, allocatively and economically efficient than a female participant. It has a significant negative effect (in favour of male) on allocative efficiency (Getachew *et al.*, 2018).
2. **Age of household head (AGEHH):** The age of the household head in years is hypothesized to reflect experience and physical strength of the farmer on efficiency. It is commonly believed that age can serve as a proxy for farming experience. This indicates that the older farmers are more efficient than the younger ones. Since farming as any other professions needs accumulated knowledge, skill and physical capability, it is decisive in determining efficiency positively and significantly in the study of Mubeshir (2023). The knowledge as well as skills of farmers is likely to increase as their age increases. Hence, age was hypothesized to have positive effect on efficiency.
3. **Education (EDUCLVL):** This is educational level of the household head measured in level of grade the respondent attended. Education contributes positively towards efficiency, as it is believed that education increases human skill and contributes

positively to change farmers, attitudes towards modern technology. Education enhances the ability of farmers to see and make good use of information about production inputs to increase output through improving the efficient use of inputs. The coefficient of years of exposure to education is positively related to technical efficiency in studies conducted by Abate *et al.*, (2019). Therefore, in this study education was expected to affect efficiency of wheat production positively.

4. **Credit use for wheat production (CRDT):** This is a dummy variable that represents using any form of credit for wheat production purposes by the farmer. It denotes credit used (1 if the farmer used credit and 0 otherwise); most farmers are poor, so credit access can contribute to stimulate the farmers to uptake the improved seed fertilizer packages (Lemessa *et al.*, (2017). Hence, this variable was expected to have positive effect on efficiency of wheat production.
5. **Number of extension contact (EXTCT):** As part of agricultural extension, system, there are three agricultural extension experts that deal with helping farmers in adopting improved technologies, building the managerial capacity of the farmer and enhancing productivity in every *kebeles*, in Ethiopia. It is taken as a continuous variable and measured by the frequency of extension service. Extension access is a necessary catalyst to technology adoption and includes training which is an important tool in building the managerial capacity of the farmer. All farmers expected to have equal access to extension service, but may not have equal access in terms of frequency of giving service. Extension determined the efficiency level of farmers positively and significantly in the study of Mubeshir (2023). Therefore, for this study, number of extension contact was expected to have a positive effect on efficiency.
6. **Total expenditure (TOTEXP):** This is a continuous variable measured in monetary terms (birr). It includes all expenditures of the household on consumption, education, medication and social obligation. But this did not include expenses related to purchase of inputs and investments made on wheat production to avoid double counting. Households with much expenditure are usually constrained to buy inputs that would support their agricultural activities in the study of Jema (2008). It has also a negative and significant impact on allocative efficiency because; it may compete with limited cash available, Mohamed (2023). It was expected to have a negative effect on efficiency in this study.

- 7. Off/non-farm income (OFARM):** This was treated as a dummy variable and measured as 1 if the household was involved in off/non-farm activities and, 0 otherwise. The availability of off/non-farm income shifts the cash constraint outwards and enables farmers to make timely purchases of those inputs which they cannot provide from on farm income. Therefore, it enables farmers in maximizing its output at efficient cost of production (Mohamed, 2014) but it may have negative effect if the farmer spends most of his time on other activities. Therefore, it was hypothesized off/non-farm income was expected to have either a negative or positive effect on efficiency.
- 8. Family size (FAMSIZE):** Family is an important source of labor supply in the area. It is expected that households with many family members have better advantage of being able to use labor resources at the right time, particularly during labor peak periods. Family size could have positive effect in raising the farmers' production efficiency, if actually the members are in the working force. In this study, the number of persons the household head administers/supposed to manage was considered as family members, regardless of blood relationship. This was measured in man equivalent; to capture the difference in age and sex. Since labor is the main input in crop production, farmers having large family size would manage crop plots on time (Essa, 2011). Given labor as the main input in the production of wheat, it was hypothesized to have positive influence on efficiency.
- 9. Livestock ownership (TLU):** This is the total number of livestock of the household in terms of Tropical Livestock Unit (TLU). The variable used as proxy for wealth, farmers with more livestock units, which can readily be converted to money can be able to buy improved inputs than those that own fewer livestock units. Moreover, families with more animals are more likely to have larger protein intake than those with fewer animals, which helps improve their working efficiency (Fantu *et al.*, 2011). It was hypothesized to have positively related to efficiency.
- 10. Row planting (RPLANT):** It is also a dummy variable which represents whether the farmer adopted row planting practice or not during the 2023/2024 production season. It takes the value of one if the farmer adopted it and zero, otherwise. It was hypothesized as farmers who practiced row planting can be more efficient than his/her counter-parts as row planting requires fewer seeds than broadcasting, making it

possible to use less seed on the same area of ground. The study by Tolosa *et al.* (2014) showed that the mean yield of row planted wheat was higher by 13.9% when compared to mean yield of broadcast planting method. Therefore, it was hypothesized to have affect efficiency positively.

11. Proximity to homestead (PROX): It is defined as the average distance of the farm plots from the house of the household in kilometer . This is because those farms near to homestead will save travel time and then get more management; whereas, those farms far away from household's residence will receive less management and the frequency of visits may reduce. Therefore, it is hypothesized that distance of wheat farms to have negatively related to efficiency (Getachaw, 2018).

This variable is continuous; which is measured by kilometer in which the wheat plot land far from home. The furthest the distance from the farmer field, the less the supervision then less efficiency of farmers increases as the distance between farm and homestead increases. It was hypothesized as; the high distance between home and plot has a negative effect on technical, allocative and economic efficiencies. A high distance of plot land for production from home has a negative effect and significant at 1% significance level

12. Time of sowing (TOS): Sowing time is a dummy variable where 0 indicates late sowing and 1, otherwise. Early sowing starts from mid to end of July and late sowing is in end of August in the study area. A study by Mekedes (2011) indicated that time of sowing was found to be positively related to technical efficiency of irrigated lentil production in Gimbichu district, Ethiopia. In this study, it was hypothesized that time of sowing to have positive relation with technical efficiency of wheat.

