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Abstract

Purpose: This study investigated the factors influencing wheat productivity in Ngororero district of Rwanda. Wheat is a major food security crop in many countries and has a significant role in poverty reduction, food security and income generation among households in many countries. In Rwanda wheat is a source of food and income and ranks second to maize. Despite its importance, wheat productivity in Rwanda remains low.

Methodology: Simple random sampling method was used to select a sample of 100 wheat farmers and an interview schedule was adopted to collect the data from the respondents. The collected data were first entered in MS Excel and then exported to SPSS for editing, coding, classification and then analysed with relevant statistical analysis tools. In addition to SPSS, Frontier 4.1 software was also used to generate outputs necessary for the data analysis. The data were analyzed using a linear regression model and stochastic frontier model.

Findings: The ordinary least square estimates revealed that seeds, labour, organic fertilizer and education were significant and influenced wheat productivity among the smallholder farmers in Ngororero district. The maximum likelihood estimates indicated that inputs such as farm size, seed, labour, and organic fertilizer influenced wheat productivity positively while inorganic fertilizer influenced it negatively. Socio-economic factors such as age and farmers' group membership reduced inefficiency while education and household size increased inefficiency among smallholder wheat farmers in Ngororero district. The estimated technical efficiency scores (TE) ranged from 3% to 100% with an average of 49%.

Unique Contribution to Theory, Practice and Policy: Since the calculated likelihood ratio value (23.107) was less than the critical value (26.22) of χ^2at 12degrees of freedom at 1% level of significance, it means that the null hypothesis is accepted and all the coefficients of the second order in the translog function were equal to zero. Thus, the Cobb-Douglas frontier production function adequately captured the production pattern of wheat farmers in Ngororero district. The estimated value of gamma parameter (γ) which is the ratio of the variance output to variance of error was 0.999 and highly significant at 1% level. It is in accordance with the theory that true γ-value should be greater than zero. The estimated value of γ is significantly different from zero indicating that random error is playing a significant role in explaining the variation in wheat production and this is evident especially in case of agriculture where uncertainty is assumed to be a main source of variation. However, it should be noted that 99.9 percent variation in output was due to differences in technical inefficiency and the remaining 0.1 percent was due to stochastic random error. The likelihood ratio test is significant at 1% implying that the inefficiency effects are highly significant in the stochastic frontier model.

Based on the findings, the study recommends that there is need to enforce and improve mechanisms to avail the required amount of inputs to farmers and at the right time, and to encourage a big number of wheat farmers to join different farmer associations and the cooperatives available in the study area as it was found that being a member of a group enhanced technical efficiency and therefore enhanced the productivity capacity of the farmers through acquisition of inputs such as fertilizer or certified seeds.

Keywords: *Productivity, Wheat, OLS, MLE, Ngororero District*

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INTRODUCTION

Agriculture is an important economic activity in Rwanda. It plays a key role in economic growth, poverty reduction, food security and employment (MINAGRI, 2009). In 2014, agriculture sector constituted an estimated of 32.5% in the Rwandan GDP (MINAGRI, 2009). Rwandan agriculture has made significant progress in the last decade, with much emphasis being placed on the improvement of crop productivity including wheat. Due to the efforts made by the Ministry of Agriculture and Animal Resources (MINAGRI) in collaboration with its allied institutions production has increased for a number of crops and especially for wheat. For example, wheat production increased from 24,000 tons in 2007 to 158,975 tons in 2012, land area allocated to wheat increased from 24,000Ha to 750,000Ha in 2012 (Habarurema, 2012). Wheat is an important food security crop in Rwanda, ranking second in terms of economic importance after Maize (Kathiresan, 2011). According to the US Department of Agriculture, Foreign Agricultural Service (USDA FAS, 2015), the highest amount in grain production in Kenya belonged to corn; it was 2,6 million tons in 2014/15 and Corn consumption of Kenya was parallel with corn production. The second highest amount in Kenya's grain production was wheat and was recorded as 415 thousand tons in 2014/15. Wheat consumption of Kenya has been gradually increasing and exceeding production amount and it was recorded as 1,8 million tons in 2014/15. In Tanzania, Wheat production was the four important grain after Corn, Rice and Sorghum with 5 million tons, 1,7 million tons, 840 thousand tons in 2014/2015 respectively and 113 thousand tons of wheat in 2011/12. Wheat consumption was 950 thousand tons in 2014/15.

