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Full Length Research Paper

An efficiency assessment of irrigated tomato (*Solanum lycopersicum)* production in the Upper East Region of Ghana

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This study employed the input-oriented DEA approach with variable returns to scale assumption to assess the technical, scale, allocative and economic efficiencies of 124 randomly selected tomato farmers under irrigation in the Upper East Region using data of the 2017/2018 production season. The mean technical efficiency and scale efficiency were 97.1 and 97% respectively with many farmers experiencing increasing returns to scale. The mean allocative and economic efficiencies were 42.1 and 41.5% respectively. Farmer's age, tomato land size, fuel quantity, fertilizer quantity and chemical quantity (herbicide and pesticide) were all significant determinants of technical efficiency scores whereas extension visit, tomato land size and chemical quantity significantly influenced both allocative and economic efficiencies. It is recommended that agro-inputs and fuel usage for tomato farmers under irrigation in the dry season be increased to improve technical efficiency. It is also recommended that extension education to farmers on effective inputs allocation and cost minimization strategies be intensified.

Key words: Allocative, economic and technical efficiency, data envelopment analysis, Tobit regression, tomatoes, Upper East Region of Ghana

INTRODUCTION

The crops sub-sector of Ghana forms a key component of the agricultural sector, holding a larger share of agricultural GDP of the country with annual growth of 9.4% in 2017 (Ministry of Food and Agriculture - MoFA, 2018). Tomato (*Solanum lycopersicum*) production which is one of the prominent farming and major activities in the country falls within the crop sub-sector. Tomato (*S. lycopersicum*) is a major and important vegetable which forms vital ingredient in almost every one's diet in Ghana. Ghana has a comparative advantage in the production of tomatoes in large scale for domestic consumption and export. This is as a result of the favourable environmental conditions that support the growth of the crop. Although reports on tomato yield in recent times indicate an increasing output levels, the average yield of the crop is still 7.2 metric tonnes per hectare, which is far below the potential yield of 15.0 metric tonnes per hectare. This therefore leaves farmers with a yield gap of about 7.8

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metric tonnes per hectare (MoFA, 2013). In effect Ghana imports tomatoes from neighbouring Burkina Faso to supplement domestic consumption. Ghana Business News [GBN] (2018) reported that Ghana imports over $99.5m worth of tomatoes every year from Burkina Faso.

Tomato production is a major business of the people of the Upper East Region of Ghana especially during the dry season where the crop is grown under irrigation. This form of production is a source of livelihood to many farmers and market women living close to water sources. In their view, Sugri et al. (2013) noted that tomato production in the Upper East Region could be an important tool for tackling the widespread unemployment and poverty for the majority of households and for preventing the rampant rural – urban migration. This potential is however in limbo since the sector experiences erratic production trends according to Puozaa (2015), due mainly to higher inputs cost especially in irrigated systems. It has been established that although the cost of production of tomatoes is generally high in Ghana as compared to other countries, Upper East Region is ranked highest in terms of tomato production cost relative to other regions of the country (Robinson and Kolavalli, 2010). Kalinga (2014) indicated that farmers' inability to combine with precision, improved inputs such as seeds and appropriate technologies like recommended rate of chemicals including fertilizer, pesticides and herbicide application lead to economic inefficiency. It is imperative therefore that to comprehensively and effectively inform policy decisions on lower tomato productivity, the levels of and factors that explain inputs usage and cost efficiencies in the frame of high cost of tomato production in the region must be understood. Several studies have been carried out to estimate and explain efficiency of smallholder farmers in many developing and developed economies using the data envelopment analysis (DEA) or the stochastic frontier modelling (SFM) approaches. Using the SFM, Weldegiorgis et al. (2018) studied farmers producing tomato under irrigation in northern Ethiopia and reported average levels of technical and economic efficiency of the tomato farmers as 0.75 and 0.67, respectively. They concluded that farmers were technically inefficient in using labour and seed inputs and were not cost efficient in using land, labour, seed, and fertilizer inputs. The study further revealed that the degree of education, experience in tomato production, and application of pesticides were variables that affected technical and economic efficiencies positively. Singh and Kumar (2014) used the DEA to estimate the farm level efficiencies of crop production and indicated that the overall technical efficiency scores were 0.75 and 0.73 for wheat and bajra respectively leading to 25 and 27% inefficiencies in the production of the two crops. According to Yusuf and Malomo (2007), a mean technical efficiency of 0.873 was recorded when they analyzed the technical efficiency of poultry egg production in Ogun State in Nigeria with the DEA. In their study, farmer experience and household size were significant determinants of technical efficiency. Through the DEA approach, Galluzzo (2018) reported that the highest level of economic efficiency of 100% was recorded among Irish farms with dairy farms having the modest levels of economic efficiency close to 77%. Mburu et al. (2014) reported technical, allocative, and economic efficiency scores of small scale wheat farmers as 85, 96, and 84% respectively with number of years of formal education, distance to extension advice and the size of farm strongly influencing the efficiency levels of wheat farmers in Kenya. Dogan et al. (2018) recorded mean technical and economic efficiencies of 98.7 and 88.7% respectively with only 17.9% of laying hen farms being fully efficient. They observed that farmer educational level and capacity utilization ratio had positive effect on technical efficiency.

