European Journal of Academic Essays 2(2): 57-64, 2015
ISSN (online): 2183-1904
ISSN (print): 2183-3818
www.euroessays.org

Analysis of Allocative Efficiency among Small Scale Farmers in Musanze District, Northern Rwanda

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Abstract

This article analyses the productive efficiency of small scale farmers coached by DERN (the Development Programme of Ruhengeri Diocese), in Musanze District, Northern Rwanda. Data used for the analysis were collected among 107 farmers, selected purposively from the study area. Both descriptive and inferential statistics were used to validate the study objective. A Cobb-Douglas production function was specified and estimated in the context of agricultural production for small scale farmers. This was complemented with APP, MPP and TFP. Results from the analysis substantiate that the agricultural production for the study period is positively correlated to the inputs used, namely labour, fertilizers and seeds as expected. The estimated coefficients were found also highly statistically significant and these can be relied on for inference ($p \leq 0.05$). Therefore, it is concluded that these factors contribute significantly to the production of agricultural crops in the study area. The average physical product (APP) in Kgs is 31.35 for labour, 1.06 for fertilizers and 9.09 for seeds, and the marginal physical product (MPP) in Kgs is 14.96, 0.27 and 3.18 for labour, fertilizers and seeds respectively, whereas the total factor productivity (TFP) is 1.47. In view of these results, we recommend that farmers need to adjust the use of these inputs if more crop productivity is to be achieved.

Key words: Cobb-Douglas agricultural production, total factor productivity, small scale farmers, DERN, Musanze District, Rwanda

1. Introduction

Agriculture is a key sector in the development of Africa. It is well documented that most people in Sub-Saharan Africa are rural based and rely on agriculture for their livelihood [1, 2]. Despites its importance, the agriculture is held mainly by small-scale farmers who use traditional methods and rudimentary tools. As one of the development priorities of Rwanda, agriculture was recognised as the engine of the primary growth [3,4]. It has been chosen as the first and strongest leverage to put the country on a sustainable development process and to fight against poverty and the investment policy in agricultural sector will contribute to change in the structures, methods, marketing and efficiency of agricultural activities with a very high impact on the revenue of the majority of the population and most of the poor, on exports and on the GDP. The major agricultural policies adopted by the Government of Rwanda to transform and mechanize the agriculture through the development of modern agriculture include the promotion of more intensive agricultural practices through the increased use of agricultural inputs, agricultural professionalization that promotes high enterprise profitability, the promotion of soil fertility and land protection, improved marketing initiatives, and the reinforcement of agricultural research and advisory including a greater role for farmer cooperatives and associations [5]. Another government policy known as Economic Development and Poverty Reduction Strategy, EDPRS [6] identifies the agricultural sector as a

crucial area for a growth and calls for energetic public action in collaboration with private and nongovernmental development partners to encourage greater input use and to assist in the provision of services and their monitoring.

Various researches have analysed the agricultural efficiency in different countries. Adepoju [7] analysed the technical efficiency of egg production in Osun State, Nigeria. This study looked at the socioeconomic characteristics which influence the technical efficiency of farmers. Data collected from a sample of 86 farmers were analysed using descriptive statistics, budgetary analysis and stochastic frontier production function. The results reported that inputs were efficiently allocated and utilised. Yet in Nigeria, Adeola et al. [8], Adeyemo et al. [9], Forolunso *et al*. [10], Adewuyi *et al*. [11] and others have conducted different researches aiming at analysing farm production efficiency. In Rwanda, different researches have been conducted to analyse agricultural production [12, 13,14,15, 16, 17, 18] but most of them did not concern the resource use analysis. In different countries, most of the researches about the resource use in agriculture have used the Cobb-Douglass production function to analyse to agricultural production efficiency.

Given that in Rwanda, like in other African countries, farmers face the resource constraint, and as famers need to be aware of the appropriate way to use their inputs, this study analyses the efficiency-use of limited resources among the small scale farmers in Musanze District, Northern Rwanda.