In Rwanda wheat is cultivated in the Congo-Nile Crest, volcanic soils and Buberuka highlands at altitudes greater than 1900 m asl, and covers 11 districts, i.e. Burera, Musanze, Nyabihu, Rulindo, Gakenke, Gicumbi, Karongi, Ngororero, Rutsiro, Nyamagabe and Nyaruguru.

In 2013 only, Africa spent more than $12 billion to import over 40 million metric tons of wheat (Macauley, 2015) while Rwanda only imported Spelt, common wheat and meslin, worth US$ 51,405.92 million (Word Bank, 2013). The value of imports of Wheat and meslin to Rwanda totalled $ 60 million in 2021 and $59 million in 2020 (TrendEconomy, Nov 2022). In this context, there is a need to increase the volume of wheat production in Rwanda despite the efforts of the Government of Rwanda (GoR) to enhance wheat production through the different initiated programs. This show that there is a gap to be filled and will be filled once the production of wheat is increased. This implies that more efforts are needed to increase wheat productivity. The challenges facing wheat production in Rwanda include low use of appropriate inputs such as improved seed and fertilizer, use of traditional facilities and low knowledge on grain production by the farmers (Muhayimana, 2012).

Despite the interventions made by the GoR, wheat productivity is still low since the total production cannot satisfy the total demand of the country; in 2015 the total domestic consumption was 145,000T while Wheat production was 65,000T with productivity of 2T/ha and Wheat import was 80,000T (USDA FAS, 2015). Examining existing literature, no studies that exist that investigate the productivity of wheat in Rwanda and its determinants. Further, the productivity and profitability of wheat in Ngororero district has not been investigated so far. Thus, the purpose of this study is to investigate the productivity and profitability of wheat in Rwanda using Ngororero district as a case study. Further, the determinants of wheat productivity are investigated. The

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findings are useful in policy decision making in order to improve the productivity of wheat in Rwanda. In this study, Cobb-Douglas production function was used to assess the relationship that exists between wheat output and inputs involved in producing it.

The variables included wheat production, economic and socio-economic. In economics, production is defined as the transformation of goods and services into finished products. In agriculture, the physical inputs which are mostly land, labour or capital are transformed into final output such as crop or livestock output. Productivity is efficiency in production i.e. how much output is obtained from a given set of inputs. As such, it is expressed as an output-input ratio (Chad, 2011). Iqbal, et al., (2017) in their paper on the determinants of various factors for wheat production defined output as the total value of crops produced by the farm which includes crops used for feed and seed by the farm business and those consumed in the household. He concluded that output is the main indicator of individual crop and livestock. In this study wheat productivity depends on the various inputs given as follows:

Independent Variables **Dependent Variable**

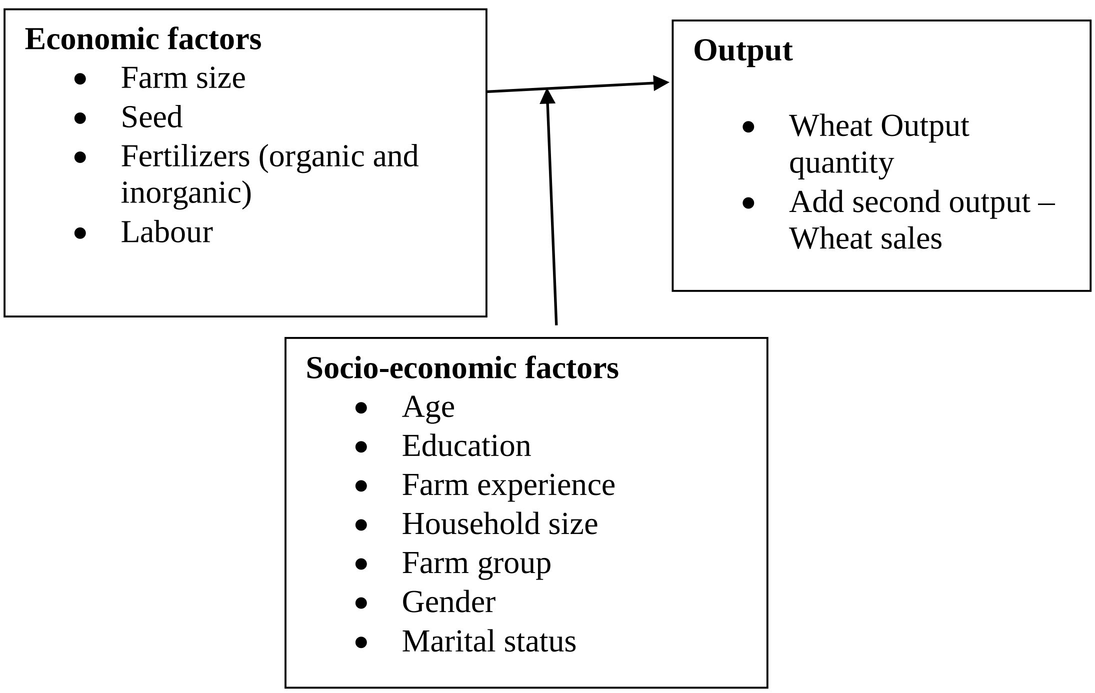

Figure 1: Conceptual Framework

From the reviewed empirical studies factors such as farm size, seed, fertilizers, access to credits, farmers' educational, number of training received, farming experience and labour were found to be significant. According to Ahmed (2013) after estimating a Cobb-Douglas production function type found that labour, organic fertilizer, oxen and seed were the factors determining farm productivity in Ethiopia. Kebede et al., (2017) concluded that gender, improved variety, fertilizer, farming experience, access to extension, harvesting time, nature of access to land and access to irrigation schemes affect potato productivity.

After reviewing the literatures related to productivity and profitability of crops among the smallholder farmers, it is evident that a number of studies exist in the literatures of productivity and profitability of crops. However, very little work has been concerning the determinants of crops productivity in Rwanda in general and in the area of study in particular. Assessing the determinants of crop productivity of smallholder farmers is useful since it provides a deeper understanding of the factors that influence crop productivity, identifying and evaluating the challenges available that impede to increase farm income and subsequently farm profit. In this study a production function model is used to analyse the factors affecting wheat productivity in Rwanda with Ngororero district being used as a case study. To do this, the study adopts a deductive approach of research in which a Cobb-Douglas theory of production is applied.

In the context of Rwanda, little emphasis has been accorded to the analysis of factors affecting the production in agriculture. Thus, to fill the gap and to further investigate the existing relation between wheat production and the related factors, this research was conducted.

METHODOLOGY

Materials and Methods

The study was conducted in Ngororero district, western province of Rwanda. It lies about 59 kilometers, by road, northwest of Kigali, the capital of Rwanda. Ngororero district lies at 2135 meters above sea level with a surface area of 679 Km^2 with majority of the residents being farmers. The major crops grown in the district include wheat, sorghum, maize, beans, vegetables, potatoes and onions with a majority of the cultivators in the district growing wheat for home consumption and sale. Ngororero district is one of the top five producers of wheat among the thirty districts of Rwanda.

A household survey was conducted so as to collect primary data which was collected using well-structured questionnaire that were administered to 100 wheat farmers through an interview schedule. Secondary data were also collected from the relevant published reports of the MINAGRI, National Institute of Statistics of Rwanda (NISR) and Rwanda Agricultural Board (RAB).

Sampling Procedures and Sample Size

The population of study was wheat farmers in Ngororero district of Rwanda. Using random sampling technique, a sample of 100 wheat farmers was obtained. To determine the sample size; this study employed a simplified formula by Kotari (2004) at 95% confidence level as given below:

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

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Where:

n: Sample size

N: Size of population

P: population reliability where p is given as 0.5 and p+q=1

e: Margin of error considered is 10% for this study

$Z_{\alpha/2}$: Normal reduced variable at 0.05 level of significance z is 1.96

According to the above formula, the sample size is:

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5 \times 2000}{(0.1)^2(2000-1)+[(1.96)^2 \times 0.5 \times 0.5]} = 92$$

Thus, based on the formula, 92 wheat growers were to be selected from the population by simple random sampling method. 8 additional respondents were also selected to form a sample size of 100 for more statistical significance, more precision of the estimates, less multicollinearity between variables and the higher coefficient of determination (R-square).