In Ghana, Abdulai et al. (2018) reported that maize farmers in Northern Ghana had a mean technical efficiency of 77% and production exhibited increasing return to scale. Agricultural mechanization and farmers' level of formal education did not show positive relationship to technical efficiency but agricultural extension influenced technical efficiency positively. Average technical and scale efficiencies of 77.26 and 94.21% were respectively recorded among farm households in the study of Abatania et al. (2012). They indicated that hired labour, geographical location of farms, gender and age of household head significantly affected technical efficiency of the farm households. Abunyuwah et al. (2019) assessed technical efficiency of carrot production in Mampong Municipality of Ghana and found out that labour and fuel used in irrigation significantly and positively influenced output levels of carrot. Socioeconomic characteristics of farmers such as farm size, access to credit, household labour, age and years of education were also significant determinants of technical inefficiency. On tomato production in Ghana, and in the Upper East region in particular, very limited research has comprehensively focused on efficiency of tomato production especially technical, allocative, scale and economic efficiencies of the farmers. Puozaa (2015) and Ayerh (2015) worked on allocative and technical efficiencies of tomato production respectively. This leaves a dearth of information and limited empirical findings for policy recommendations. This paper seeks to estimate the technical, scale, allocative and economic efficiencies of tomato farmers in selected irrigated farms in upper east region; and to explain farming and socio-economic factors that influence production efficiencies using Tobit regression and input-oriented DEA.

MATERIALS AND METHODS

Study area

The study was conducted in the Upper East Region of Ghana. The region has a total land area of 8,842 square kilometres, with a unimodal rainfall pattern, which is erratic in nature. The raining

season falls between May/June and September/October with the mean annual rainfall of 800 mm to 1100 mm (GSS, 2013). It lies between longitude 0° and 1° West, and latitudes 10° 30′N and 11°N.

The Upper East Region is largely agrarian and has two major irrigation schemes which aid cultivation of vegetables such as tomatoes in the dry season (from November to April). In addition, there are 172 dams and dugouts scattered over the region (MOFA, 2013) which contribute immensely to crop production.

Theoretical concept of data envelopment analysis (DEA) models

The DEA model was used to analyse the various efficiency measures of the tomato farmers in the Upper East Region. The DEA is a non-parametric mathematical linear programming method used for the measurement of efficiencies of firms (Coelli, 1996). The purpose of DEA is to get a production frontier formed by enveloping the inputs and outputs of the most efficient enterprises that can be compared with those regarded as having the best production frontier. The use of the DEA procedure is advantageous in the sense that it simultaneously measures technical, allocative, cost and scale efficiency scores (Dao, 2013) and this can allow for the assessment of the performance of each decision making unit (DMU) with regards to each of these efficiency measures. The DEA provides efficiency scores of values in a range of zero and one with firms that are most efficient assuming the value of one whereas inefficient firms have values of efficiency less than one (Dogan et al*.,* 2018; Dao, 2013).

The DEA has two main approaches based on whether efficiency is measured in input or output dimensions. The input based approach attempts to measure the performance of a decision making unit in terms of its ability to minimize input quantities and still achieve the same level of output while the output –oriented approach considers the ability of firms to maximize output from a given set of inputs (Fare et al., 1994; Coelli et al., 2005). The choice of the input or output oriented approaches largely depends on which of the quantities the decision maker has control and can regulate (Coelli et al*.,* 2005).

The input-oriented model is widely adapted in studying efficiency of agricultural firms because of the ability to regulate the usage level of inputs rather than having control over output quantities. In view of this, the study used the input – oriented approach to assess the efficiencies of tomato farmers in the Upper East Region of the country. In recent times, several studies have adopted this approach especially in analysis of agriculture efficiency (Dogan et al*.,* 2018; Mburu et al*.,* 2014; Yusuf and Malomo, 2007).

In DEA analysis, Charnes et al*.* (1978) initially proposed a model that had the assumption of constant returns to scale (CRS) which was later extended by Banker et al. (1984) who proposed a DEA with the assumption of variable returns to scale (VRS). In agricultural production system, an increase in inputs in the production system may not generally result in proportional increase in the output of the firm and therefore the variable returns to scale (VRS) was considered appropriate for this paper.

Model specification and structure

In this study, the DEA was estimated using input-oriented approach with an assumption of imperfect competition existing among the selected tomato farmers and as such their inability to operate at optimal scale (Dogan et al*.,* 2018). The model was assumed to have variable returns to scale due to the fact that tomato producers may not be operating at optimum because of inputs and financial constraints (Banker et al*.,* 1984).

