Determinants of Technical Efficiency of Teff (*Eragrostis tef* (Zucc.) Trotter) Yield in Southern Ethiopia, in the Case of Kecha Birra District in the Kambata Zone

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Summary

Agriculture has been and continues to assume center stage in the economic policy of Ethiopia. Adoption of teff crop (*Eragrostis tef* (Zucc.) Trotter) yield-enhancing technical efficiency is key to improving agricultural production and productivity. The general objective of this study aims to investigate determinants that influence the technical efficiency of teff yield in the Kache Birra district, Kambata Zone. The primary data was collected among 378 teff growers in research locations during the 2020/21 season. Descriptive statistics and econometric methods were developed for the data analysis. The estimated average value of technical, allocative, and economic efficiencies was 71.52%, 67.23%, and 63.54% respectively, which shows the existence of inefficiency in teff yield in the district. The findings of OLS regression indicated that technical inefficiency was affected by age, sex, education status, landholding, livestock holding, credit, extension, off-farm activity, land ownership and fertilizer use. Teff yield technical efficiency was associated with a significantly higher teff crop yield and per capita annual income of teff cultivator. Concerned bodies should give important attention to teff yield technical efficiency which is the base for improving yield. The summary of this teff yield technical efficiency by policymakers and plan designers could bring better enhancement to the teff cultivator in the study area.

Key words

agriculture, Ethiopia, Kecha Birra, technical efficiency, teff yield

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Introduction

In Ethiopia agriculture dominates a large portion of the population, income, foreign exchange, and job creation (Anbes, 2020; CSA, 2018; Mekonen, 2015). The sector is crucial in the economy characterized by developed economic policy of agricultural growth leading to industrialization. Consequently, agriculture is based on and generates over 35.8% of national GDP, 50% of gross domestic product, 90% of export revenue, 85% of the labor force, and 72.7% of raw material to country industries (Anbes, 2020; CIA, 2018; CSA, 2018; Teklu and Tefera, 2005). Hence, the yield, productivity and efficiency levels of agriculture are generally below the world's mean due to poor attention given to the sector. The output, productivity, and efficiency status of the sector are, well below the world average. For example, in cereal production, which is the largest in the sector, the global average cereal yield is 3.574 t ha^{-1}, while Ethiopia's average cereal yield is 2.538 t ha^{-1} (CSA, 2019). In general, teff (*Eragrostis tef* (Zucc.) Trotter) growers face problems with management inefficiency inputs, poor extension, the output variations per hectare, insufficient credits, inadequate marketing, backward teff growing technology, weak infrastructural access, and inappropriate agricultural development policies (Cheng et al., 2017; CSA, 2019). Of different cereals, teff is a major cereal food security crop in the country in terms of coverage and volume of yield. Teff covers 95% of yield, accounts for 87.5% of the grain yield, and is planted by 43% of teff growers in the country. In terms of yearly production, teff is the second most crucial cereal crop next to coffee with 100 gram of teff cereals having 357 kcal in terms of nutrition (CSA, 2019; Minten et al., 2013; Moges, 2019). Teff cereal is very suitable for people because it is rich in amino acids and protein, is gluten-free and has poor glycemic index and contains substances against both types of diabetes (Anbes, 2020; Cheng et al., 2017; CSA, 2018; Moges, 2019; Teklu and Tefera, 2005; Thiam et al., 2001). Teff is a gluten-free grain indigenous to the country and consumed in a fermented state.

In Ethiopia teff is important to produce stable dish enjera and local beer with high protein, fiber, complex carbohydrates, low-calorie contents, and gluten-free (Berhane et al., 2011). The national mean yield is low due to rain-fed orientation, the subsistence of agriculture, a backward farming system, reduced soil fertility, poor infrastructure and environmental degradation (Kebede et al., 2017). Teff crop has rich mineral contents and amino acids that are crucial for the health of consumers (Bekele, 2016; Arega et al., 2010). It is used as a daily food for two-thirds of the country's population (Ahmed et al., 2013; Biftu et al., 2016; Moges, 2019). Improving more efficient farming strategies, practices and technology is key to improving environmental sustainability, economic growth, food security and poverty alleviation (Anbes, 2020; Teklu and Tefera, 2005). Hence, advanced agricultural technologies were adopted slowly (Bandiera and Rasul, 2010). This crop is planted well in moisture stress and waterlogged better than other cereal crops (Engdawork, 2009). Teff has good taste and is preferred over other grains that are a very poor substitute for teff. Therefore, this leads to a high demand for teff grain and its increasing production over time more than other cereals in Ethiopia. The yearly volume of yield reached from 1,677,348 tones in 2003/04 to 4,750,657.279 tones in 2013/14, with a mean yearly growth rate of 15.8%.

In the country, improving the total yield and productivity is a necessity and the most important concern in their plan and policies. Yield and productivity can be enhanced by using recommended inputs and advancements in technology and efficiency of growers (CSA, 2019; Thiam et al., 2001). Improving technical efficiency in yield allows growers to improve their yield without any additional inputs and advanced yield technologies (CSA, 2017; FAO, 2015; Fischer et al., 2014). That means using new improved technologies is less cost-effective than applying existing technologies. Yield-enhancing technical efficiency indicates the teff growers have reached the optimum output with existing technology (Bamiro and Janet, 2013; CSA, 2018). The use of the inputs in maximum proportions can be indicated at allocative efficiency (Ayele et al., 2019; Debebe et al., 2015). The expansion of teff yield in suitable agroecologies is the option to alleviate food insecurity and poverty. Backward method of sowing such as chemical fertilizer use, growing and plowing has resulted in a higher reduction in yield and productivity in Ethiopia (Moges, 2019; Solomon, 2014). Like in other developing countries, in Ethiopia teff yield is featured by low use of inputs, backward technology, and the inefficiency of employing scarce resources. Hence, to enhance yield and productivity of teff at the grower level with efficient use of scarce resources or inputs needs to be improved. A large number of teff growers face low use of existing technologies and inputs due to socio-economic and socio-cultural constraints. The average national productivity of teff in Ethiopia is 1.75 t ha^{-1} at the cultivators' level which is very low. However, through research and applying improved agricultural technologies, teff productivity can be raised to 5 t ha^{-1}. In the Kache Birra district, the average productivity of teff is 1.32 t ha^{-1}, which is lower than the national average (CSA, 2019).