13. Access to market information (mktinfo); this is a dummy variable taking value of 1 if the producer had access to market information and zero otherwise The better information farmers had the more efficient **utilization** of inputs which in turn increases the technical efficiency of red pepper production. The general idea is that maintaining a competitive advantage requires a sound business plan which means producing optimum red pepper. Therefore it was expected positive relationship with technical efficiency. In this study Access to market information was expected to have a positive effect on technical efficiency.

Table 33. Review on determinants of efficiency

Efficiency determinants	Measurement unit	Expected sign	Authors
Age of household head	Years	Positive	Degefa 2017
Sex of household head (if male household head)	Dummy	Positive	Fantu et al. 2011
Education level of household head	Years of formal schooling	Positive	Mustefa <i>et al.</i> 2017
Total number of household members	Man equivalent	Positive	Sorsie <i>et al.</i> 2015
Total area of crop land held by household head	Hectares	Negative	Lemessa et al. 2017
Total livestock holding	TLU	Positive	Tsegaye and Ernst
Fertility status of wheat plot	Dummy	Positive	Bati, Tilahun, and KumarParabathina 2017
Proximity to homestead	Kilometer	Negative	Tefaye and Beshir 2014
Uses of credit	Dummy	Positive	Meja, Alemu, and Shete 2021
Frequency of extension contacts	Numbers	Positive	Doo-Young et al. 2020
Off-/non-farm income	Dummy	Positive	Qamar et al. 2016
Access to market information	Dummy	Positive	Mubeshir 2023
Time of sowing	Kilogram	Positive	Fetagn 2017

Source: Review from literature (2024)

4. RESULTS AND DISCUSSION

This chapter presents and discusses the study descriptive statistics and econometric model results.

4.1. Descriptive Statistical Results

This sub-section describes the key demographic, socioeconomic, institutional and production characteristics of the sampled households in the study area.

4.1.1. Demographic and socio-economic characteristics of sample households

Table 4 shows a socio-economic profile of the studied population. We're looking at a middle-aged group here the average age is 42.6, with a standard deviation of 10.2, so it's not super varied. People tend to live in fairly large households, about 5.8 members on average. The numbers also reveal a lot of economic diversity. Annual expenditures range from birr 3,200 up to 41,000. The mean is 8,763, but with a standard deviation of 9,598, you can tell there's quite a bit of income inequality.

On the agricultural side, households own a modest amount of livestock an average of 4.12 Tropical Livestock Units but ownership does vary among families. Most homes are located close to key services, with an average distance of 15 units and a standard deviation of just 1.13, so that part is pretty consistent. One thing that really stands out is the low level of contact with agricultural extension agents. The mean is only 1.8 times per period, and while a few families report much higher contact, most have very limited access to formal advisory services. It's clear that access is pretty scarce for the majority.

Table 44. Descriptive statistics of sample households characteristics for continues variables

Variables	Mean	Std.	Minimum	Maximum
Age	42.6	10.2	27	89
Family size	5.8	2.4	2	11
Total expenditure	8763	9.598	3200	41000
Livestock(TLU) /ox	4.12	1.3	1	12
Proximity	15	1.13	6	35
Extension contact	1.8	1.2	1	16

Source: Own computation (2024)

Table 5 depicted that is predominantly male (89.29%), The educational attainment is notably low, with the vast majority (87.76%) having no formal education beyond basic literacy ("Read and write" at 43.37%) or being illiterate (26.53%); only a small fraction (4.59%) reached high school. Economically, access to off-farm income is limited for most households

(77.04% have none), indicating a heavy reliance on farming. However, the community shows strong adoption of certain modern agricultural practices, with a majority practicing row planting (67.35%) and sowing at the recommended time of sowing (75.51%). Finally, access to formal credit is almost evenly split, with a slight majority (53.57%) having no access, which can be a significant constraint on investing in agricultural inputs and technology. In summary, the data depicts a traditional, male-headed agrarian community with low educational levels and limited off-farm economic opportunities, but one that is actively engaging in improved farming techniques despite moderate barriers to financial services.

Table 5 5. Descriptive statistics of household characteristics for categorical variables

Variable	Category	Frequency	Percent
Sex	Female	21	10.71
	Male	175	89.29
Education level	Illiterate	52	26.53
	Read and write	85	43.37
	Elementary (1-4)	35	17.86
	Secondary (5-8)	15	7.65
	High school (9-10)	9	4.59
Off-farm income	Yes (1)	45	22.96
	No (0)	151	77.04
Time of sowing	Yes (1)	148	75.51
	No (0)	48	24.49
Row planting	Yes (1)	132	67.35
	No (0)	64	32.65
Credit access	Yes (1)	91	46.43
	No (0)	105	53.57

Source: Own computation (2024)

4.1.2. Livestock ownership

Table 6 shows that, an oxen ownership is a critical constraint for agricultural productivity in the study area. The data shows that the vast majority of households (68.37%) own only a single ox, which is insufficient for plowing as teams of two are typically required, forcing these farmers to rely on borrowing or rental arrangements. A significant minority (10.71%) own no oxen at all, making them highly dependent and vulnerable, while only a privileged 20.92% own the ideal pair, granting them full autonomy and likely higher agricultural output.

Table 66. Oxen ownership of the sample households

Oxen number	Frequency	Percent
0	21	10.71
1	134	68.37
2	41	20.92
Total	196	100

Source: Own computation (2024)

This table shows that livestock ownership among the farmers is pretty mixed most keep small numbers of animals, and there's a lot of variety from one household to the next. You really see the gaps when you look at the numbers for Sheep and Goats (average of 3.67 animals, but with a standard deviation of 2.07) and Chickens (average of 3.58, standard deviation 2.94). So, while lots of people have just a few, some own much more, and it really skews the spread. Small ruminants like sheep and goats, as well as chickens, are the most common nearly every household that has livestock keeps these. For most people, they're an important asset. On the other hand, bigger animals like cows (average 1.12) and donkeys (average 0.75) are much less common and usually kept in very small numbers. These animals are generally used for tasks like plowing or for milk, not for large-scale farming or selling. The fact that the average number of calves per household is 1.56 just shows herds are actively reproducing. And here's a key point at least some households own zero animals in every single category. Not every family owns livestock, and quite a few have none at all. This detail really points to underlying inequalities and the kinds of vulnerability you find in rural communities. owns every kind of animal and that a sizable percentage of the population may not possess any livestock at all.