Under variable returns to scale (VRS), it is assumed that there are i farmers using N inputs and producing M outputs, where the ith farmer can be represented by the vectors x_i and y_i. Due to the assumption that the tomato producers are not operating at optimal scale, the convexity constraint, $\mathbf{N1'}\lambda = \mathbf{1}$ was introduced to relax the CRS assumption. Using DEA with the assumption of variable return to scale to determine the efficiency of each farmer (θVRS)**,** the following linear programming model was solved (Coelli, 1996).

$$\text{Min}_{\theta,}\ \lambda\theta \tag{1}$$

Subject to

$$-y + Y\,\lambda \geq 0 \tag{2}$$

$$\theta xi - X\,\lambda \geq 0 \tag{3}$$

$$N1'\lambda = 1 \tag{4}$$

$$\lambda \geq 0 \tag{5}$$

Where: N1 is an N×1 vector of ones, θ is a scalar, λ forms part of the convexity constraint that efficiency scores are between 0 and 1.

The cost minimization model was estimated to help calculate the economic efficiency scores for the sampled tomato producers of the region. Similar to the above assumptions, the following mathematical model was used (Coelli et al*.,* 2005)

$$\text{Min}^{*}\ \lambda_{,Xi}\ W_i'X_i^{*} \tag{6}$$

Subject to

$$-y + Y\,\lambda \geq 0 \tag{7}$$

$$xi^{*} - X\,\lambda \geq 0 \tag{8}$$

$$N1'\lambda = 1 \tag{9}$$

$$\lambda \geq 0 \tag{10}$$

where: W is an N × 1 vector of input prices for the ith farm, Xi* is the cost minimizing vector of input quantities for the ith farm with the input prices, λ is an I × 1 vector of constraints. The DEAP version 2.1 software by Coelli (1996) was used in this study to analyse the technical, allocative, scale and economic efficiencies of the tomato farmers of the Upper East region of Ghana.

Tobit Regression of factors affecting efficiency scores

The factors that influenced efficiency scores of the farmers were investigated by regressing the socioeconomic factors of the individual farmers on their various efficiency scores. In efficiency studies, the DEA efficiency scores assume values between 0 and 1 thereby making the dependent variables 'limited dependent' or of a truncation below 0 and above 1. Such dependent variables require the application of models such as the Tobit model (Tobin, 1958). In this study, three models were estimated for the farmers which captured Technical Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE). The Tobit regression models for this study were specified as follows

$$\boldsymbol{Y}* = \begin{cases} y*; & 0 <= y* <= 1 \\ 0; & y* < 0 \\ 1; & y* > 1 \end{cases} \tag{11}$$

Where

y* is the DEA TE, AE, EE scores respectively, $\boldsymbol{\varepsilon}_i$ ~ that is, N(0, σ_2)

y* represents an unobservable variable
β represents the vector of unknown parameters that establishes the relationship between the independent variables and the latent variable
xi is the vector of explanatory variables (socioeconomic factors).
εi is the disturbance term.

From the study of related literature of agricultural efficiency studies and the characteristics of tomato farmers in the Upper East Region, the following Tobit models for the various efficiencies were specified below.

$$TE = \beta_0 + \beta_1 Gen + \beta_2 Age + \beta_3 EduF + \beta_4 EXTV + \beta_5 LandSize + \beta_6 FuelQ + \beta_7 FertQ + \beta_8 ChemQ + \beta_9 LAB + \varepsilon i \quad (12)$$

$$AE = \beta_0 + \beta_1 Gen + \beta_2 Age + \beta_3 EduF + \beta_4 EXTV + \beta_5 LandSize + \beta_6 FuelQ + \beta_7 FertQ + \beta_8 ChemQ + \beta_9 LAB + \varepsilon i \quad (13)$$

$$EE = \beta_0 + \beta_1 Gen + \beta_2 Age + \beta_3 EduF + \beta_4 EXTV + \beta_5 LandSize + \beta_6 FuelQ + \beta_7 FertQ + \beta_8 ChemQ + \beta_9 LAB + \varepsilon i \quad (14)$$

Where**:** TE = Technical Efficiency, AE = Allocative Efficiency, EE = Economic Efficiency, β_0 = Constant, $\beta_1 - \beta_9$ represents coefficients of the selected factors that influence the various efficiencies. Gender was dummied with (Male = 1, Female = 0), Age = Age of farmer in years, EduF = Formal Education in years, EXTV = Extension visit received (dummy, Yes = 1, No = 0) LandSize = Land size of tomato farm in acres, FuelQ = Fuel quantity used for irrigation measured in litres, FertQ = Quantity of inorganic fertilizer in kilograms, LAB=Labour measured in man-hours and ChemQ = Quantity of inorganic chemicals made up of weedicides and insecticides measured in litres. The Tobit Model was estimated using STATA Version 15 (StataCorp, 2018).

Sampling technique and sample size

Multistage sampling technique was adopted to select respondents for this study: The first stage involved the purposive selection of the Upper East Region of Ghana. The region was selected for its prominence in irrigated tomato production. The second stage also used another purposive selection of four districts namely Talensi, Bolga Municipal, Bawku East and Kasena Nakana East for their production prominence and accessibility to irrigation facilities for irrigated tomato production in the region. The third and final stage was the random selection of a total of 124 tomato farmers for the study. The 124 was determined by taking a standard 25% of the estimated target population.