2. Materials and Methods

2.1 Description of the study area

The study was conducted in Musanze District, Northern Rwanda. Musanze District is located at 1°30'6.94″S of the latitude and 29°37'59.75″E of longitude. The average altitude is of 2,000 m above the sea level including the chain of the volcanoes Kalisimbi (4,507 km), Muhabura (4,127 km), Bisoke (3,711 km), Sabyinyo (3,574 km), Gahinga (3,474 km) which offers beautiful and attractive touristic site. Musanze District faces tropical climate of highlands with has mean temperature of 20ºC. Generally with enough rain the whole year, the precipitations vary between 1,400 mm and 1,800 mm. Two main and two small seasons characterize the study area namely the rainy and the dry seasons: from June to mid-September, we have the great dry season; from January to mid-March, the small dry season; from mid-March to the end of May, the great rainy season; and from mid-September to the end of December, the small rainy season. In terms of physical characteristics of the study area, the soil of Musanze District is dominated by volcanic soil which is essentially fertile. The main crops of Musanze District are Irish potato, bean, corn and wheat [19]. According to current statistics, the population of Musanze District rises to an average density of 695 inhabitants per km^2 [20].

2.2 Sampling method, sample size determination and data collection methods

For the purpose of data collection, a field survey was conducted in Musanze District during August and September 2012 from a purpose sample of 107 farmers' organizations assisted by the Programme DERN in Musanze District through the self-administered questionnaire. Besides the field survey, the documentary method was used in collecting data.

2.3 Definition and measurement of the variables

The table 1 below summarizes the definition, the symbol and the measurement of both dependent and independent variables. The dependent variable is the agricultural output, and the independent variables include the labour used, the fertilizers, the pesticides, and the seeds. Each independent variable is positively related to the dependent variable. This means that the signs of the coefficients are expected to be positive**.**

Table 1: Definition and measurement of variables

Variables	Symbol	Measurement	Definitions
Agricultural output	Y	Kilograms	Agricultural produce for the crop grown
Labour	L	Man days	Number of workers used
Fertilizers used	F	Kilograms	Minerals and organic manure used
Seeds	S	Kilograms	Seeds used