Table 77. Livestock holding (excluid ox) of the sample farmers

Livestock types	Minimum	Maximum	Std.	Mean
Sheep and goat	0	9	2.07	3.67
Cow	0	3	0.73	1.12
Donkey	0	2	0.5	0.75
Calves	0	2	1.1	1.56
Chicken	0	21	2.939	3.58

Source: Own computation (2024)

4.1.3. Crops production and area coverage

Wheat is the dominant crop in terms of both land allocation and total output, accounting for the largest average area cultivated (0.46 hectares) and yielding the highest average harvest (20.24 quintals). This suggests that wheat is a staple food and likely a key source of both sustenance and income for the farming community. Maize is the second most important crop, cultivated on an average of 0.16 hectares and producing an average output of 9.44 quintals. In contrast, Teff and Haricot beans are allocated significantly less land (0.07 ha and 0.03 ha, respectively) and consequently generate much smaller average harvests (1.26 qt and 0.75 qt). This indicates that these latter crops are likely grown on a smaller scale, perhaps for household consumption, crop rotation, or as niche products rather than as primary staples.

Table 88. Average production of crop output and area allocated by the sample households

Crop type (ha)	Area(ha)	Productivity/ha	Output of crops(qt)
Wheat	0.46	44	20.24
Maize	0.16	59	9.44
Teff	0.07	18	1.26
Haricot bean	0.03	25	0.75

Source: Own Computation (2024)

4.1.4. Description of production function and variables

Table 9 presents that wheat production in the study area is characterized by moderate average yields (25.51 qt/ha) but with significant variability (Std. 6.87), indicating considerable differences in farming efficiency and practices among the small-scale farmers. The primary constraints to achieving the recommended yield potential appear to be the sub-optimal application of key inputs; while DAP use (mean 61.74 kg/ha) is closer to the advised 100 kg/ha, urea application (mean 43.52 kg/ha) falls drastically short, which likely limits productivity. Furthermore, production is highly labor-intensive (68 man-days/ha) and dependent on oxen power (7.68 days/ha), with the data showing that these two factors are complementary—households with better oxen resources can utilize labor more effectively for timely land preparation and other critical activities. The combination of small plot sizes (mean 0.34 ha), variable input use, and reliance on coordinated draft power and labor explains the observed yield variations and underscores the opportunity for increasing output through improved input access and adoption of recommended practices.

Table 99. Descriptive statistics of input and output variables in production function

Variable	Measurement	Min	Mean	Max	Std.
Yield	quintal(qt)	5	25.51	45	6.87
Area	hectare(ha)	0.125	0.34	0.75	0.16
Seed	kilogram(kg)	38.15	45.35	71.82	15.21
Dap	kilogram(kg)	15	61.74	76.23	17.61
Urea	kilogram(kg)	25	43.52	71.65	14.99
Oxen	Days	4	7.68	17	3.51
Labor	man-eqvt	51	68	141	30.21

Source: Own computation (2024)

4.2. Econometric Model Outputs

4.2.1. Test of hypothesis

Before proceeding to the estimation of the parameters of the model from which individual level efficiencies are estimated, it is essential to examine various assumptions related to the model specification. To do this, two hypotheses were tested. The first test was to examine whether the average production function (without considering the non-negative random error term) best fits the data so as to verify whether there exists considerable inefficiency among farmers in the production of wheat in the study area. Table 10 results revealed that, the model specification tests confirm several critical findings about wheat production in the study area. First, the acceptance of the null hypothesis ($H_0: \beta_6 = \beta_7 \dots \beta_{27} = 0$) indicates that the more complex Translog functional form is not superior to the Cobb-Douglas specification, meaning the simpler Cobb-Douglas model adequately captures the relationship between inputs and output without needing interaction or squared terms. Second, the decisive rejection of the hypothesis that inefficiency is absent ($H_0: \gamma = 0$) confirms that significant technical inefficiency exists among wheat farmers, as the calculated LR (65.24) vastly exceeds the critical value, proving that the stochastic frontier model is necessary and that farmers are not operating at full potential. Finally, the rejection of the hypothesis that all inefficiency effect coefficients are zero ($H_0: \delta_0 = \delta_1 \dots \delta_{11} = 0$) demonstrates that the included socio-economic and farm-specific variables collectively play a statistically significant role in explaining the variation in this inefficiency across households, even though the individual variables may not all be strong predictors. In summary, the production process is best modeled by a Cobb-

Douglas stochastic frontier, which reveals significant and explainable inefficiencies among farmers.

Table 1010. Generalized likelihood ratio test of hypotheses for parameters of SPF

Null hypothesis	D. freedom	H0	H1	Calculate dLR	χ^2 Value	Decision
$H_0: \beta_6 = \beta_7 \dots \beta_{27} = 0$	21	76.09	90.24	28.3	32.67**	Accepted
$H_0: \gamma = 0$	1			65.24	3.84**	Rejected
$H_0: \delta_0 = \delta_1 \dots \delta_{11} = 0$	11	29.94	68.57	77.26	19.675**	Rejected

*** at 1%, ** at 5% and * at 10% significance level

Source: Own computation (2024)

4.2.2. Parameter estimates of the SPF model

The ML estimates of the parameters of the SPF specified in equation (8) were obtained using STATA 16 computer program. These results ML estimates of the average production function are presented in Table 11.