Data Collection

A well-structured questionnaire consisting of open-ended and closed –ended questions and an interview schedule technique was applied to collect the data from the sampled wheat farmers. The questionnaire was pretested using farmers who were not part of the sample and a final questionnaire was prepared using responses obtained from the wheat farmers. The survey took place between November/2016 and January/2017 in Ngororero district.

Model Specification

Multiple Linear Regression Model

The determinants of productivity of wheat were examined using the multiple regression analysis. The model fitted was explicitly expressed as:

$$Y = AX_1^{\beta 1} X_2^{\beta 2} \ldots\ldots (1)$$

Where, Y= Dependent variable

X_1 and X_2= independent variables

A and βi are the parameters to be estimated

The generalized linear regression model is defined as:

$$lnY = lnA + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + \beta_5 lnX_5 + \beta_6 lnX_6 + \beta_7 lnX_7 + \beta_8 lnX_8 + \beta_9 lnX_9 + \beta_{10} lnX_{10} + \beta_{11} lnX_{11} \square + \beta_{12} lnX_{12} \ldots\ldots (2)$$

Where:

Y: wheat output

X_1: Farm size (in hectares)

X_2: Seed (in kilograms)

X_3: Labour (in man-days)

X_4: Inorganic fertilizers (in kilograms)

X_5: Organic fertilizers (in kilograms)

X_6: Age of the respondents (in years)

X_7: Gender of the respondents (Dummy variable whereby 1 denotes male and 0 female)

X_8: Marital status (Dummy variable whereby 1 denotes married and 0 otherwise)

X_9: Educational level (years of schooling)

X_{10}: Household size (Number of persons living in a house)

X_{11}: Farming experience (in years)

X_{12}: Farmers group ((1 if a farmer belongs to any group and 0 if not)

β_i are the parameters that denote the coefficient of inputs to be estimated by the ordinary least square method.

Stochastic Frontier Model

The stochastic frontier model is theoretically defined as:

$$ln\, Y_i = ln\, f\,(xi, \beta) + \varepsilon_i \quad (3)$$

Where: Y_i is wheat production, Xi is a set of k inputs, β is a vector of k parameters to be estimated using maximum likelihood method and $\mathcal{E}_i$ is the error term. The stochastic frontier production is also called composed error model because it assumes that the error term $\mathcal{E}_i$ is decomposed into two components such as a stochastic random error component (random shocks) and a technical inefficiency component as follows:

$$\varepsilon_i = \nu_i - u_i \quad (4)$$

where $\nu_i$is the symmetrical two sided normally distributed random error.

Data collected were analyzed using the stochastic frontier approach as it gives estimates of the efficiency level of each farmer and the different variables associated with the farmer's efficiency. The empirical model is shown in the equation (3) as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln \delta 1 + \beta_7 \ln \delta 2 + \beta_8 \ln \delta 3 + \beta_9 \ln \delta 4 + \beta_{10} \ln \delta 5 + \beta_{11} \ln \delta 6 + \beta_{12} \ln \delta 7 + \nu_i - \mu_i \quad (5)$$

Where

X_1: Farm size (in hectares)

X_2: Seed (in kilograms)

X_3: Labour (in man-days)

X_4: Inorganic fertilizers (in kilograms)

X_5: Organic fertilizers (in kilograms)

δ_1: Age of the respondents (in years)

δ_2: Gender of the respondents (Dummy variable whereby 1 denotes male and 0 female)

δ_3: Marital status (Dummy variable whereby 1 denotes married and 0 otherwise)

δ_4: Educational level (years of schooling)

δ_5: Household size (Number of persons living in a house)

δ_6: Farming experience (in years)

δ_7: Farmers group ((1 if a farmer belongs to any group and 0 if not)

β_i are the parameters that denote the coefficient of inputs to be estimated by the maximum likelihood method.