Teff main growing area has been highly concentrated in the central and northwestern highlands of the country. Lack of yield system, climatic changes, improved seed varieties, yield inputs, management system, weed management system, pest management and soil fertility maintenance are serious challenges for teff crop in general (ATA, 2016; CSA, 2019; Wudineh and Endrias, 2016). Teff cereal in terms of productivity is low due to a lack of high-producing growers, erratic rainfall, a lack of a good management system, and low inputs application (CSA, 2018; Gela et al., 2019). According to (Bekele et al., 2019), a study presented that the losses of teff yield could decrease the number of teff cereals by up to 50% and the mean yield of teff in the country is 1.8 t ha^{-1} at the growing level. In Ethiopia, the teff production gap is large among growers due to low access to seed and a lack of well managed agronomic system (ATA, 2016; Abraha et al., 2017). Improved production and productivity are key to improved technology since minimum cereals productivity in general and teff productivity in particular are due to backward technology, weak finance, and the high price of cultivating technologies. Cost-effective technologies are developed by using existing inputs and technologies. Therefore, technical efficiencies are important to indicate growers are efficient in the use of the existing economic resource and the decision to apply the new cultivating agricultural technologies (ATA, 2016; Thiam et al., 2001). Hence, some research concerning new and improved agricultural technology is highly focused on factors that influence agricultural technology adoption, but it is not complementary to its determinants of technical efficiency implementation (Ahmed et al., 2013; Kebede et al., 2017; Arega et al., 2010; Biftu et al., 2016). Therefore, it is very difficult to have a clear understanding of the adoption of improved new agricultural technology and its technical efficiency.

The study was evaluated by (Beyan et al., 2013), using a stochastic production frontier model on the topic of technical efficiency of the yield of growers in the Garawa district. According to his study, the average technical efficiency was 81.5%, and technical efficiency was significantly affected by education status, ownership of livestock, access to extension services, growers' training, access to social services and adoption of irrigation. The study conducted by (Idiong, 2007), on technical efficiency on rice yield in Nigeria applying the stochastic production frontier model, revealed that the mean technical efficiency was 77%. According to the study, education status, yield-improving associations, and having access to credit significantly influenced technical efficiency. A similar study by (Bamiro and Janet, 2013), conducted using the stochastic production frontier model indicated that having access to credit negatively influenced technical efficiency, whereas women were positively affected by technical efficiency. Research (Wondimu and Hassen, 2014), was conducted by applying a stochastic production frontier model on maize yield growers in the Dhidhessa district and it evaluated that 73% of gamma parameters of the total variation in maize yield were due to technical inefficiency. Their study indicated that technical inefficiency was affected by age of growers, seed varieties, distance to the market, educational status, family labor, grower training, ownership of livestock, and off-farm income.

In a study developed by (Solomon, 2014), the technical efficiency of teff yield was influenced by age, educational status, adoption of soil and water prevention activities, off-farm income, ownership of livestock, poverty level, and seed varieties. The study by using the stochastic production frontier model in wheat yield (Wudineh and Endrias, 2016), showed that most wheat growers were not efficient, with average technical efficiency of 57%. The sex of wheat growers, age of cultivators, education status, ownership of livestock, size of cultivated land, distance from growers to market and use of chemical fertilizer are important documented factors affecting technical efficiencies. Similarly, in the study conducted in South Wolega Zone (Hassen, 2016), the mean technical efficiency of wheat yield was 79%, revealing the important potential for enhancing wheat yield by 12% with given economic resources and technology. According to the stochastic yield, the frontier model results showed chemical fertilizer, labor and ownership of livestock influenced the technical efficiency. Ethiopia's economy is extremely based on backward agriculture and traditional analysis of efficiency on yield. In particular, the key role of the agricultural sector in securing food security and alleviating poverty is very considerable. Despite this, the agricultural yield is very poor and low. The rationales for this low agricultural yield and productivity are low adoption of technology, poor ensuring efficiency of yield, bad weather conditions, poor soil fertility and poor infrastructure. There are some inconsistent results on technical, allocative, and economic efficiencies of the agricultural crop (Abdulai and Eberlin, 2001; Ahmed et al., 2002; Mwangi, 2014). These inconsistent results are very important rationales to study factors influencing the technical efficiency of teff crop production and productivity in the study area.

The study developed by (Debebe et al., 2015) on the efficiency of maize yield using parametric stochastic frontier production function employing the Cobb – Douglas production function was conducted in the Jimma Zone of Southwestern Ethiopia. The results presented that average technical efficiency was found to be 62.3%, presenting inefficiency in maize yield. (Mekonnen et al., 2015) developed their study employing stochastic frontier production function to estimate cereal crop efficiency in South Omo Zone, Southern Ethiopia. The findings presented that average technical efficiency was found to be 67.11%. The study developed by (Bifarin et al., 2010), assesses the technical efficiency of applying the frontier model by using the Cobb-Douglas production function for cereal crop grower farmers in Nigeria. The results revealed that age and use of extension positively related to technical efficiency. Also, the findings of the inefficiency model presented that education and credit use were positively related to technical inefficiencies. (Ogisi et al., 2013; Okeke et al., 2012), developed studies on the technical efficiency of rice yield in Nigeria using stochastic frontier production function. Their results revealed that education, farm experiences, use of extension, and increasing return to scale significantly affected the efficiency of rice yield. Understanding the determinants underlying growers of technical efficiency is important to improve teff yield through enhanced participation of such technical efficiency. There is different literature focusing on factors affecting technical efficiency (Bamiro and Janet, 2013; Danso-Abbeam et al., 2012; Gebrehaweria et al., 2012; Geta et al., 2013; Kadiri et al., 2014; Tefera et al., 2014; Tolga et al., 2009). According to their studies, technical efficiency is affected by age, sex, educational status, oxen, area, pesticide costs, family size, landholding, land ownerships, experience, off-farm income, credit, extension, infrastructure, seed, training, land distance and fertilizer. In these different empirical studies, there were not the same findings and results on the technical efficiency of teff growing but teff growth and productivity and technical efficiency were very poor in general. (Beyan et al., 2013; Idiong, 2007,Alemu et al., 2018; Mamo et al., 2018; Solomon, 2014; Toma et al., 2017). Developing on the existing studies, this research expands the analysis by looking into important set of poverty and food insecurity measures.