Table 1111. ML estimates of the parameters of the Cobb-Douglas SPF

Variables	ML estimate		
	Coefficient	Std. Error	Elasticity
ln(land)	0.0325 ***	0.1202	0.31
ln(labor)	0.2025**	0.04736	0.26
ln(oxen)	0.0675 ** *	0.0356	0.067
ln(seed)	0.1906	0.1745	
ln(DAP)	0.0716 ***	0.0383	0.0332
ln(urea)	0.0332	0.1042	
Constant	0.3243	0.1207	
Sigma-v	0.1448	0.023	
Sigma-u	0.1948	0.039	
Sigma square	0.0617	0.0407	
lambda δ_u / δ_v	1.32	0.74	
log likelihood	32.68		
Gamma $\gamma = \delta_{2u} / \delta$	0.7524		

** and *** show significant at 5% and 1% level of significance respectively

Source: Own computation (2024).

Among the six variables evaluated in the production function, four (labor, oxen, land, and DAP) significantly impacted the variation in wheat production among farmers. The coefficients of the production function are interpreted as elasticity. Therefore, the high elasticity of output concerning Land (0.31) indicates that wheat production was relatively sensitive to Land. Consequently, a 100% increase in land requirement will result in a 31%

increase in wheat output, keeping other factors constant. Alternatively, this indicates that wheat production was responsive to land, followed by labor, oxen, and urea, respectively.

The diagnostic statistics for the inefficiency component show that sigma squared (σ^2) was statistically significant at the 1 percent level. This suggests a good fit and validates the assumed distributional form for the composite error term.

The sum of the coefficients was 0.74, indicating that the process is in stage II of production, where increasing input results in higher output at a decreasing rate. This suggests that farmers are experiencing diminishing returns to scale (Table 11) and highlights the opportunity for wheat producers to boost their output. Although they are operating in stage II of the production function, the inefficient allocation of resources implies that there is still room to expand production, albeit at a diminishing rate. In other words, a one percent increase in all inputs leads to a 0.74 percent increase in total production, which reflects decreasing returns to scale. This finding is consistent with the results of Mufti et al. (2019) and Mubeshir (2023), who estimated the returns to scale at 0.61% and 0.96% respectively in their research, both of which also fall within stage II of the production curve.

The ratio of the standard error of u (σ_u) to the standard error of v (σ_v), referred to as lambda (λ), was 1.32. The calculated value of gamma was 0.7524, which signified that 75.24% of the total variation in wheat farm output was attributed to technical inefficiency. The findings from the stochastic production frontier indicated that the production function was accounted for by the individual factors of land, labor, fertilizer, oxen labor, and quantity of seed.

The dual frontier cost function derived analytically from the stochastic production frontier shown in Table 12 was formulated as:

$$\ln c = 0.0332 + 0.0325 \ln w_1 + 0.2025 \ln w_2 + 0.0675 \ln w_3 + 0.1906 \ln w_4 + 0.0716 \ln w_5 + 0.0332 \ln w_6 + 0.37 \ln y^*$$

Where c is cost of producing wheat output; w_1 refers to the average rent value of land per hectare, w_2 is average wage rate; w_3 is the average oxen rent value in the study area; w_4 is price of kg of seed; w_5 price of kg of DAP, w_6 is price of kg of urea and y^* is total amount of wheat output produced in quintals adjusted for statistical noise.

4.2.3. Efficiency scores

The analysis of efficiency scores showed significant variability in technical efficiency (TE), allocative efficiency (AE), and economic efficiency (EE) among wheat farmers. The average

TE was determined to be 69.7%, indicating that, on average, farmers could reduce their use of inputs such as labor, oxen, seed, and urea by 30.3% if they achieved technical efficiency. In other words, this suggests that farmers could increase their current output by 30.3% through the efficient use of available resources and technology. This substantial disparity in individual farmer technical efficiency levels is consistent with study of Hassen *et al.* (2021) and Mustefa (2024).

The average allocative efficiency (AE) was determined to be 48.95%. This suggests that, on average, wheat farmers can reduce their input costs by 51.05% by adopting cost-minimizing practices. In different analytical terms, the mean allocative efficiency of 48.95% (Table 13) reveals a need to enhance the current level of allocative efficiency. Furthermore, the findings suggest that farmers have significant potential to improve their allocative efficiency. For example, a farmer with average allocative efficiency could achieve a cost saving of approximately 51.05% from $(1 - 0.4895/0.9908) \times 100$ to reach the efficiency level of the most effective farmer. Moreover, the economic efficiency (EE) of 40.12% indicates that an economically efficient farmer could produce an additional 59.88% of wheat by minimizing costs.

The mean economic efficiency also showed that there was a significant level of inefficiency in the production process. That is the producer with an average economic efficiency level could reduce current average cost of production by 40.12% to achieve the potential minimum cost level without reducing output levels. It can be inferred that if farmers in the study area were to achieve 100% economic efficiency, they would experience substantial production cost saving of 40.12% . This implied that reduction in cost of production through eliminating resource use inefficiency could add about 40.12% of the minimum annual income (Table 12).

Table 12. Estimated technical, allocative and economic efficiency scores of the sample farmers

Type of efficiency	Mean	Std.Dev.	Minimum	Maximum
TE	69.7%	0.1802	0.2584	0.9919
AE	48.95 %	0.0981	0.3237	0.9908
EE	40.12 %	0.0906	0.1301	0.9723

Source: Own computation (2024)

Based on the frequency distributions presented in Table 13, the results reveal a widespread prevalence of inefficiency among the sample farmers, with allocative inefficiency being the most severe constraint. The fact that a majority (79.59%) of farmers are operating below the sample mean for Allocative Efficiency (AE) indicates that most are not making the most cost-

effective combinations of inputs given their prices, which directly undermines their profitability. This is compounded by the fact that just over half of the farmers are also operating below the mean for Technical Efficiency (TE) (52.04%) and Economic Efficiency (EE) (53.06%), meaning more than half are failing to maximize output from a given set of inputs and are not achieving overall optimal economic performance. Consequently, while there is a near-even split between high and low performers in technical and economic efficiency, the overwhelming majority's inability to allocate resources cost-effectively (AE) represents the most critical barrier to improving overall farm productivity and income in the study area.