Data Analysis

The study applied both descriptive statistics and inferential statistics in analyzing data. Descriptive statistics included means, minimum, maximum and standard deviation, and inferential statistics was employed to study the factors influencing wheat productivity among smallholder wheat farmers in Ngororero district. To analyze the data two methods were applied which is ordinary least square (OLS) and maximum likelihood (ML) and the results were compared. OLS was used to estimate the linear regression model while the maximum likelihood was used to estimate the stochastic frontier model and both SPSS 16 and Frontier 4.1 softwares were used to generate outputs for the analysis.

Results and Discussion

Summary Statistics

The summary statistics of the wheat farmers are presented in Table 1. The mean age for the farmers was 47.83 years and the minimum age being 28 years while the maximum age was 65 years. This means that most of the wheat farmers were middle aged, an age group that is active and greatly involved in farming activities. The study area seems highly populated since the mean household size was approximately 7 persons per household with a maximum of 12 and a minimum of 3 members. Distribution of sampled farmers according to years of experience in wheat production showed that on average, the farmers had 6.5 years of wheat farming experience with a standard

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deviation of 3.5 years. This simply implies that the farmers were experienced in wheat farming enabling them to perform better their practices and leading to increased wheat production. The mean farm size was 0.76 Ha with the standard deviation of 0.59 Ha. This indicates that the farmers were classified as the smallholder farmers based on the land size holding pattern in Rwanda (NISR. 2012) where the farmers with farm size between 0.3-0.9 Ha are classified as small farmers. The mean quantity of sown seed was found to be 78kg which signifies that, seed accessibility had improved especially with the establishment of the National Seed Policy (NSP) by the Government of Rwanda, a policy that facilitated farmers to get seed at an affordable price. The distribution of farmers according to man-days of labour in wheat production had an average of 115. The Mean of both organic and inorganic fertilizers were 3470kg and 120Kg respectively. This was due to the fact that, majority of wheat farmers in the study area were applied organic fertilizers in large quantity compared to inorganic fertilizers and also the government of Rwanda through Girinka (have a cow) programme facilitated farmers to avail organic manures.

Table 1: Summary Descriptive Statistics of the Wheat Farmers

Continuous Variables	Minimum	Maximum	Mean	Std. Dev
Output Variable				
Wheat Quantity (Kg)	20	7000	1435.78	1176.75
Input Variables				
Farm Size (Ha)	0.02	3	0.76	0.59
Quantity of Seed (Kg)	5.00	250	78.3	41.85
Labour (Man days)	10	690	115.43	123.69
Organic fertilizer (Kg)	350	15000	3470.25	2475.99
Inorganic fertilizer (Kg)	15	350	120.67	59.90
Socio-economic variables				
Age (years)	28	65	47.83	8.08
Gender (Dummy; 1= Male; 0=Female)	0	1	0.71	0.456
Marital status (Dummy: 1 = Married; 0=Otherwise)	0	1	0.90	0.302
Education (years of schooling)	6	16	6.62	2.044
Household Size (No)	3	12	6.67	1.65
Farm Experience (Years)	2	22	6.48	3.54
Farmer group (Dummy; 1=Member; 0=Otherwise)	0	1	0.34	0.476

Source: Author's Computation

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Determinants of Wheat Production

Linear Regression Model Estimates

Multiple linear regression was employed to analyze the factors affecting wheat productivity in Ngororero district. Results showed that the coefficient of determination, R squared is equal to 0.593 which denotes that 59.3 percent of the variation of the dependent variable (wheat productivity) is explained by the explanatory variables included in the multiple regression model. The remaining 40.7 percent is due to random error in the model. Results reported in Table 3 revealed that the following independent variables had an influence on wheat productivity including seeds, labour, organic fertilizer and education. It was hypothesized that the variables would be expected to influence positively or negatively wheat productivity. The result showed that seeds rate affected wheat productivity positively at 1 percent level of significance. This is in the line with the findings of the study by Kiliç and Gürsoy (210) who found that seed rate affected positively the wheat grain yield.