However, there is little research evidence regarding the potential of technical efficiency on teff productivity (Alemu et al., 2018; Bekele, 2016; Arega et al., 2010; Biftu et al., 2016). In particular, the determinants of technical efficiency and the sources of technical inefficiency of small-scale teff growers have not been explored in detail. Most of these studies were limited in dealing with identifying the factors affecting the level of technical efficiency, a measure of teff production and sources of technical inefficiency of teff cultivators and their, findings were often mixed and at times conflicting (Abdulai and Eberlin, 2001; Ahmed et al., 2002; Mwangi, 2014). To this end, the current study has been conducted to investigate determinants that influence the technical efficiency of teff production in the Kache Bira district in Kambata Zone, Southern Ethiopia. Specifically, the objectives of this paper are to investigate factors affecting the level of technical efficiency and identify sources of technical inefficiency of teff growers in the study area.

The study estimation strategy was guided by the conceptual framework. This conceptual framework was developed and modified based on the empirical literature (Fetagn, 2017).

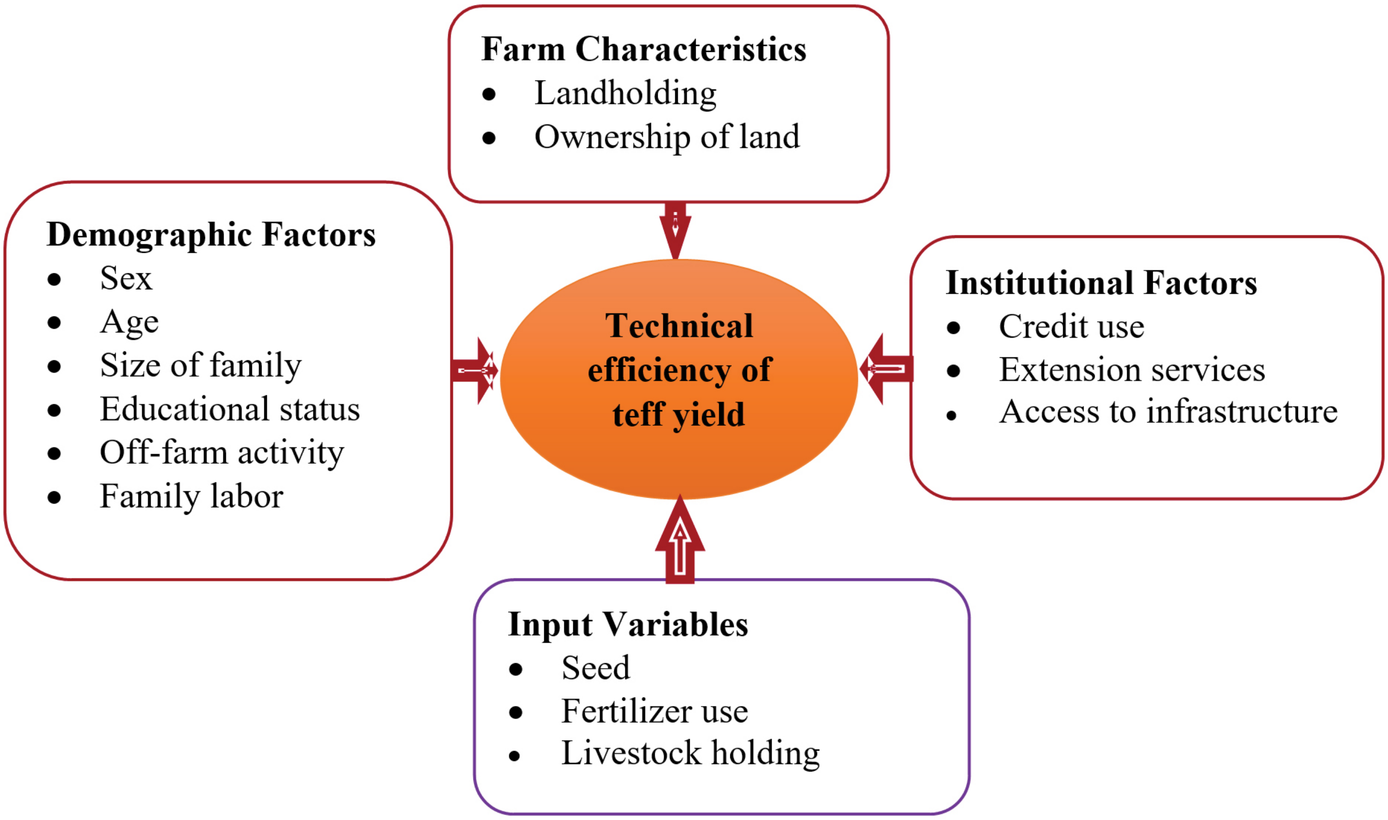

Figure 1. Conceptual framework

The conceptual framework presented in figure 1, indicates that teff growers' characteristics such as age, sex, educational status, size of family, family labor, and off-farm activity; institutional factors like access to credit, infrastructure, and extension; farm-level characteristics like landholding and ownership of land; input variables like livestock holding, fertilizer and seed are some crucial determinants influencing teff crop yield technical efficiency. Technical efficiency is very key in terms of increasing grower teff yield. The developed conceptual framework indicates that important determinants and their relationships with each other are expected to influence the technical efficiency of teff cereals.