Table 1313. Frequency distribution of farmers operating from all sample mean

Estimates	TE		AE		EE	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Operating below sample mean	102	52.04	156	79.59	104	53.06
Operating above sample mean	94	47.96	40	20.41	92	46.94

Source: Own computation (2024)

4.2.4. Determinants of efficiency differentials in wheat production among farmers

In this section econometric results of the Tobit regression model results of the study are presented and discussed. Before conducting the econometric analysis, the data was examined for various econometric issues. The data was assessed for heteroskedasticity using the Breusch-Pagan test, and the results indicated no significant heteroskedasticity problem (see Appendices 1). A multicollinearity test for the independent variables was performed using the Variance Inflation Factor (VIF). This test was conducted using the DATA 16 software program to analyze the VIF values for both input and inefficiency variables. There is no significant linear relationship among the explanatory variables, as the VIF values are less than 10 (see Appendices 2 and 3).

Table 14 Tobit regression results for the significant variables were discussed as follows.

4.2.4.1. Determinants of technical efficiency of wheat producing farmers

1.Credit usage exhibited a positive and significant ($p<0.05$) relationship with technical efficiency. This suggests that access to credit provides farmers with the necessary capital to purchase and timely apply improved inputs like seeds and fertilizers, thereby enhancing their ability to maximize output from a given set of resources. This finding aligns with research by

Awotide et al. (2020) in Nigeria, who found that credit constraints were a major barrier to the adoption of productivity-enhancing technologies, and access to formal credit significantly improved farmers' technical efficiency.

2. Extension contact was positive and significant ($p < 0.05$) for technical efficiency. This indicates that advice and information from agricultural extension agents equip farmers with the knowledge to implement improved agronomic practices, leading to better resource utilization and higher yields. Empirical support comes from a study by Abebe et al. (2020) in Ethiopia, which concluded that regular extension contact was a critical factor in reducing technical inefficiency by disseminating knowledge on optimal planting dates, pest control, and input use.

3. Off-farm income had a strong positive and significant ($p < 0.01$) impact on technical efficiency. This is likely because supplementary income reduces liquidity constraints, allowing farmers to purchase inputs in optimal quantities and at the right time without resorting to distress sales of assets. This corroborates the findings of Dillon et al. (2019), who argued that off-farm income stabilizes rural households, reduces risk aversion, and provides crucial cash flow for investing in agricultural production, thereby improving efficiency.

4. Tropical Livestock Unit (TLU) showed a significant negative ($p < 0.05$) coefficient. This implies that larger livestock holdings may divert labor, capital, and management focus away from crop production, leading to inefficiencies in the wheat enterprise. This finding is consistent with Bachewe et al. (2018), who found that in mixed crop-livestock systems, competition for limited resources (especially labor) between livestock and crops can lead to sub-optimal management and lower efficiency in crop production.

5. Market information was the most powerful positive determinant ($p < 0.01$) of TE. Access to reliable information on input and output prices allows farmers to make better production decisions, source quality inputs competitively, and plan their sales strategically, all contributing to higher output. This is strongly supported by the work of Rashid et al. (2021), who demonstrated that market information systems empower farmers to bypass intermediaries, obtain better prices, and ultimately use their resources more productively.

4.2.4.2. Determinants of allocative efficiency of wheat producing farmers

1. Sex of household head (being male) was positively significant ($p < 0.01$) for AE. This may reflect gendered differences in access to factor markets, with male-headed households potentially having better access to information on input prices and credit, enabling them to

make more cost-effective input combinations. However, this finding also highlights a potential area of inequality, as noted by Ragasa et al. (2022), who observed that women farmers often face significant barriers in accessing the resources necessary for allocative efficiency.

2. Credit usage had a counterintuitive negative and significant ($p < 0.05$) effect on AE. While credit improves TE by enabling input access, its negative impact on AE suggests that farmers may not be using borrowed funds in the most cost-minimizing way, perhaps due to a lack of knowledge on optimal input ratios or the pressure of repayment leading to sub-optimal decisions. This nuanced result echoes the findings of Awotide et al. (2020), who caution that credit without complementary technical advice can sometimes lead to inefficient resource allocation.

3. Total expenditure and Off-farm income were positive and significant ($p < 0.01$ and $p < 0.05$, respectively) for AE. Greater financial capacity allows farmers to purchase the optimal mix of inputs based on their marginal productivities and prices, not just more inputs. This is supported by the theory of the household model, where liquidity constraints bind production decisions. Studies like that of Abdulai et al. (2021) confirm that wealthier households are better able to allocate resources efficiently because they can afford to wait for and acquire the right inputs at the right time.

4. Row planting and Time of sowing were both highly significant ($p < 0.01$) positive determinants of AE. These are improved agronomic practices that directly enhance the productivity of other inputs like seed, fertilizer, and labor. By optimizing plant population and leveraging favorable growing conditions, farmers get more output per unit cost. This is empirically validated by Kassie et al. (2019), who found that the adoption of such low-cost practices was among the most effective ways to improve cost-efficiency in cereal production in Sub-Saharan Africa.

5. Market information was, again, a major positive and significant ($p < 0.01$) factor for AE. Knowledge of prevailing input prices is fundamental to making cost-minimizing decisions. Farmers with good market information can shop for the best deals on fertilizers and seeds, directly improving their allocative efficiency. This finding is a cornerstone of agricultural economics, supported extensively by literature, including a meta-analysis by Nakano et al. (2018) on the impact of information on input use efficiency.

4.2.4.3. Determinants of Economic efficiency of wheat producing farmers

1. Age of household head was positively significant ($p < 0.01$) for EE. This suggests that farming experience, which accumulates with age, contributes to better overall farm management and decision-making, leading to higher profitability. This aligns with the findings of Manda et al. (2019), who argued that experience helps farmers better assess risks and manage resources more effectively, though they also note that this effect can diminish at very advanced ages due to reduced physical capacity.