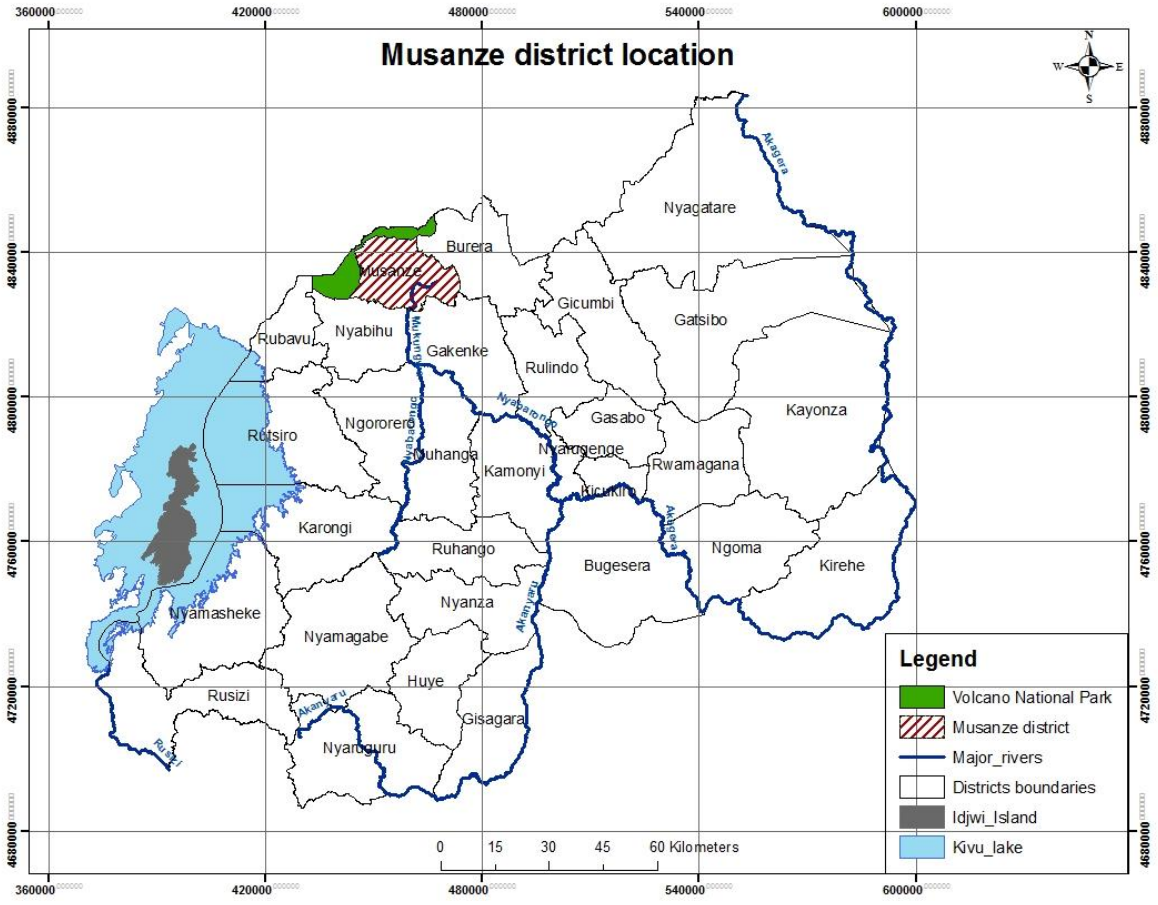

Figure 1: Location of Musanze District on the map of Rwanda

2.4 Specification of the model

In the intent of the model specification, Gujarati [21] and Gujarati and Sangeetha [22] classify the Cobb-Douglas production function as the best production functions besides constant elasticity of substitution production function. Its stochastic form and its log-linear form are below presented respectively:

$$Y = \beta_1 X_{2i}^{\beta_2} X_{3i}^{\beta_3} e^{u_i}$$

$$LogY = \beta_0 + \beta_2 LogX_{2i} + \beta_3 LogX_{3i} + u_i \quad (1)$$

where Y is a dependent variable, Xs are independent variables, Log stands for Neperian logarithm, e is the Neperian number equal to 2.72121, u_i is a disturbance term, β s are parameters to be estimated and $\beta_0 = Log\beta_1$ are the intercepts. Following Gujarati, the model to be estimated for this case study is below described:

$$LogY = \beta_0 + \beta_1 LogL + \beta_2 LogF + \beta_3 LogS + U \quad (2)$$

where *LogY* stands for agricultural output in kilogrammes, *LogL* is labour in mandays, *LogF* is the fertilizers in kilogrammes and *LogS* is the amount of seeds in kilogrammes, *Log* means natural logarithm, U stands for the disturbance term, and β_0 to β_4 are parameters to be estimated.

2.5 Methods of productive efficiency measurement

Average physical product (APP) of a factor of production is the total output produced per unit of a factor employed [23,24, 25, 26]. The mathematical form of the APP is given by the formula 3 here below.

$$APP_X = \frac{Q}{X} \quad (3)$$

The marginal physical product (MPP) of a factor of production is defined as the increment in total output of a commodity when more one extra unit of the facto r is employed in production of that commodity, the quantities of other factors remaining the same (Barthwal, 2000; Ahuja, 1983; Ahuja, 2006; Wilkinson, 2005). It is simply the addition to the total production by the employment of an extra unit of a factor. Mathematically, if the employment of a

factor increases by ΔX units which yields an increase in total output by ΔQ units, the marginal physical product of the factor is given by the formula 4.

$$MP_X = \frac{\Delta Q}{\Delta X} \quad (4)$$

The computation of the MP_X is based on the estimates of the equation stated in formula 2.