With the help of extension agents of each district, the sampling was done by listing tomato farmers using irrigation. Nineteen (19) farmers were selected from the Talensi district, 29 from the Bolga Municipality, 13 farmers were selected from the Kasena Nankana Municipality and finally 63 farmers were chosen from the Bawku West District.

Data and definition of variables

Primary data was collected for this study. This cross-sectional primary data was collected through the administration of a well-designed questionnaire. Data on inputs and output quantities as well as their respective prices for the 2017/2018 production season were collected for the study. Tomato output was measured in kilograms, tomatoes seed was measured as quantity in kilograms of either self-produced seeds or purchased seeds, tomato farm size was determined in acres, and quantity of fertilizer in kilograms used on only tomato farms was obtained. The total quantity of fuel in litres and labour were used as proxy for the inputs quantities that directly affected the efficiency of irrigation water used, since all the sampled farmers indicated that they had access to and supplied sufficient water to their crops. In this respect, water utilization efficiency is directly captured by the labour costs/hours and efficiency of water pumping machines defined by an amount of fuel used. Another input was the quantity of chemicals including weedicides and pesticides applied over the production period and lastly, labour was measured in man hours including family and hired labour. The cost efficiency component was estimated by including output quantities and input prices. Input prices were all measured in Ghana cedis and taken from the 2017/2018 production season.

RESULTS AND DISCUSSION

Descriptive statistics of variables used for the estimations

The descriptive statistics of the variables that were used in this study are presented in Table 1. The minimum age of the farmers was 17 with a mean age of about 38 years and a maximum of 71 years. The mean age of 38 years implies that the tomato farmers in the region are within the active working group. The results also indicate that some of the farmers had no formal education though the mean age of formal education in years was 5 years with some farmers having up to 17 years of formal education. The mean age of 5 years of formal education suggests that most of the farmers had only basic education level or no formal education at all. Household labour in man-hours recorded a mean of 3378.62 man-hours with 840 and 8400 as minimum and maximum household labour in man-hours respectively. The high number of man-hours of household labour could be an indication that most of the tomato farmers rely heavily on labour provided by household members to undertake their activities. This was not surprising because household members are involved in almost all activities of tomato production process.

Tomato land size was in the range of 0.25 acres to 5 acres with a mean of about 1 acre. This probably implies that tomato farmers in the study area are predominantly smallholder farmers. Quantity of fuel used in powering water pumping machine recorded a mean value of 68.85 L and a maximum value of 588.24 L. Fertilizer usage in tomato production in the study area can be said to be intensive with as high as 3000 kg being the maximum and a minimum of 50 kg with at least a farmer applying 268.65 kg or about 5 bags to their farms. The continuous cropping on the same pieces of land implied loss of soil fertility and the need for intensive fertilizer usage. Inorganic chemicals comprising of weedicide and insecticide was not used extensively as some farmers reported not spraying at all whilst the mean inorganic chemicals in litres was about 4 L and a maximum of 18 L. This probably means that pest incidence in the study area is minimal. Hired labour denoted the labour that the farmers paid to undertake any production activity during the production season. The minimum hired-labour in man-hours was reported to be 24 man-hours while 1600

Table 1. Descriptive statistics of variables used for the estimations.

Variable	Number	Minimum	Maximum	Mean	Standard deviation
Age of farmer (years)	124	17.00	71.00	37.5565	11.996
Farmer's years of formal education	124	0.00	17.00	4.903	4.809
Household labour (Man-hours)	124	840	8400	3378.622	1378.060
Tomatoes land sizes (acres)	124	0.25	5.00	1.010	0.818
Quantity of Fuel (litres)	124	0.00	588.24	68.847	87.333
Quantity of Fertilizer (kg)	124	50.00	3000.00	268.653	326.848
Quantity of inorganic chemicals	124	0.00	18.00	3.909	2.848
Hired labour (Man-hours)	124	24	1600	282.881	286.974
Yield (kg)	124	120	12000	2700.622	2239.080

Categorical variable

	Label	Frequency	Percentage
Gender	Male = 1	120	96.8
	Female = 0	4	3.2
Extension Visit	Received extension = 1	39	27.4
	No Extension = 0	90	72.6
Total		**124**	**100**

Source: Field Survey Data (2019).

man-hours and 282.88 hours were recorded as the maximum and mean labour in man-hours respectively. The mean yield of tomatoes was 2700.622 kg while the minimum and maximum yields were 120 and 12000 kg respectively. This indicates that on average, the tomato yield for the 2017/2018 production season was moderate.

The categorical variables included in the Tobit model were gender and extension visit. From Table 1, men dominated the tomato farming business recording the highest percentage of 96.8% with only 3.2% being female farmers. The low female participation could be tied to issues of land tenure which favours men and probably the high capital requirements of farming under irrigation. It was revealed that an overwhelming percentage (72.6%) did not receive any extension visit during the production season although about 27.4% claimed that they had some extension visit during the production period.