Materials and Methods

Description of the Study Area

This study was developed in the Kache Birra district, located in the Kambata Zone, SNNPR of Ethiopia. The total population of the Kache Birra district is 125,342 (100%), of which 64,525 (51.5%) are male and 60,817 (48.5%) are female. Kecha Birra district is situated 282 km southwest of the capital city of Ethiopia (Addis Ababa). The total number of cereal growers in the Kache Birra district is 20,962, the majority of growers 20,048 (95.6%) are male, whereas the remaining 914 (4.4%) are female. According to the 2020 agricultural cereal crop yield report of the Kache Birra Woreda, from total cereal crop cultivators majority of them are teff cultivators. Agroecologically, the Kecha Birra district is categorized into 3 agroecological zones: Dega (48%), Weina Dega (21%), and Kola (31%). The average annual rainfall varies from 2145 mm to 2872 mm with an average yearly temperature of 19 °C. The total land elevation in the Kecha Birra district ranges from 2,987 m asl to 1,215 m asl. The total land area is 45,215 ha (233.4 square km), of which 30,172.8 ha (69.2%) is potentially highly cultivable land. The population density in the study district is high (726.4 per square km) and there is a high number of young cereal crop growers in the study district. Kecha Birra district is a suitable district for cultivating teff for many reasons. Firstly, this district has a high potential for teff yield. Secondly, the district technical efficiency application has been expanded and implemented for teff production. Widely applicable extension service and recommendation on teff growing technical efficiency has been conducted in the Kache Birra district.

Sampling Technique

For the study, multi-stage sampling methods were developed to select teff growers. In the first stage the Kache Birra district was purposely selected based on agroecology, the potential of teff yield and the application and introduction of technical efficiency of teff crop. Kache Birra district is better in terms of teff production, application of teff yield enhanced new agricultural technology and it practices teff yield technical efficiency more than the remaining district in Kambata Zone. This is an important point why the research location was selected regarding teff yield and influencing factors. In the second stage teff-growing kebeles in the district were selected based on the teff yield and five teff-growing kebeles, namely Awaye, Gamasha, Ashira, Buge and Lada were randomly selected. Thirdly, the total number of teff growers in the yield year 2020/21 was identified. Total teff cultivators (12,040) were selected from teff cultivators kebeles stratified by employing technical efficiency status. The sample size was determined based on the formula given by (Yamane, 1973). Accordingly, a total of 387 teff crop growers were selected for the field survey data during the 2020/21 cropping season. Teff grower is an adopter of technical efficiency with innovation and he is well aware of the importance of this innovation and its application in enhancing technical efficiency.

$$n = N/(1+N(e2)) = 12{,}040/(1+12{,}040\ (0.05^2)) = 387$$

A total number of 387 teff growers were selected from each stratum using proportionate selecting procedures.

$$n_i = N_i / N\,(n)$$

where, 'n_i' is the total number of selected samples from each i^th^ selected kebeles; 'N_i' is the total number of headed households from i^th^ selected kebeles; 'N' is the total number of headed households in the selected kebeles; 'e' is an acceptable error margin, and 'n' is a total sample size. Finally, a total number of 387 teff growers were selected from five kebeles by employing a simple random sampling method.

Table 1. Sample of teff (*Eragrostis tef* (Zucc.) Trotter) cultivator based on the level of technical efficiency

Selected Kebeles	Total Number of Teff Growers (N_i)	A Total Sample Size of Teff Grower (n_i)
Awaye	2,471	79
Gamasha	2,452	79
Ashira	2,407	77
Buge	2,395	77
Lada	2,315	75
Total	12,040	387

Note: n_i = total sample size of teff grower i (i = 1, 2, 3, 4, 5); N_i= total number of teff grower

Types and Sources of Data

In this study, descriptive and econometric data analyses were developed. Primary and secondary data sets as well as both qualitative and quantitative primary data were developed for the study. The primary data sets were collected including teff grower environmental, demographic, institutional, and inputs characteristics and adoption decision of technical efficiency. Before the field study, the instrument was rigorously reviewed and necessary changes were made. The questionnaires were administered in 387 teff grower-headed households in the Kache Bira district, Ethiopia. The structural questionaries employed were prepared to contain questions on teff outputs, prices of teff yield, quantity inputs and all environmental, demographic and institutional factors that influence the teff grower's technical efficiency. Both open and close-ended questionnaires were conducted to achieve all objectives of the study. Primary data were prepared from February to June 2020/21 teff growing seasons. Suitable and reliable persons were contacted to respond to the questionnaire. Classically, the questionnaires were distributed and collected at a later date after completion. The supplementary data such as secondary data sets were collected from published and unpublished sources, agricultural and rural development administrative offices, the internet, empirical literature, rural teff cultivators and non – cultivators. The study was conducted through cross-sectional field survey data of the 2020/2021 main growing season.

Data Analysis

The data for the study were analyzed by using both descriptive and econometrics data analyses. Descriptive analysis identified teff grower environmental, demographic, institutional and input characteristics. For the descriptive analysis frequency, percentages, averages, standard deviation, maximum values, minimum values, t-test and $\chi 2$ were employed. Particularly, this study employed $\chi 2$ tests for examining relations between teff growing technical efficiency and qualitative determinants of technical efficiency. Additionally, a t-test should be employed for assessing associations between teff growing technical efficiency and quantitative factors affecting technical efficiency. Furthermore, this study developed econometric methods to evaluate in-depth analysis. The study also developed a stochastic production frontier model to examine factors influencing the teff grower technical efficiency among teff cultivating farmers (Aigner et al., 1977; Coelli and Battese, 1996).