Another measure of the resource-use efficiency is the total factor productivity (TFP). This was used to estimate the total productivity of inputs used. If the TFP equals 1, resources are optimally used; when it is less than 1, resources are overutilized; and when it is greater than 1, resources are underutilised. It is given by the formula 5 below defined [27] and adapted to the study:

$$TFP = \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} P_{qij}Q_{ij}}{\sum_{j=1}^{m}\sum_{t=1}^{n} P_{xtj}X_{tj}} = \frac{V_{TO}}{V_{TN}} = \frac{TR}{TVC} \quad (5)$$

where V_{TO} is the value of total output, V_{TN} is the total input used in agricultural production, P_q is the price of agricultural output in RwF, P_x is the price of input, Q is the quantity of agricultural output, and x is the quantity of inputs, TR is the total revenue and TVC is the total input cost or the total variable cost.

3. Results and Discussion

3.1 Distribution of the respondents

Respondents are distributed in sectors and according to the crops. The table 2 below describes the sector distribution of respondents in the study area. This table shows that 107 respondents are distributed differently in the sample sectors. The sector of Musanze is the first with 14.95% of respondents, Rwaza the second with 14.02%, Busogo the third with 13.08%, Gataraga the fourth with 12.15%, up to Kinigi the last with 6.54%. As the table shows, the numbers of respondents are distributed in sectors from 7 to 16.

Table 2: Distribution of respondents in sample sectors

Sector	Number of organizations	Percentage
Busogo	14	13.08
Cyuve	9	8.41
Gataraga	13	12.15
Kinigi	7	6.54
Muko	11	10.28
Musanze	16	14.95
Nkotsi	13	12.15
Nyange	9	8.41
Rwaza	15	14.02
Total	**107**	**100.00**

Source: Field survey data, August and September 2012

Not only were the respondents distributed in sectors, but also according to the crop as it is described by the table below. The crop distribution of respondents was also presented in order to know in which importance the CIP (Crop Intensification Programme) selected crops are grown in sample sectors. This table shows that 53.27% of the respondents grow Irish potato, 27.10% grow bean, 11.21% grow corn, 5.61% grow wheat, 0.93% grow cabbage, 0.93% grow tomato, and the remaining 0.93% grow onion.

Table 3: Crop distribution of respondents

Crop	Number of organizations	Percentage
Bean	29	27.10
Cabbage	1	0.93
Corn	12	11.21
Irish potato	57	53.27
Onion	1	0.93
Tomato	1	0.93
Wheat	6	5.61
Total	**107**	**100.00**

Source: Field survey data, August and September 2012

3.2 Estimates of the Cobb-Douglas production function

The measurement of the relationship between agricultural output and various inputs was based on the estimation of Cobb-Douglas production function.

The following table concerns the analysis of estimates of agricultural production function of main crops grown in Musanze District. These crops are Irish potato, bean, corn, wheat, tomato, onion and cabbage. This table shows that positive relationship exists between agricultural production (LogY) and farm labour (LogL), fertilizers (LogF), and seeds (LogS). This implies that as more of these inputs are used, there is an increase in agricultural production. The test of significance shows that labour, fertilizers, and seeds are statistically significant at 5% level of significance. The R^2 estimated as 0.58 shows that 58% of variations in agricultural production are explained by the explanatory variables included in the model.

Table 4: Estimates of agricultural production function in Musanze District

Dependent Variable: LogY

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.857916	0.580039	3.203087	0.0018
LogL	0.481715	0.111503	4.320183	0.0000
LogF	0.250934	0.055399	4.529588	0.0000
LogS	0.348725	0.045124	7.728240	0.0000
R-squared	0.586056	F-statistic		48.60857
Adjusted R-squared	0.573999	Prob(F-statistic)		0.000000
Durbin-Watson stat	1.593254	Observations		107

Source: Estimation of agricultural production function by using EViews

The stochastic form of the Cobb-Douglas production function whose estimates are contained in the table 4 above is $Y = 6.42L^{0.48}F^{0.25}S^{0.35}$. This equation was used to compute the MPP of labour which is 14.96, 0.27 for fertilizers and 3.18 for seeds. This implies that an increase by one unit of labour, fertilizer and seeds makes the agricultural production to increase by 14.96 kgs, 0.27 kgs and 3.18 kgs respectively as it is indicated in table 5.