Technical, allocative and economic efficiencies distribution of tomato farmers

The technical, allocative and economic efficiencies of the tomato farmers were analysed with the input-oriented DEA under the variable return to scale assumption. The results of the distribution of the technical efficiencies and descriptive summaries of the efficiency scores are presented in Table 2. These scores were organized into 7 groups ranging from >0.50 to 1.00. The mean technical efficiency was 0.97 indicating that the mean observed output of an average tomato farm was about 3% less than the maximum output that could be realized by the current inputs. This could be attributed to inefficiency in inputs management and other socioeconomic factors. Some of the farmers (n=39, 31.45%) were fully technically efficient with most (n= 80, 64.52%) clustered around technical efficiency scores of 0.90 – 0.99. High technical efficiency scores have also been observed in studies such as Yusuf and Malomo (2007), Mburu et al. (2014) and Dogan et al. (2018).

A mean allocative efficiency score of 0.421 was recorded in the study though some tomato farmers (1.61%) were fully efficient in inputs allocation with majority (68.55%) recording allocative efficiency scores of less than 50%. In all, only 31.45% of the farmers were allocatively efficient and obtained AE scores between 0.50 – 1.00. This implies that allocative efficiency could be increased by an average farmer [(1-0.421/1.00) × 100 = 57.9] by reducing cost of about 57.9% in order to achieve the level of the most allocatively efficient farmer. Low allocative efficiency score agrees with Musa et al. (2015) but contradicts that of Mburu et al. (2014) who had 96% of allocative efficiency in their study.

The economic efficiency followed a similar trend as the allocative efficiency with most of the farmers (71.77%) obtaining economic efficiency scores less than 50% and about only 28.23% managing to obtain economic efficiency scores between 50 - 100%. Although the maximum economic efficiency was 1.00, the mean

Table 2. Description of technical, allocative and economic efficiencies of tomato farmers.

Range of efficiency score	Technical efficiency		Allocative efficiency		Economic efficiency	
	Frequency	%	Frequency	%	Frequency	%
< 0.50	0	0	85	68.55	89	71.77
0.50 - 0.59	0	0	15	12.10	16	12.90
0.60 - 0.69	0	0	10	8.06	7	5.65
0.70 - 0.79	0	0	8	6.45	8	6.45
0.80 - 0.89	5	4.03	1	0.81	1	0.81
0.90 - 0.99	80	64.52	3	2.42	1	0.81
1.00	39	31.45	2	1.61	2	1.61
Total	**124**	**100**	**124**	**100**	**124**	**100**
Minimum	0.83		0.070		0.060	
Mean	0.971		0.421		0.415	
Maximum	1.00		1.00		1.00	
Standard Deviation	0.03390		0.21105		0.21311	

Source: Authors' Computation from Survey Data (2019).

Table 3. Scale efficiency of tomato farmers.

Type of scale efficiency	Frequency	%
CRS	33	26.6
DRS	2	1.6
IRS	89	71.8
Total	**124**	**100.0**
Minimum		0.521
Mean		0.970
Maximum		1.000

Source: Authors' Computation from Survey Data (2019).

efficiency score of 0.415 implies that on average, in order to be economically efficient, tomato farmers need to reduce their production cost by 58.5%. The efficiency score in this study relates to Musa et al. (2015) but contradicts those of Mburu et al. (2014), Dogan et al. (2018) and Galluzzo (2018). The results are presented in Table 2.

Scale efficiency of tomato production

The mean scale efficiency of tomato farmers in the region was 0.97 in a range of 0.521 to 1.000. The mean scale score means that an average farmer is only about 3% scale inefficient. This is similar to Abatania et al. (2012) who recorded higher scale efficiency score among farmers in Northern Ghana. Majority of the farmers (71.8%) were experiencing increasing returns to scale (IRS) whilst 26.6% had constant return to scale (CRS) with some few (1.6%) encountering decreasing returns to scale (DRS). The mean scale and distribution of return to scale (RTS) reflect similar observation by Abdulai et al. (2018) in maize farmers of the three regions of the North. Table 3 presents the scale efficiency scores.

Factors affecting efficiency scores

The Tobit regression result of the determinants of the various efficiencies is presented in Table 4. There were five determinants that were significant in explaining the variation in Technical efficiency (TE) among the farmers. Age of farmer in years significantly reduced TE at 10% level of significance. Older farmers were less technically efficient than younger farmers and depicts that as a tomato farmer gets older, the less the technical efficiency. This is probably because older farmers are less likely to try and adopt new technologies. Tomato land size was highly significant (1%) and negatively related to TE scores. An increase in land size reduced technical efficiency of the farmer. Having larger farm size may affect the right proportion of inputs and these could affect technical efficiency. Fuel quantity and fertilizer quantity both positively influenced TE at 5 and 1% significant levels respectively. This means that farmers who irrigate their farms with pumping machines instead of manual supply of water were as expected more technically efficient. This might not imply allocative or economic efficiency, as our results on AE and EE indicate, though both coefficients of labour and fuel have insignificant values, their respective signs support the above assertion. Continuous cropping on these lands due to their proximity to the water source means that loss of soil fertility is very likely and hence farmer's intensive application of fertilizers aimed at increasing yield. Litres of inorganic chemicals applied significantly (5%) reduced TE among the farmers probably due to the synergy

Table 4. Tobit results on factors affecting efficiency scores.