The studies conducted by (Beyan et al., 2013; Idiong, 2007), on teff growers' technical efficiency were significant because they showed that users of teff growing technical efficiency enhanced production more than non–users. This study addresses evaluating the effect of teff grower technical efficiency on yield, which is crucial in measuring teff growers' food security. The use of teff grower technical efficiency and growers' food security are positively related. This indicates that any change in teff grower technical efficiency brings a change in growers' yields and food security. To assess factors affecting teff grower technical efficiency among teff cultivating farmers, the analysis model to be developed shall take the following form:

$$ln(Y_i) = X_i B_i + v_i - \mu_i \qquad (1)$$

$$i = 1, 2, 3, 4, \ldots\ldots\ldots\ldots\ldots, N$$

where, 'ln' is a natural logarithm of the teff grower; **i is an** i^th^ farm in the sample; 'Y_i' is an observed teff output of the ith sample farmer; β is a vector of unknown parameters to be estimated; $\mathbf{X_i}$ **is a** vector of covariates evaluating environmental, demographic, institutional and inputs characteristics that are assumed to affect teff grower farmer (Table 2); u_i is a stochastic term of the method which is assumed to be independently and identically distributed as $u_i \sim N(0, \sigma^2)$.

The stochastic yield frontier model is mostly conducted model to estimate teff grower technical efficiency given by equation (1). Various equation forms have been conducted to evaluate the association between input and teff output. Most of them are Cobb – Douglas and the trans-log equations. The current research was conducted by applying Cobb – Douglas yield equation with the log-likelihood test. The teff growing yield technical efficiency is interpreted in terms of observed output to the corresponding frontier output applying the given constant technology will take the below form:

$$TE_i = \frac{Y_i}{Y_{i^*}} = \frac{Actual\ yield}{Potential\ yield} = \frac{\exp(X_i B - u_i)}{expX_i B} = \exp(-u_i) \qquad (2)$$

Technical efficiency takes the value on the interval (0, 1), where 1 reveals an optimum efficient farm. The yield gap of the i^{th} teff grower in teff yield is the difference between potential yield and actual yield i.e., $YG_i = PG_i + AY_i$. Economic efficiency is the ratio of minimum conducted total production cost (C*) to actual total production cost (C) i.e., $EE_i = C_i / C_i^*$. The allocative efficiency index can be evaluated as the ratio of economic efficiency to allocative efficiency i.e., $AE_i = EE_i / TE_i$. To evaluate the determinants that affect the technical inefficiency of teff yield, the empirical estimation methods of data analysis were developed. The stochastic yield frontier model is a crucial model to evaluate this effect on teff yield. The Cobb – Douglas yield-enhancing functional form employed is specified as:

$$ln(Y_i) = B_0 + B_1\,ln(age) + B_2\,ln(sex) + B_3\,ln(fas) + B_4\,ln(edu) + B_5\,ln(lah) + B_6\,ln(ofa) + B_7\,ln(fal) + B_8\,ln(cru) + B_9\,ln(exs) + B_{10}\,ln(aci) + B_{11}\,ln(feu) + B_{12}\,ln(seed) + B_{13}\,ln(lio) + B_{14}\,ln(lao) + v_i - \mu_i \quad (3)$$

Output is the total yield of teff cultivated measured in kg/ha. β is unknown yield equation parameters, v_i is the disturbance error term, independently distributed as N (0, σv^2), and μ_i - is a non-negative random variable, identically distributed as N (μ, $\sigma\mu^2$). The stochastic cost frontier model is formulated as:

$$ln(Cost) = \alpha_0 + \alpha_1\,ln(age) + \alpha_2\,ln(sex) + \alpha_3\,ln(fas) + \alpha_4\,ln(edu) + \alpha_5\,ln(lah) + \alpha_6\,ln(ofa) + \alpha_7\,ln(fal) + \alpha_8\,ln(cru) + \alpha_9\,ln(exs) + \alpha_{10}\,ln(aci) + \alpha_{11}\,ln(feu) + \alpha_{12}\,ln(seed) + \alpha_{13}\,ln(lio) + \alpha_{14}\,ln(lao) + vi - \mu i \quad (4)$$

Cost is the TC of inputs spent to produce teff cereal crop measured by euros /hectare, the seed is TC of teff seed measured by euros /hectare, feu is TC of fertilizer use measured by euros / hectare, lah is TC of the rental value of land measured by euros, fal is TC of labor measured by euros /hectare, α is unknown cost equation parameters.

Eterminants of inefficiency are evaluated by applying Ordinary Least Squares. This function was developed to measure the key determinates that affected the technical inefficiency of teff growers in the Kecha Bira district. The inefficiency equation is specified as follows:

$$\mu_i = \alpha_0 + \alpha_1\,age + \alpha_2\,sex + \alpha_3\,fas + \alpha_4\,edu + \alpha_5\,lah + \alpha_6\,ofa + \alpha_7\,fal + \alpha_8\,cru + \alpha_9\,exs + \alpha_{10}\,aci + \alpha_{11}\,feu + \alpha_{12}\,seed + \alpha_{13}\,lio + \alpha_{14}\,lao + \xi_i \quad (5)$$

where, *i* is the i^{th} teff growers; μ_i is a technical inefficiency score; δ_i is a vector of the parameter to be estimated; ξ_i is an error term; *age* is age of teff growers measured by year; *sex* is sex of teff growers measured by 1 if male and 0 if female; *fas* is the size of the family measured by the number; *edu* is educational status of teff growers measured by year of school; *lah* is landholding measured by hectare; *ofa* is an off-farm activities measured by Birr; *fal* is an availability of family labor measured by 1 if yes and 0 otherwise; *cru* is a credit use measured by 1 if yes and 0 otherwise; *exs* is an extension service measured by 1 if yes and 0 otherwise; *aci* is an access to infrastructure measured by 1 if having access and 0 otherwise; *fep* is a fertilizer perception measured by 1 if yes and 0 otherwise; *seed* is a total quantity teff seed of teff measured by kilogram/hectare; *lio* is a livestock ownerships measured by TLU, and *lao* is the land ownerships measured by 1 if landownerships and 0 otherwise.

These variables are intended to evaluate the technical inefficiency of i^{th} teff growers. For the study dependent variable is the technical inefficiency score and all the above demographic, environmental, institutional and inputs variables are explanatory variables.