Examining labour, the result revealed that labour was significant at 5 percent level and affected positively wheat productivity in the study area. This supports the findings of Sibiku et al. (2013) who reported that labour had a positive influence on common bean productivity in Eastern Uganda. But in contrast, Fawole and Rahji (2016) found that labour was significant and affected negatively cocoa productivity among farmers in Ondo State of Nigeria. Result revealed that organic fertilizer was significant at 5percent level and affected positively wheat productivity in the study area. This result is in consistency with that of Kavi (2015) which showed that organic fertilizer had a positive relationship with rice output in the Ketu northern district of the Volta region, Ghana. Again, in line with that of Beyan et al. (2013) who reported that organic fertilizer was an important factor determining farm production of smallholder farmers in Girawa district of Ethiopia as it influenced positively farm production. Education was significant at 5 percent and negatively contributed to wheat productivity is the area. The negative effect of farmers' formal education on productivity was also found by Iwala et al. (2006) and Hasnah et al. (2004) in Oil Palm Production in Nigeria and in West Sumatra respectively.

Table 2: Ordinary Least Square Results of the Factors of Wheat Productivity among Smallholder Farmers

Independent variables	β	Std. Error	t	P-value
Intercept	41.756	725.050	0.058	0.954
Land (FS)	253.171	219.313	1.154	0.252
Seed	13.059	6.753	1.934	0.056*
Labour	1.764	0.830	2.125	0.036**
InorFert	1.211	4.470	0.271	0.787
OrFert	0.091	0.038	2.385	0.019**
Age	5.261	14.015	0.375	0.708
Gender	-30.437	207.538	-0.147	0.884
Marital status	115.157	323.774	0.356	0.723
Education	-101.825	47.589	-2.140	0.035**
Household size	-40.311	68.947	-0.585	0.560
Experience	9.606	24.934	0.385	0.701
Farmer group	177.896	204.502	0.870	0.387

Source: *Author Computation*

Note: Dependent variable was wheat quantity. R-Square was 0.593 while Adjusted R-square was 0.537 * Significant at 10% level of significance, ** Significant at 5% significance and *** Significant at 1% level of significance.

$$Ln\hat{Y} = 41.756 + 253.171lnFS + 13.059lnSd + 1.764lnL + 1.211\ln Ino + 0.091\ln Org + 5.261\quad Ag - 30.437\quad Gen + 115.157\quad MS - 101.825\quad Edu - 40.311HS + 9.606\quad Exp + 177.896\quad FG$$

R^2=0.593
R^{-2}=0.537

Maximum Likelihood Estimates

Results shown in the Table-4 are the estimated parameters of the stochastic frontier production function. The results indicate that nine out of twelve variables were statistically significant at 1, 5 and 10 percent level of significance which included age, education, household size, farmers' group membership, farm size, seed, labour, inorganic fertilizer and organic fertilizer. Four out of five input factors influenced positively wheat production thereby confirms the hypothetical signs of the parameters in the stochastic frontier wheat production; only inorganic fertilizer influenced negatively wheat production in the study area. This indicates that the four variables increased wheat production while inorganic fertilizer decreased it in the study area.

The estimated coefficients of farm size, seed, labour and organic fertilizer were positively associated with wheat output at 1 percent level of significance. This implies that farm size, seed, labour and organic fertilizer are variables that crop production depends on and increasing farm size, seed, labour and organic fertilizer implies increasing crop production. An increase of 1 percent in the size of land would increase wheat output by 0.39 percent other things being same. In the study of Tiruneh and Geta (2016), it is shown that farm size influenced positively technical efficiency in Central Oromia, Ethiopia. An increase in seed increases wheat output which implies that an increase of 1 percent in the quantity of seed would increase wheat output by 0.44 percent other things being same. The finding of this study supports that of Baten and Hossain (2014) who found a positive relationship between quantity of seed and rice production in Bangladesh. In contrast, Ahmed et al. (2013) found that seed was significant and negatively associated with farm production of small-scale farmers in Girawa district of Ethiopia.

The positive sign of labour implies that there is a positive relationship between labour and wheat production at 1 percent level of significance indicating that an increase in man days by one unit would increase wheat output by 0.31 units holding all other factors constant. This finding is in consistency with the findings of Ismail (2018) who reported that labour was a significant factor since it increased maize production in Dodoma region, Tanzania. The author concluded that an increase of 1 percent in labour will increase maize production by 56.7 percent other things being the same. It is also in line with the findings of Kaddy (2014) who revealed that labour was positively significant at 1 percent level and influenced positively rice production in Gambia.