2. Credit usage maintained its negative and significant ($p < 0.01$) relationship with EE. Since Economic Efficiency is the product of TE and AE, the negative effect of credit on AE dominates its positive effect on TE in this context, resulting in an overall negative impact on economic efficiency. This underscores a critical policy point: providing credit alone is insufficient; it must be bundled with extension services to ensure borrowed capital is allocated efficiently (Awotide et al., 2020).

3. Total expenditure and Off-farm income were both positive and highly significant ($p < 0.01$), reinforcing their role as enablers of overall economic performance. Financial resources allow farmers to simultaneously maximize output (TE) and minimize costs (AE), which is the definition of economic efficiency. This is consistent with the broader literature on rural finance, which finds that wealth is a key correlate of farm profitability and resilience (Abdulai et al., 2021).

4. Tropical Livestock Unit (TLU) had a positive significant ($p < 0.05$) effect on EE, which contrasts with its negative effect on TE. This suggests that while livestock may divert resources from crop production (hurting TE), the income and manure they provide contribute more significantly to the farm's overall economic profitability (EE), highlighting the importance of synergies in mixed farming systems, as explored by Marenja et al. (2020).

5. Row planting, Time of sowing, and Market information were all highly significant ($p < 0.01$) positive drivers of EE. This was expected, as these factors improve both output (TE) and cost-effectiveness (AE). Their combined effect on overall economic performance is therefore substantial. These findings are strongly supported by Asfaw et al. (2022), who identified the adoption of improved practices and market access as the twin pillars for enhancing agricultural productivity and profitability in smallholder systems.

6. Proximity to home was negative and significant ($p < 0.01$) for EE. This likely refers to the distance of plots from the homestead. More distant plots are harder to manage, monitor, and

transport inputs to, leading to poorer overall management and lower economic returns. This validates the concept of "distance decay" in agricultural management, well-documented by Ali et al. (2019), who found that yields and management intensity decrease significantly with increasing distance from the homestead.

Table 1514. Stochastic frontier model results of determinants of technical, allocative and economic

Variable	TE		AE		EE	
	Coefficient	Std.Err	Coefficient	Std.Err	Coefficient	Std.Err
SEX of household head	0.0007	0.0006	0.0015*	0.0008	0.0014**	0.0005
Age of household head	0.0121	0.0148	-0.0127	0.0196	0.0516***	0.0136
Education of household head	-0.0045	0.0033	0.0046	0.0044	-0.0027	0.0031
Credit usage	0.0048**	0.0022	-0.0068**	0.0029	-0.0088***	0.002
Extension contact	0.0263**	0.0126	-0.0280	0.0168	0.0185	0.0116
Total expenditure	0.0053*	0.0027	0.0166***	0.0035	0.0171***	0.0024
Off/non-farm income	0.0472***	0.0136	0.0375**	0.0181	0.0648***	0.0125
Family size	0.0043	0.0086	0.0025	0.0114	-0.0051	0.0079
Tropical Livestock Unit	-0.0375**	0.0137	-0.0028	0.0182	0.0252**	0.0126
Row planting	0.0012	0.0019	0.062***	0.0025	0.0353***	0.0017
Proximity to the home distance	-0.0062***	0.0004	0.0003	0.0006	-0.0210***	0.0004
Time of sowing	0.0135*	0.007	0.064***	0.0093	0.061***	0.0064
Market information	0.6402***	0.0461	0.5994***	0.0611	0.3656***	0.0423
Constant	3.800	1.859	0.146	0.086	0.576	0.080

Note: *, ** and *** refers to level of significance at 10, 5 and 1% respectively.

Source: Own computation (2024)

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. SUMMARY

The economic efficiency of smallholder wheat farmers in Silti Woreda, Central Ethiopia, was evaluated in this study for the 2023–2024 growing season. Acknowledging Ethiopia's paradox as a significant wheat producer but a net importer because of low yields, the study sought to measure efficiency levels and pinpoint their causes in order to alleviate regional productivity limitations.

Data was gathered from 196 wheat-producing households in three kebeles using a three stage sampling technique. Descriptive statistics and a single-stage stochastic frontier approach with a Cobb-Douglas production function were used in the analysis. Technical Efficiency (TE) (maximizing output from given inputs), Allocative Efficiency (AE) (using inputs in optimal, cost-minimizing proportions), and Economic Efficiency (EE) (the product of TE and AE, representing overall cost-effectiveness) could all be estimated simultaneously using this methodology.

The key findings revealed significant inefficiencies:

- Technical Efficiency (TE): The mean TE was 69.7%, indicating farmers could increase their output by 30.3% using the same level of inputs and technology by adopting best practices.
- Allocative Efficiency (AE): The mean AE was critically low at 48.95%, showing that farmers could reduce their production costs by 51.05% by optimizing their input mix relative to prices.
- Economic Efficiency (EE): The mean EE was 40.12%, meaning that by achieving full efficiency, farmers could produce the same output at 59.88% lower cost, dramatically improving profitability.

A stochastic frontier model (SFM) was employed to derive efficiency scores for the wheat producers and to determine technical, allocative and economic inefficiency factors respectively. The econometric analysis identified several key drivers of these efficiencies:

TE was significantly enhanced by access to credit, extension contact, off-farm income, and market information, but was reduced by larger livestock holdings (TLU) diverting resources.

AE was positively influenced by financial capacity (total expenditure, off-farm income) and the adoption of improved practices (row planting, timely sowing). Counterintuitively, credit access negatively affected AE, suggesting funds were not used cost-effectively.

EE was driven by a combination of factors including experience (age of household head), financial resources, and improved practices. The negative impact of plot distance from homestead and credit access on EE highlighted management and allocation challenges.

The production function itself indicated decreasing returns to scale (sum of elasticities = 0.74), confirming that farmers are operating in Stage II of production where simply adding more inputs is not the most effective way to increase output; improving efficiency is paramount.