Results and Discussion

Descriptive Analysis

Table 3 indicates the descriptive summary statistics of the teff cultivator by type of teff growing yield using technical efficiency (i.e., achieving technical efficiency status). Out of a total of 387 (100%), about 229 (59.17%) of the teff cultivators' used technically inefficient methods of sowing teff crop, which was relatively larger than those 158 (40.83%) during the 2020/21 sowing season.

According to the sample respondents of teff growers, high teff crop technical inefficiency due to low interest to grow teff cereal, topography not suitable of planted land due to shortage of available family labor, poor access to infrastructure, low credit access, and weak fertilizer distribution and logging water. To achieve teff crop technical efficiency applying the row planting technique of teff crop is essential and the time-consuming practice of the row-sowing method of teff cereal was among the reasons found to face teff yield technical inefficiency. Additionally, some of them mentioned that the government should consider distributing achieving teff yield technical efficiency machines to substitute labor force by machine and to save teff growing time.

According to Table 4, the study reveals the descriptive summary statistics means and standard deviations for a major independent variable by achievement status. This study conducted t – values and $\chi 2$ values indicated the evaluation of averages of these explanatory variables across the technical efficiency and inefficiency categories of teff grower. According to the summary statistics majority of teff growers were headed by males (74.25%), growers relatively older (54.66 years average age), literate (58.32% of whom are above primary education), on the average size of the family (5.58 persons per household), having own 11.78 livestock unit (LU), and on average grow 2.65 hectares of land. These findings of the current study are in line with the findings of (Gebrehaweria et al., 2012; Geta et al., 2013). As mentioned, (67.43%) of the teff growers are extension service users, (54.57%) of the teff growers have used credit and (75.38%) followed available family labor. As to the teff grower, 184.05 euros per year came from non-farm activity, on average (74.38%) of fertilizer utilized, and (66.74%) of teff growers had infrastructure on average. As presented in Table 4, on average 78.27 kg ha^{-1} of seeds were utilized, followed by on average (57.91%) ownership of land. The listed findings of this study are consistent with the findings of (Mamo et al., 2017; Solomon, 2014; Toma et al., 2017).

Additionally, crucial significant variations were addressed among technical efficiency and inefficiency in terms of teff grower characteristics. Accordingly, teff growers with technical efficiency had better educational status than those with technical inefficiency, suggesting that the education status of teff growers might be negatively related to technical inefficiency (Cheng et al., 2017). Similarly, teff growers with technical efficiency had significantly larger family sizes than teff growers with technical inefficiency (Beyan et al., 2013). Besides, efficient growers produced larger landholding and had more livestock units than their inefficient counterparts showing how crucial teff grower assets and ownership are in the adoption of technical efficiency decisions (Thiam et al., 2001). Technically efficient and inefficient groups significantly varied in terms of access to the infrastructure whereas efficient groups had better access to infrastructure than

Table 2. Variables summary of technical inefficiency

S. No	Variable name	Variable type	Variable description and its measurement	Expected sign
	Dependent Variable			
	Technical inefficiency	Continuous	Stochastic yield frontier model	
	Independent Variable			
1	Age	Continuous	In years	-
2	Sex	Dummy	If 1 = Male and 0 = Female	-
3	Size of family	Continuous	In numbers	-
4	Education status	Categorical dummy	In my year of school	-
5	Landholding	Continuous	In hectares	-
6	Off-farm activity	Continuous	In euros	-
7	Family labor	Continuous	If 1 = Yes and 0 = otherwise	-
8	Credit use	Dummy	If 1 = Yes and 0 = otherwise	-
9	Extension service	Dummy	If 1 = Yes and 0 = otherwise	-
10	Access to infrastructure	Dummy	If 1 = Having and 0 = otherwise	-
11	Fertility use	Continuous	Kilograms/hectares	-
12	Seed	Continuous	Kilograms/hectares	-
13	Livestock ownerships	Continuous	TLU	-
14	Land ownership	Dummy	If 1 = landownership and 0 otherwise	-

Source: Author's hypothesis 2020/21

Table 3. Sample teff (*Eragrostis tef* (Zucc.) Trotter) growers by technical efficiency status

Technical Efficiency Status	Frequency	Percent	Cumm. percent
Technical inefficiency	229	59.17	59.17
Technical efficiency	158	40.83	100
Total	387	100	

Source: Computed from own survey data 2020/21

their inefficient counterparts (Danso-Abbeam et al., 2012). The technically efficient grower was on average better in terms of extension services, credit use, landholding, and land ownership than counterparts (Kadiri et al., 2014). Regarding off-farm activity and fertilizer use, efficient growers on average are better than their inefficient counterparts (Tefera et al., 2014). Furthermore, there were no significant differences in terms of age and sex of teff growers suggesting a lack of relation between technically efficient and inefficient. However, there was no variation in terms of availability of labor between technically efficient and inefficient. Teff grower's technical inefficiency is negatively related to education status, size of family, producing land holding, ownership of livestock, extension and credit use, infrastructure, off-farm activity and fertilizer utilization. Any better variation in the above-listed explanatory variable brings a better variation in technical efficiency of teff crop production than inefficiency (Wudineh and Endrias, 2016).

Econometric Results

According to the maximum likelihood estimation of Cobb – Douglas teff yield function, out of fourteen explanatory variables in function ten (age, sex, education status, landholding, livestock holding, credit uses, extension uses, off-farm activity, land ownerships, and fertilizer uses) affected teff yield among teff growers. Among these variables like education status, credit uses, extension uses, land ownership, and fertilizer utilization influence teff crop yield at a 1% probability significance level. Teff crop yield is also affected by age, sex, landholding, and off-farm activity at a 5% probability significance level. Landholding significantly influences teff yield at a 10% probability. The yield elasticity concerning age, sex, education status, landholding, livestock holding, credit uses, extension uses, off-farm activity, land ownership and fertilizer uses indicates that as these variables increase, teff yield will enhance.