The estimated coefficient of inorganic fertilizer was negatively associated with wheat production at 1 percent level of significance. This means that an increase of 1 unit of the quantity of inorganic fertilizer would decrease wheat production by 0.17 units other factors remaining constant. Patra et al. (2016) with empirical evidence found that the use of chemical fertilizers has failed to enhance agricultural production and yield and there was no strong correlation between the two variables in Hooghly district, West Bengal, India. Though the annual rate of fertilizer use was stable, the yield has fluctuated. According to Velthof et al. (2011), acidification of soil can take place due to decrease of organic matter in the soil by excessive use of chemical fertilizers causing threats to survival of plants. Balfour (1943) & Howard (1947), claimed that inorganic fertilizer increases the breakdown of humus in soil, leading to a decline in soil fertility.

The estimated coefficient of organic fertilizer was positively associated with wheat output at 1 percent level of significance. It implies that an increase of 1percent in the quantity of organic fertilizer would increase wheat output by 0.36 percent ceteris paribus. This finding is in consistency with the finding of Kavi (2015) who found that organic fertilizer had a positive relationship with rice output in the Ketu northern district of the Volta region, Ghana. The finding is also consistent with that of Ahmed et al. (2013) who concluded that organic fertilizer was an important factor determining farm production of smallholder farmers in Girawa district of Ethiopia and in line with the result of Okon (2009) which showed that the quantity of the organic manure was positive and influenced garden egg (*solanum* Spp) production in Uyo Metropolis, Akwa Ibom state of Nigeria.

Among socio-economic factors, age and farmers' group membership were significant at 1 percent; education was significant at 5 percent while household size was significant at 10 percent level of significance. The negative sign of age and farmers' group membership means that these factors reduced inefficiency while the positive sign of education and household size means that these factors increased inefficiency of wheat production in the study area.

The result showed that old farmers were more technically efficient compared to young farmers in the study area. This finding is supported by Guo et al. (2015) who found that elderly farmers who do not intend to abandon farming had higher agricultural output compared to other farmers in Jiangsu Provincial Department, China. The experience of older farmers leads to more efficient combinations of input, which makes a unit of labor more effective. Varina et al. (2020) conducted research on efficiency of oil palm smallholders in Indonesia and the results showed that farmer's age was significant in improving technical efficiency while Tauer (1995) found that efficiencies of younger and older farmers were lower than middle-aged (35-44) farmers in the USA.

It was found that farmers with formal education were less efficient than farmers without formal education among wheat farmers of Ngororero district. This finding is supported by that of Iwala et al. (2006) who found that farmers' education level negatively contributed to efficiency among oil palm farmers in Nigeria because educated farmers tend to have off-farm jobs and delegate hired labor to operate their farms. Hasnah et al. (2004) also found that education had negative impact on technical efficiency in smallholder scheme for oil palm production in West Sumatra.

Household size was significant at 10 percent level of significance and increased inefficiency in wheat production in the study area. This is supported by Ngongi & Urassa (2014) who found that the total number of individuals in a household negatively and significantly influenced food production in Kahama District, Tanzania. According to Scully (1962), though some adult family members may contribute to farm labour they also compete with the farm when the income is being allocated between the demands of both; available funds are shared between family living expenses and reinvestment in the farm hence reducing the total farm output. Havanon et al. (1992) and Urgessa (2015) also found that household size affect negatively the household income in rural areas. Olayemi (2012) found that family size had negative impact on food security in Osun state, Nigeria.

Farmers' group membership is a dummy variable where farmers who were in a group were assigned a value 1 while those who were not in a group were given a value 0. The result indicates that farmers who are in a group were technically efficient compared to those who were not in the group. Hence, putting farmers in the group is considered to be the best approach to enhancing farmers' efficiency. Results of this study were in line with that of Evaline et al. (2015) who found that membership in association influenced positively technical efficiency in Kenya and in consistency with Asiimwe (2011) who concluded that being a member of a group reduces risks that are always associated with agriculture and therefore provides incentives to produce efficiently in Uganda. It is also in agreement with the findings of Ismail (2018) who reported a positive impact of group membership on technical efficiency among smallholder maize farmers in Dodoma region, Tanzania.