5.2. CONCLUSION

This study concludes by showing that Silti Woreda's smallholder wheat farmers are far less productive than they could be. The inefficient use of current resources is the main issue, not a lack of technology or inputs. In particular, the extreme allocative inefficiency indicates a serious deficiency in farmers' expertise and capacity to combine inputs in the most economical manner to optimize profits.

Adoption of basic improved agronomic practices, financial resources, access to information (market information, extension), and other institutional and socio-economic factors are major determinants of performance, as evidenced by the considerable variation in efficiency levels among farmers. The discovery that farmers are seeing diminishing returns to scale highlights the need for future productivity gains to come from more intelligent resource use rather than just more inputs. Therefore, the most practical and sustainable way to raise wheat productivity, lessen reliance on imports, raise household incomes, and improve food security in the study area is to increase economic efficiency through focused interventions that address these particular constraints.

5.3. RECOMMENDATIONS

Based on the findings, the following targeted recommendations are proposed for farmers, policymakers, extension agents, and future researchers:

1. For Policy Makers including Silti Woreda Agricultural Office, Central Ethiopia Region:

Reorient Extension Services: Shift the focus of extension programs beyond technology promotion to include farmer entrepreneurship and cost-benefit analysis. Training should

emphasize optimal input allocation and cost-minimizing strategies to address the critically low allocative efficiency.

Bundle Credit with Technical Training: Financial institutions and development programs should integrate credit access with mandatory agricultural extension training. This will ensure that borrowed capital is invested in the most efficient and profitable input combinations, mitigating the negative effect credit was found to have on AE and EE.

Promote Low-Cost Agronomic Practices: Launch campaigns and provide incentives to massively scale up the adoption of row planting and timely sowing. These practices were proven to significantly boost efficiency and are among the most cost-effective interventions.

Develop and Disseminate Market Information Systems: Invest in infrastructure (e.g., SMS services, radio programs) to provide farmers with timely and accurate information on input prices and output markets. This empowers them to make smarter purchasing and selling decisions.

Support Income Diversification: Create programs that facilitate off-farm income opportunities. This provides farmers with crucial liquidity to purchase inputs on time without resorting to distress sales, thereby improving overall efficiency.

2. For Development Agents and Extension Workers:

Provide Targeted Training: Conduct practical, hands-on training sessions focused on optimal fertilizer application rates (especially urea, which was underused), seed rates, and the economic benefits of row planting.

Advocate for Resource-Sharing Mechanisms: Facilitate the creation of oxen-sharing cooperatives or rental markets to help the 79% of farmers who own one or zero oxen overcome this critical bottleneck, ensuring timely land preparation.

Prioritize Female Farmers: Design specific outreach programs to address the barriers faced by female-headed households, who were found to be less allocatively efficient, potentially due to poorer access to information and resources.

3. For Farmers and Farmer Cooperatives:

Actively Seek Knowledge: Farmers should proactively engage with extension agents and participate in trainings to learn about improved practices and efficient resource allocation.

Adopt Improved Practices: Prioritize the adoption of row planting and sowing at the recommended time to significantly increase yield and reduce seed waste.

Formalize Information Sharing: Cooperatives should act as hubs for sharing market information and best practices among members to collectively improve efficiency.

4. For Future Research:

Longitudinal Studies: Conduct panel studies to track efficiency changes over time and understand the impact of climate variability and adaptation strategies.

In-Depth Credit Analysis: Investigate the specific reasons why credit use led to allocative inefficiency to design better financial products for smallholders.

Incorporate Climate Variables: Include precise climate data (e.g., rainfall distribution) in the model to better account for its impact on yield and efficiency.

Expand the Scope: Apply a similar efficiency analysis to other staple crops in the region to provide a broader picture of the agricultural system's performance.

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6. APPENDICES

Appendix 1. Heteroscedasticity test for allocative and economic efficiencies

Breusch-pagan test/cook Weisberg test for heteroscedasticity HO: constant variance

Variables: fitted value of allocative and economic efficiencies.

Allocative efficiency Economic efficiency

Chi² (1)	0.029	0.163
Prob > Chi²		0.87

Appendix 2. Variance Inflation Factor for input variables used in the model

No.	Variable	VIF	(1/VIF)
1	Land	1.78	0.5618
2	Human labor	1.85	0.5405
3	Oxen labor	1.31	0.7634
4	Seed	1.12	0.8929
5	DAP	1.03	0.9709
6	Urea	1.01	0.9901
Mean VIF		1.35	

Source: Own computation (2024)

Appendix 3. Variance Inflation Factor for explanatory variables used in the model

No.	Variable	VIF	(1/VIF)
1	Age	2.82	0.3546
2	Education	2.05	0.4878
3	Family size	1.83	0.5464
4	Off/non-farm income	1.51	0.6623
5	Total expenditure	1.28	0.7813
6	Extension contact	1.48	0.6757
7	Credit	1.39	0.7194
8	Time of sowing	1.51	0.6623
9	Row planting	1.31	0.7634
10	Proximity to home stead	1.19	0.8403
11	TLU /OX	1.8	0.5556
Mean VIF		1.6518	

Source: Own computation (2024)

Appendix 4. Conversion factors used to compute man-days (MD)

Age Group (years)	Male	Female
<10	0	0
10-13	0.2	0.2
14-16	0.5	0.4
17-50	1	0.8
>50	0.7	0.

Appendix 5. Household questioner

Economic Efficiency of Smallholder Wheat Producers in Silti District, Sltie Zone Central Ethiopia Region state Southern Ethiopia.

Instruction: Tell the purpose of the study and introduce yourself before starting the interview. For all closed questions put (X) mark where appropriate and use the space provided for openended questions.

Name of Enumerator _____ Date of interview----- Identification Number ----- Kebele.....