Variable	TE		AE		EE	
	Coefficient	P-Value	Coefficient	P-Value	Coefficient	P-Value
Gen	-0.0153173 (0.012576)	0.226	0. 0540987 (0.089045)	0.545	0.0475072 (0.089677)	0.597
Age	-0.0042658* (0.001891)	0.026	-0. 004432 (0.013435)	0.742	-0.0060805 (0.0135304)	0.654
EduF	-0.0025757 (0.002480)	0.301	-0.0192644 (0.017557)	0.275	-0.0196123 (0.017681)	0.270
EXTV	0.0051958 (0.005330)	0.331	-0.072839* (0.037713)	0.056	-0.0729241* (0.037981)	0.057
LandSize	-0.0415018*** (0.004934)	0.000	-0.065288* (0.034938)	0.064	-0.0761364* (0.035186)	0.033
FuelQ	0.0000717** (0.0000318)	0.026	-0.0001688 (0.000225)	0.455	-0.0001459 (0.0002269)	0.521
FertQ	0.0000503*** (0.0000128)	0.000	-0.0000939 (0.000090)	0.301	-0.0000712 (0.000091)	0.435
ChemQ	-0. 0019326** (0.0008106)	0.019	-0.011700* (0.00574)	0.044	-0.01221* (0.00578)	0.037
Lab	0.000000690 (0.0000020)	0.674	-0.0000052 (0.000012)	0.656	-0.000004751 (0.0000116)	0.684
Constant	1.031758*** (0.015554)	0.000	0.5976*** (0.1063)	0.000	0.6062*** (0.10706)	0.000

***, **, * Significant at 1, 5 and10% respectively. Standard errors in parentheses.
Source: Authors' Computation (2019).

between chemical applications and flowering. Though spraying is done to control pests, some inorganic pesticides are scorching and influence flower abortion thereby reducing yield and TE.

Extension visit, tomato land size and chemical quantity were all significant at 10% respectively and negatively influenced allocative efficiency (AE) of the tomato farmers. Contrary to expectation, farmers who received extension visit during the production season rather had reduced allocative efficiency. Probably these farmers were not given education on inputs allocation by these extension personnel. The findings relate to Musa et al. (2015) who also reported negative relationship between extension contact and allocative efficiency of maize producers. On the contrary, land size significantly increased the allocative efficiency, similar to that of wheat farmers as reported in Mburu et al. (2014).

Again, extension visit, tomato land size and chemical quantity were significantly and negatively related to farmers' scores of economic efficiency (EE). Some farmers rent land and increasing the land size could increase cost and reduce EE of the farmer, as they could have used such monies for other inputs. Inorganic chemicals are costly and overusing chemicals especially when farmers disregard the appropriate spraying regime could lead to increasing cost of production thereby reducing economic efficiency. Similar findings have been reported in Mburu et al. (2014) and Musa et al. (2015). Results from the AE and EE models clearly indicate that farmers disproportionately spend on inputs supporting the relatively higher cost of producing tomatoes in the Upper East region of Ghana.

CONCLUSION AND RECOMMENDATIONS

Understanding socio-economic factors and farming practices that explain inputs combination and cost efficiencies is crucial for appropriate agricultural extension and input market policies. This study employed the input-oriented DEA with variable return to scale assumption to assess the technical, allocative and economic efficiencies of randomly selected tomato farmers of the Upper East Region using data of the 2017/2018 production season. The mean technical efficiency and scale efficiency were 97.1 and 97% respectively with many farmers experiencing increasing returns to scale. On the contrary, there were low allocative and economic efficiency scores among the farmers as the mean allocative and economic efficiencies were 42.1 and 41.5% respectively. These results imply that there are chances for tomato farmers to increase their current inputs and minimize cost of production without any compromise on tomato yield with the current available technologies.

Farmers' age, tomato land size, fuel quantity, fertilizer quantity and chemical quantity (weedicide and pesticide) were all significant determinants of technical efficiency scores whereas extension visit, tomato land size and quantity of chemical used significantly influenced both allocative and economic efficiencies. It is recommended that government should extent subsidy on agro inputs and fuel for irrigated tomato farmers in the dry season to increase production and improve on technical efficiency.

Farmers are recommended to increase farm sizes to improve their scale efficiencies. Extension education should include allocation of inputs and cost minimization strategies to enable farmers achieve allocative and economic efficiencies in tomato production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abatania LN, Hailu A, Mugera AW (2012). Analysis of farm household