Table 4. Teff (*Eragrostis tef* (Zucc.) Trotter) growers (means) by achieving technical inefficiency status

Variables	Total Sample	Efficiency	Inefficiency	Comparison [a]	*P*-value
Technical Inefficiency Indicators					
Teff crop yield (Tons year^{-1})	1.61	1.825	1.224	-10.462	0.000***
Household Characteristics					
Sex of teff grower (1 = male)	74.25%	76.73%	27.68%	0.59	0.739
Extension service (1 = yes)	67.34%	86.72%	52.81%	26.78	0.000***
Credit use (1 = yes)	54.57%	69.73%	44.86%	17.47	0.000***
Family labor (1 = yes)	75.38%	80.26%	71.76%	5.84	0.304
Land ownership (1= yes)	57.91%	60.75%	57.16%	0.64	0.832
Educational status (1 = literate)	58.32%	93.41%	31.73%	36.42	0.000***
Age teff grower (years)	54.66	50.83	57.42	30.13	0.605
Family size teff grower (number)	5.58	6.27	5.15	46.87	0.000***
Landholding of teff grower (ha)	2.65	2.78	2.46	33.71	0.000***
Livestock ownership (TLU)	11.78	12.34	10.87	49.36	0.000***
Off-farm activity (euros)	184.05	210.63	161.13	3654	0.000***
Fertilizer use	74.38	86.82	57.65	32.43	0.000***
Access to infrastructure	66.74%	86.18%	53.62%	0.54	0.000***
Seed	78.28	72.73	80.26	37.76	0.865
Total observations	387	158	229		

Source: Computed from own survey data 2020/21. [a] t-values developed to measure continuous independent variables; Pearson's χ^2 values developed to measure categorical dummy and dummy independent variables. The figures in the present are standard errors.

Teff grower's increases, educational status, credit uses, extension uses, land ownership, and fertilizer utilization on average for the yield of teff by 1%, can enhance the level of teff yield by 31.46%, 25.15%, 33.28%, 29.52%, and 34.87% respectively. This indicates that there is potential for teff yield in the study area.

The stochastic yield frontier model assesses the factors affecting teff growers' decisions to the technical inefficiency suggested in (Table 5). The goodness fit of the teff grower concerning predictive inefficiency of technical inefficiency was high with 324 (83.72%) of the 387 (100%) teff cultivators included in the model perfectly predicted.

Table 5 suggests that from a total of fourteen explanatory variables ten explanatory variables (age, sex, education status, landholding, livestock holding, credit uses, extension uses, off-farm activity, land ownership, and fertilizer uses) were found to have significant relation with the level of technical inefficiency of teff growing. Particularly, age was revealed to have a strong negative relationship with the technical inefficiency of teff. Specifically, cetris paribus, an extra year of teff grower age is expected to be found in a 3.24% decrease in the probability of teff yield technical inefficiency at ($P < 0.01$). Furthermore, teff growers who are on average 10 years older are suggested to be 32.4% less likely to teff crop yield technical inefficiency than their counterparts, the variable is scientifically determining teff yield technical inefficiency (Mesay et al., 2013; Wudineh and Endrias, 2016). The main reason for this is that teff growers are more skillful at an elder age due to cumulative growing experiences. The ability, physical capacity, information, knowledge and skills increase at an elder age.

The regression result found that variables such as sex, education status of teff grower, landholding of teff grower, livestock holding, off-farm activity, fertilizer uses, credit uses, extension uses and land ownerships were all expected to have negative relations with teff yield technical inefficiency and significantly influence it.

The marginal effect of all these significant variables ranges between 3.45% to 34.87% on average (other factors remain constant). Furthermore, sex, an extra schooling year of teff grower's educational status, size of produced land, livestock possession, off-farm activity, fertilizer uses, credit uses, extension uses and land ownerships were respective relations with a 3.45%, 31.46%,

Table 5. Maximum-likelihood estimates of determinants of technical inefficiency (n = 387)

Variable	Robust Coef.	SE [a]	Z	P >|Z|	dy/dx [c]
Age of teff grower	-0.1346**	0.015	-1.81	0.012	0.0324
Sex of teff grower	-0.237**	0.325	-0.16	0.041	0.0345
Size of family	-0.329	0.154	-2.31	0.418	0.0732
Education status	-0.573***	0.160	-1.24	0.007	0.3146
Landholding	-0.748*	0.435	-1.53	0.074	0.2865
Livestock holding	-0.451**	0.217	-1.88	0.046	0.2894
Credit uses	-0.654***	0.326	-2.98	0.004	0.2515
Family labor	-0.536	0.374	-0.92	0.814	0.3527
Extension uses	-1.241***	0.493	-2.83	0.008	0.3328
Off-farm activity	-0.379**	0.212	-1.19	0.032	0.2145
Land ownership	-1.226***	0.517	-2.63	0.005	0.2952
Fertilizer uses	-0.514***	0.337	-2.59	0.000	0.3487
Access to infrastructure	-0.485	0.358	-2.74	0.187	0.2453
Seed	-0.772	0.525	-1.29	0.739	0.3678
Constant term	4.475***	1.526	2.42	0.000	-

Source: Computed from own survey data 2020/21; Number of observations = 387; LR chi2 (14) = 59.87; Probability > chi2 = 0.0000; Log likelihood = -78.127; Pseudo R^2 = 0.427; ***, **and * are 1%, 5%, and 10% statistically significant levels respectively

28.65%, 28.94%, 21.45%, 34.87%, 25.15%, 33.28%, and 29.52% lower probability of teff yield technical inefficiency on average, cetris paribus. Specifically, teff growers with credit and extension use are expected to be 25.15% and 33.28% less probable to fall victim of teff yield technical inefficiency than their counterparts. Credit is a key element of the teff cultivating system in terms of satisfying teff growers' needs by solving liquidity and working capital problems. Teff growers who get more credit at a given cultivating season are expected to have less technical inefficiency than their counterparts.