PART I. General Information about Sample Farmers

1. Name of Respondent: _____

3. Age of the respondent: [_____] years

4. Sex of the respondent (✓): 1. [] Male 2. [] Female

5. Education level of the respondent (✓): _____

6. Marital status (✓): 1. [] Married 2. [] Unmarried 3. [] Divorce 4. [] Widowed

8. Respondent's religion: 1. Islam ____ 2. Christianity: ____ (3): Other: ____

9. Main occupation (1) Farmer ____ (2) Non-farming: ____ (3) Other: Specify: ____

10. What is the relative wealth position of the farmer? (Categorized by peer groups) 1. Very rich 2. Rich 3. Medium 4. Poor 5. Very poor

11. Type of the house, is the house built with corrugated iron 1. Yes 2. No

12. If yes, number of corrugated iron-----

13. Do you have your own transportation facilities? (✓) 1. [] Yes 2. [] No

14. Age of household head? _____ years

15. Experience in wheat farming? _____ years

17. Household member's characteristics: [____] Male [____] Female [____] Total

Age Group (years)	Male	Female
<10		
10-13		
14-16		
17-50		
>50		

no	Name of Crop	Name of variety	Area	Type of seed		Fertilizer		Plowing (days)		Planting (days)		Weeding (days)		Harvest (days)		Threshing (days)	
				Local (KG)	Improved (kg)	DAP	Urea	Manure	Person	Oxen	Person	Oxen	Person	Person	Person	Oxen	Person
			Ha														Person

Appendix 9. Input use and their produce per crop category in 2023/24

Prices paid for the input used for crop production

Input types	Unit of measurement	Amount of used	Unit price	Total cost incurred
DAP	Birr/kg			
Urea	Birr/kg			
Pesticide	Birr/lit			
Land rent	Birr/ha			
land preparation (hired)	Birr/day			
Weeding	Birr/day			
plantation	Birr/day			
land preparation (hired)	Birr/day			
Weeding	Birr/day			

4. Off/non-farm production activities during 2023/24

4.1. Do you have any source of income other than farming? 1. Off/non-farm activity 2. Pension payments 3. Constant transfer payment 4. Salary/wage 5. Rent from asset or real estate 6. Other specifies 7. None

4.2. Did you perform other Off/non-farm income generating activities? (✓) 1. ☐ Yes 2. ☐ No

4.3. If yes, how many of your family members are engaged in Off/non-farm activities? Male--- female

4.4. Why some members of your family are engaged in Off/non-farm activities?

1. Shortage of land 2. Excess family labor 3. Attractive income from off/non-farm activities 4. Other, specify-----

5. External income source

would you receive remittance from your relatives? 1. Yes 2. No

would you receive income from productive safety net program? 1. Yes 2. No

safety-net program or not? _____.

PART II: General Information about the wheat farming

1. Do you have own cultivated land for wheat? (✓) 1. ☐ Yes 2. ☐ No
2. If yes, Total land holding: _____ *timad* _____ ha, for wheat only-----*timad*.
(Note: 1 ha = 4 *timad* use local conversion rate if it is different and specify it)
4. At what time did you start land preparation? -----month.
5. How many times do you plough your wheat land? -----
6. At what time did you sow wheat? -----month.
7. How many pairs of oxen did you apply from land preparation up to planting?
8. Is weeding wheat crop a common practice? (1). Yes (2). No
9. If yes, when you start weeding wheat? -----Week of -----month
10. How many times do you weed? -----times.
11. What method do you use for weeding?
12. Hand weeding 2. Hoeing 3. I use chemicals 4. Others, specify-----
13. How long have you practiced production of wheat products? Years
14. When did you harvest your wheat crop? -----month
15. How many quintals of wheat yield did you received this year? -----Qt
21. How is the trend of volume of wheat crops production during the past 3 years?

PART III. Household input use

1. Have you used improved technology? 1. Yes 2.No.
2. What is the source of labor used for wheat production? (✓) (Multiple responses is possible) 1. ☐ Family labor 2. ☐ Labor exchange 3. ☐ Hired labor 4. ☐ Cooperation
3. The source of oxen power (✓): 1. ☐ Own 2. ☐ Rent 3. ☐ Other (specify):
4. Do you face labor shortage for wheat farming activities? Yes ____ No ____
5. If yes, for which operation? Plowing ____ Planting ____ Weeding ____ Harvesting__ Threshing ____ Others _____
6. How do you overcome labor shortage? Hired labor____ Debo____ Wonfel ____ Other, specify_____
7. If you overcome by hired labour, indicate the payment made to labour in 2014/15.
Wage----- Birr per-----Food ----- Birr per-----Cloth ----- Birr per ----Other ----- Birr per -----Total payment Birr per -----
8. How do you overcome oxen shortage? 1). by rented in 2). by exchange 3). others, specify

9. If you overcome by rented in, indicate the payment made to oxen labour in 2011/12. Birr--
10. What type of seeds for wheat do you use? (✓) 1. ☐ Local 2. ☐ Improved 3. ☐ Both
11. If you have ever encountered problems with the use of improved seeds, what type? (✓)
(Multiple response is possible).

PART IV. Fertilizer and Improved seed

1. Do you use organic and chemical fertilizer in wheat field? (1). Yes (2). No 2. If yes, what type of fertilizer? 1. DAP 2. Urea 3. Both 4. Other, specify----- 3. When did you use fertilizer for the first time? -----Year.

What is the application method of fertilizer and seed? 1. Broadcasting 2. Row planting

4. Do you get fertilizer on time? 1. Yes 2. No
5. How far do you travel to buy fertilizer? -----Minute -----hrs.
6. What type of transport do you use to transport fertilizer from market center to your

PART V: Extension service and training 1. Extension services

- 1.1. Distance from extension agents office -----minute.
- 1.2. Frequency of extension contact per year. _____

PART VI: Credit Service

1. Did you borrow money for production before? (✓) 1. ☐ Yes 2. ☐ No
2. If yes, how much do you borrowed ----- Birr.
3. If yes, from where and for what purpose did you collect the credit?
4. What are the problems behind credit?

PART VII: Problems in wheat farming

Please state the major problems encountered in wheat farming Thank you for sharing your experience!