technical efficiency in Northern Ghana using bootstrap DEA (No. 423-2016-27040).
Abdulai S, Nkegbe PK, Donkoh SA (2018). Assessing the technical efficiency of maize production in northern Ghana: The data envelopment analysis approach. Cogent Food and Agriculture 4(1):1512390.
Abunyuwah I, Yenibehit N, Ahiale ED (2019). Technical efficiency of carrot production in the Asante-Mampong municipality using stochastic frontier analysis. Journal of Agriculture and Environmental Sciences 8:2. DOI: 10.15640/jaes.
Ayerh F (2015). Technical efficiency of tomato farmers in the Ashanti region of Ghana. Doctoral dissertation,University of Ghana, Legon
Banker RD, Charnes A, Cooper WW (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science 30(9):1078-1092.
Charnes A, Cooper WW, Rhodes E (1978). Measuring the efficiency of decision making units. European Journal of Operational Research 2(6):429-444.
Coelli T (1996). A guide to DEAP version 2.1. A Data Envelopment Analysis (Computer) program, Centre for Efficiency and Productivity Analysis, Department of Economics, University of New England, Armidale, NSW. P. 2351.
Coelli TJ, Rao DSP, O'Donnell CJ, Battese GE (2005). An introduction to efficiency and productivity analysis. Springer Science and Business Media.
Dao GTN (2013). An Analysis of the technical efficiency of crop farms in the Northern Region of Vietnam. Canberra: University of Canberra.
Dogan N, Kaygisiz F, Altinel A (2018). Technical and Economic Efficiency of Laying Hen Farms in Konya, Turkey. Brazilian Journal of Poultry Science 20(2):263-272.
Fare R, Färe R, Fèare R, Grosskopf S, Lovell CK (1994). Production frontiers. Cambridge: University Press.
Galluzzo N (2018). Analysis of Economic Efficiency in Some Irish Farms Using the DEA Approach. Turkish Journal of Agriculture-Food Science and Technology 6(2):156-162.
Ghana Business News [GBN] (2018). Ghana imports $99.5m worth of tomatoes every year from Burkina Faso. GBN. Retrieved from https://www.ghanabusinessnews.com. Accessed on 12th Sept 2019.
Ghana Statistical Service (GSS) (2013). 2010 Population and housing census: Regional analytical report Upper East Region. Accra, Ghana. GSS.
Kalinga A (2014). Input use efficiency in the Madibira smallholder farmers' irrigation scheme in Tanzania (Doctoral dissertation, Sokoine University of Agriculture).
Mburu S, Ackello-Ogutu C, Mulwa R (2014). Analysis of economic efficiency and farm size: A case study of wheat farmers in Nakuru District, Kenya. Economics Research International https://doi.org/10.1155/2014/802706.
Ministry of Food and Agriculture (MoFA) (2013). Agriculture in Ghana: Facts and Figures. Accra: Ghana. MoFA.
Ministry of Food and Agriculture (MOFA) (2018). Agriculture Sector Progress Report, 2017. Accra: Ghana. MoFA. Retrieved from http://mofa.gov.gh/site/?page_id=6032
Musa HA, Lemma Z, Endrias G (2015). Measuring technical, economic and allocative efficiency of maize production in subsistence farming: Evidence from the Central Rift Valley of Ethiopia. APSTRACT: Applied Studies in Agribusiness and Commerce 9:63-74.
Puozaa FZ (2015). Allocative efficiency of irrigated tomato production in the Upper East Region, Ghana (Doctoral Dissertation, University of Ghana).
Robinson EJ, Kolavalli SL (2010). The case of tomato in Ghana: Productivity (No. 19). International Food Policy Research Institute (IFPRI).
Singh DR, Kumar S (2014). Estimation of Farm Level Efficiencies in Crop Production: An Application of Data Envelopment Analysis. Markets, Trade and Institutions for Agricultural Development P 64.
Sugri I, Sargent SA, Kusi F, Berry AD, Kanton RAL, Pelletier W (2013). Improving marketable quality of tomato: A simulation of shipping conditions in Ghana. American Journal of Experimental Agriculture 3(2):392-402.
Tobin J (1958). Estimation of relationships for limited dependent variables. Econometrica: journal of the Econometric Society 24-36.
Weldegiorgis LG, Mezgebo GK, Gebremariam HG, Kahsay ZA (2018). Resources use efficiency of irrigated tomato production of small-scale farmers. International Journal of Vegetable Science 24(5):456-465.
Yusuf SA, Malomo O (2007). Technical efficiency of poultry egg production in Ogun state: a data envelopment analysis (DEA) approach. International Journal of Poultry Science 6(9):622-629.

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Measuring rural poverty among rural households in Gedeo Zone, SNNP Region, Ethiopia

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Poverty is a phenomenon that is complex and has multidimensional features. It involves people experiencing various degrees of material deprivation; the concept is used to cover a wide ranging set of interrelated life chances. The purpose of this study was to measure poverty in rural Gedeo zone, southern Ethiopia with specific objectives of measuring poverty among the rural households. The research was undertaken using a cross sectional design on a random sample of 325 households in the study area. The sample size was determined based on multi stage sampling procedure. In order to achieve its objective, primary data was collected through survey and interview using semi structured questionnaires. Analysis of data was made after the data collection. In this regard, the Cost of Basic Needs (CBN) approach and FGT measures were employed to set the poverty line and compute the magnitude of rural poverty in the study respectively. The food and absolute poverty lines were calculated based on food basket of 2200 Kcal per adult per day. Accordingly, the food and absolute poverty lines for the study area were determined to be Birr 3952.74 and 4463.35, respectively. The food expenditure takes the lion's share accounting for about 88.56% (relative to the non-food expenditure) in the consumption expenditure of the poor and thus this substantial expenditure was used for estimating the poverty line. Thereafter, the poverty indices were computed using FGT indices. The incidence, depth and severity of food poverty stood at 0.052, 0.021 and 0.010 respectively, while respective measures for absolute poverty were found to be 0.302, 0.085 and 0.034. These measures indicated that poverty significantly prevails in the study area. All the measures confirm that poverty has been problems and remain major concern in rural development agenda in Ethiopia. Thus, rural poverty alleviation in the study area in particular and rural Ethiopia in general requires context based policies and adoption of strategies to alleviate poverty among the rural households.