The estimated value of gamma parameter (γ) was found to be 1.00 and significant at 1 percent level which indicates that random error plays a significant part in explaining the variation which happened in wheat production. Hence, 100 percent variation in the output was due to differences in technical inefficiency.

Table 3: Maximum Likelihood Estimates of the Stochastic Frontier Model

Variable	Parameter	Coefficients	Standard Error	t-ratio
Intercept	β_0	2.710	0.008	319.473
Farm Size	β_1	0.386***	0.001	598.833
Seed	β_2	0.440***	0.004	120.167
Labour	β_3	0.306***	0.001	356.687
Inorganic fertilizer	β_4	-0.167***	0.002	-106.910
Organic fertilizer	β_5	0.362***	0.001	332.999
Age	δ_1	-0.035*	0.020	-1.771
Gender	δ_2	-0.028	0.322	-0.088
Marital status	δ_3	0.855	0.682	1.254
Education	δ_4	0.141**	0.068	2.059
Household size	δ_5	0.350***	0.074	4.720
Farming Experience	δ_6	-0.030	0.070	-0.426
Farmers group	δ_7	-0.840*	0.438	-1.916
Sigma squared		2.088***	0.353	5.913
Gamma		1.000***	0.000	2588776.800
Log Likelihood function		-89.329		
Likelihood Ratio test		27.561		

Source: Author Computation

Note: ***Significant at 1% Level; **Significant at 5% Level; *Significant at 10% Level

Technical Efficiency of Smallholder Wheat Farmers in Ngororero District

Table 5 provides the distribution of the technical efficiency scores among smallholder wheat farmers in Ngororero district. From the results, the overall mean technical efficiency of the sample was 0.49 with the minimum efficiency score being 0.03 while the maximum being 1 and the standard deviation was 0.27. This implies that on average output can be increased further by 51 percent while keeping all other factors constant.

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Table 4: Distribution of the Technical Efficiency of Smallholder Wheat Farmers in Ngororero District

Efficiency score	Frequency (No of Wheat Farmers)	Percentage
0.01-0.09	5	5
0.10 – 0.19	14	14
0.20 – 0.29	8	8
0.30 – 0.39	12	12
0.40 – 0.49	16	16
0.50 – 0.59	9	9
0.60 – 0.69	7	7
0.70 – 0.79	13	13
0.80 – 0.89	8	8
0.90 – 0.99	2	2
1.00	6	6
Summary of efficiency scores		
Mean efficiency Scores	0.49	
Minimum score	0.03	
Maximum score	1.00	
Standard deviation	0.27	

Source: Author's Computation

CONCLUSION AND RECOMMENDATIONS

This study examined the determinants of wheat productivity in Ngororero district. Data were obtained from a random sample of 100 wheat farmers that was selected by applying a simple random sampling method. To analyze the data two methods were applied which are ordinary least square and maximum likelihood. The results of the estimated linear regression model revealed that among five input factors three (seed, labour and organic fertilizer) were statistically significant and positively associated with wheat output and since they determine positively wheat production it is therefore important to consider them in the process of wheat production and facilitate wheat farmers to avail them at an affordable price and at the right time. Among seven socio economic factors, only education was statistically significant and influenced negatively the technical efficiency. The results of stochastic frontier model showed that the input factors such as farm size, seed, labour and organic fertilizer were statistically significant at 1 percent level and positively associated with wheat output while inorganic fertilizer was statistically significant at 1 percent level and negatively associated with wheat output. The inefficiency factors such as age, education, household size and farmers' group membership were statistically significant; age and farmers' group membership reduced inefficiency while education and household size increased inefficiency in wheat farming in Ngororero district.

Based on the findings, the study recommends that the Ministry of Agriculture and Animal Resources and its partners should continue to strengthen systems that help timely availability of required inputs to farmers as their shortage leads to low wheat productivity, low income and hereby low profitability. They should also continue encouraging more wheat farmers to join Farmer Field Schools and cooperatives available in the area as it was found that being a member of a group enhances technical efficiency and therefore increases the capacity of being more productive. Further research on the development of modern technology and innovative extension systems in wheat production within a changing global economy is also recommended.

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