3.3 Estimates of resource-use efficiency of agricultural production in Musanze District

Given the mean quantities of 1,333.33 kilogrammes for the agricultural production, 46.01 mandays for labour, 1,358.08 kilogrammes for fertilizers, and 158.65 kilogrammes for seeds, the APP for labour is 31.35, 1.06 for fertilizers, and 9.09 for seeds. This information is summarized in the table 5 below.

Table 5: Estimates of resource-use efficiency of agricultural production

Efficiency measures	Labour (L)	Fertilzers (F)	Seeds (S)
Marginal physical product (MPP)	14.96	0.27	3.18
Average physical product (APP)	31.35	1.06	9.09

Source: Computed by the researchers

The results contained in the table 5 above indicate that the MPP of fertilizers is very low: one additional manday makes the agricultural production to increase by 0.27 kilogrammes. Yet the APP of fertilizers is 1.06 kilogrammes. The above measures have been complemented by the total factor productivity (TFP). As it is given in the formula 5 above, we were to have the value of agricultural production (Y) in RwF.

The table 6 below shows that the gross margin (GM), the total variable costs (TVC), and other profitability indicators of agricultural production in Musanze District.

Table 6: Profitability analysis of crop production in Musanze District

Items	Revenue/Cost in RwF per are	Percentage
Revenue		
Total revenue	**10,317**	
Variable costs		
Labour expenses	2,172	30.90
Fertilizers	1,580	22.48
Seeds	2,686	38.22
Pesticide expenses	590	8.39
Total variable costs	**7,028**	**100.00**
Gross Margin	**3,289**	
Depreciation	127	
Rent	889	
Total Fixed Costs	1,016	
Net farm income	**2,273**	

Source: Computation of the profitability indicators by using Microsoft Excel

Referring to the content of the table 6 above, the total factor productivity (TFP) was computed by using the formula 5 above mentioned and the results were the following:

$TFP = \frac{Y}{TVC} = \frac{10{,}317}{7{,}028} = 1.4679$. This ratio implies that resources are underutilized by small scale farmers in Musanze District, Northern Rwanda.

4. Conclusion and Recommendations

The research examined the allocative efficiency of small scale farmers in Musanze District, Northern Rwanda. Data were collected through a field survey conducted in Musanze District during August and September 2012 from a purposive sample of 107 farmers' organizations supported technically by DERN (Development programme of Ruhengeri Diocese). A Cobb-Douglas production function was specified and estimated in the context agricultural production for small scale farmers. Both descriptive and inferential statistics were used to validate the study. The ordinary least squares (OLS) technique was used and complemented with APP, MPP and TFP. The estimated agricultural production function is positively related to inputs used namely labour, fertilizers, and seeds. The test of significance shows that all these inputs are positively correlated to the agricultural production at the 5% level of significance. With the help of this model, the computed MPP in kilogrammes is 14.96 for labour, 0.27 for fertilizers and 3.18 for seeds. In addition, the APP in kilogrammes is 31.35, 1.06, and 9.09 for labour, fertilizers and seeds respectively. These results indicate that the MPP of fertilizers is very low: one additional manday makes the agricultural production to increase by 0.27 kilogrammes. Yet the APP of fertilizers is 1.06 kilogrammes. The TFP computed for the agricultural production in Musanze District is 1.47 which implies that resources are underutilised.

For further improvements in agricultural production in the study area, some recommendations have been formulated. Farmers, farmers' organizations and agricultural partners should enhance the best use of fertilizers to achieve more crop productivity. Farmers should have more access to extension services in order to improve their knowledge of efficient resource-use and land protection in order to maintain or to increase agricultural productivity.

Acknowledgements

The authors express their greatest appreciation to Dr. Jean Chrysostome Ngabitsinze and Dr. Martin Mugenzi for their comments that helped to improve the quality of this paper. They also convey thanks to the survey respondents who have contributed to the achievement of this paper by providing all necessary data.

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