On the other hand, the family size of the teff grower, availability of family labor, access to infrastructure, and seed didn't have any relation to teff yield technical inefficiency in the study area. The results presented in both Table 4 and Table 5 were availability of family labor and seed as statistically insignificant variables. In addition, in the descriptive part age of the teff grower, sex and landownerships were in no significant correlation with teff yield technical inefficiency. The results from econometrics presented that the family size of the teff grower and access to infrastructure were statistically insignificant variables. Econometric regression results were found to have similar results. (Beyan et al., 2013; Biam et al., 2016; Bizuayehu, 2014; Coelli and Battese, 1996; Getachew and Bamlak, 2014; Idiong, 2007; Khai and Mitsuyasu, 2011; Liu and Zhuang, 2000; Mesay et al., 2013; Mesfin and Zemedu, 2015), conducted a study on technical efficiencies.

The results of the efficiency found that the average value of technical, allocative and economic efficiencies was 71.52%, 67.23%, and 63.54% respectively. According to Table 6 average technical efficiency of 71.52% ranges from a minimum of 45.67% to a maximum of 97.48%, while an average allocative efficiency

Table 6. Summary statistics of efficiency score of teff (*Eragrostis tef* (Zucc.) Trotter) growers

Types of efficiency	Mean	Std. Dev.	Min	Max.
Technical efficiency	0.7152	0.23	0.4567	0.9748
Allocative efficiency	0.6723	0.21	0.3925	0.9517
Economic efficiency	0.6354	0.07	0.3862	0.8846

Source: Computed from own survey data 2020/21 also ranges from a minimum of 39.25% to a maximum of 95.17% with an average of 67.23%. Finally, economic efficiency ranges from a minimum of 38.62% to a maximum of 88.46% with an average of 63.54%. The results shower that teff growers were relatively better in technical efficiency than allocative and economic efficiencies. As the summary statistics of efficiency, the result of technical efficiency presented that the teff yield of growers could be enhanced on average by about 29.37% if better evaluations were taken to enhance the level of efficiency of teff growers (Mekonen, 2015). Teff growers achieve a better cost saving of technical efficiency than allocative and economic efficiencies.

Conclusion

The agricultural sector is crucial in deriving sustainable economic development by enhancing productivity and efficiency in yield to alleviate poverty and food insecurity. Agriculture in the study district is characterized by low teff yield and technical efficiency. Technical efficiency is a key technology to enhancing teff yield. The general objective of this study aimed to investigate determinants influencing the productivity and technical efficiency of teff yield in the Kache Birra district, Kambata Zone. For this study, cross-sectional field survey data among 387 teff growers during the 2020/21 teff growing season were collected. This study used both primary and secondary data, as well as both qualitative and quantitative primary data sets. For the data analysis in this study, descriptive and econometric methods of data analysis were developed. In the data analysis, descriptive and Cobb-Douglas production function was conducted to investigate teff productivity, and a stochastic production frontier model was investigated to assess the technical efficiency of teff, while OLS regression was developed to assess determinants influencing inefficiencies status. The finding evaluated that productivity was affected by age, sex, education status, landholding, livestock holding, credit uses, extension uses, off-farm activity, land ownerships and fertilizer uses. Results revealed that technical efficiency was associated with significant improvements in household food security as reflected in significantly increased household per capita income. The estimated average value of technical, allocative and economic efficiencies was 71.52%, 67.23%, and 63.54% respectively. Moreover, key household characteristics such as age, sex, education status, and off-farm income; institutional factors such as the use of credit and use of extension services; and farm characteristics such as land ownership and landholding; input variables such as livestock holding and fertilizer uses were found to be important factors affecting technical inefficiency in the study area. Therefore, the agricultural sector and other concerned bodies should give important attention to technical efficiency, which is a key indicator to alleviating poverty and achieving food security in Ethiopia, especially, in the study district.

Recommendations

Given these findings, several implications could emerge from my analysis upon which important suggestions could be made as key recommendations. Adoption of technical efficiency of teff yield is relatively low in the Kache Birra district, teff growers who adopted the technical efficiency should generally improve their welfare and farm productivity. Consequently, technical efficiency could be considered among the components of the agricultural improvement package implemented by local policymakers and actors as part of improving farmers' livelihoods in the study district. In particular, promoting technical efficiency practices in the district could help to achieve significant welfare and productivity gains thereby leading to better living standards among teff-producing farm households in the study area. More importantly, the study results presenting the crucial factors underlying teff growers' decision on reducing technical inefficiency should serve as a key input in designing a plan and making policies. For instance, education has a strong association with the adoption of technical efficiency in teff crop yields. To this end, strengthening rural farmers' awareness/knowledge among farm households deserves attention for promoting the adoption of technical efficiency. This is, besides the additional positive adoption-enhancing influence arising from access to extension services – a separate effect from that attributable to better education. Consequently, extension programs could be focused on the less educated teff growers through facilitating special training and technical support to improve the adoption rate of technical efficiency of teff yield. Improved access to and provision of credits and extension services could also help achieve similar goals. To this end, the use of agricultural extension needs to consider recommended and improved agronomic practices. Extension use is particularly crucial in terms of improving the adoption of technical efficiency practices, which can, in turn, enhance teff yield and subsequent improvements in household welfare. Concern bodies should create a conducive environment in education status, elder teff growers, female teff growers, fertility of cultivating land, credit uses, extension agents contact and creating appropriate off-farm activity through training and fertilizer utilization, thus helping to enhance technical efficiency in teff yield. The study tried to investigate the key determinants of teff growers' yield technical inefficiency. The research investigated the major differences between the adopted and non-adopted groups of teff crop cultivators through the utilization of technical efficiency. This research summarized the use of technical efficiency by policymakers and plan designers that could bring better enhancement to teff crop cultivators. Hence, improving technical efficiency adoption decisions should consequently create teff productivity and growers' per capita income in a sustainable way. Improving the application, recommendation, implementation and practices of such a technical efficiency of the adopted group is a crucial.

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