Key words: Rural households, measuring poverty, cost of basic needs, FGT, Gedeo zone, Ethiopia.

INTRODUCTION

The world has witnessed phenomenal advances in science, technology and wealth creation. Despite this, poverty in all its manifestations remains deep, pervasive and intractable. Poverty is a situation in which the

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underprivileged do not have adequate food and shelter, lack access to education and health services, are exposed to violence, and find themselves in a state of unemployment, vulnerability and powerlessness (Todaro, 1997). Poverty is multi-dimensional phenomenon and has to be looked at through a variety of indicators such as levels of income and consumption, social indicators and indicators of vulnerability to risks and socio-political access and participation. The most common approach to the measurement of poverty is based on incomes or consumption levels. It is widely understood that an individual is considered poor if consumption or income level falls below some minimum level necessary to meet basic needs which is a poverty line (World Bank, 2004).

With the increased awareness and availability of data, various measures of poverty have been developed overtime. According to Kimalu et al. (2002), the most widely used poverty indices are the incidence of poverty (headcount), the poverty gap (depth of poverty), and the poverty severity (measures income inequality among the poor). The headcount index indicates the share of the population whose income or consumption is below the poverty line. But it does not show how far below the poverty line the poor. Also, it forces the overall poverty index to remain constant even when the welfare of the poor has improved or worsened. Beside, with this index, an income transfer from an extremely poor person to a person just below the poverty line would show a reduction in poverty despite the decline in the income of the extremely poor (Kimalu et al., 2002). On the other side, depth of poverty index provides information regarding how far households are from the poverty line. This measure captures the mean aggregate consumption shortfall relative to the poverty line across the whole population. It measures the intensity of poverty by averaging the distance between the expenditure of the poor persons and the poverty line. This index can be used to estimate the resources that would bring the expenditure of every poor person up to the poverty line thereby eliminating absolute poverty (Aigbokhan, 2000) but it does not differentiate the degree of inequality among the poor when it is used to assess welfare (Kimalu et al., 2002). The Poverty severity index takes into account not only the distance separating the poor from the poverty line but also the inequality among the poor. It is the poverty index that shows the severity of poverty by squaring the gap between the expenditure of the poor individual and the poverty line. Because the index gives more weight to the poverty of the poorest, it measures the degree of inequality among the poor implying that transferring income to the poorest from the better-off poor should lower the poverty index (MEDaC, 1999).

Poverty has been predominantly a rural phenomenon in the majority of Saharan-Africa countries. Approximately 75% of the world's poor reside in rural areas, and at current trends, the global percentage of the poor in rural areas will not fall below 50 percent before 2035 (Ravallion, 1992). The majority of the Ethiopians have been living in rural areas and agriculture is the main stay of the economy and at present, about 72.7% of the country's population engages in various agricultural activities and generates its income for consumption. The sector contributes 34.9 % to the country's GDP next to service sector, which of course contributes 39.2 percent of GDP (NBE, 2017). The number of poor people in rural areas of Ethiopia exceeds the capacity of agriculture to provide sustainable livelihood opportunities due to low productivity, production and market linkages challenges. As a result, a significant proportion of the rural households face food insecurity and lives in poverty (MOFED, 2012). However, the current government of Ethiopia has formulated policies, and committed itself to growth and transformation plans which target sustainably improving rural livelihoods and national food security; but, there are no large-scale improvements in the living conditions of rural populations and the mass live in poverty (NPC, 2017). This calls for researching rural poverty and then design a policy for poverty alleviation and to bring improvements of lives of the poor.

Statement of the problem

Eradicating poverty remains the world's most important and urgent task. Accordingly, Ethiopian government has started the fight against poverty and demonstrated a strong commitment to poverty reduction by adopting its implementation of the integrated development plans including the Growth and Transformation Plan launched in 2010 (MOFED, 2012). This has been witnessed by the robust and sustained growth in the last two decades in the country. The per capita income has continuously increased and reached 883 USD in the same period (NBE, 2017) though it is far lower than the average per capita income for the Sub-Saharan Africa (SSA) which was 1661 USD in the same year (World Bank, 2017).

The recent empirical studies conducted in Ethiopia have indicated that poverty among the poor remains a challenge in the country that rural areas harbor the bulk of the poor; poverty has been unambiguously a rural phenomenon; and it remains part of lives of the rural Ethiopian. In this regard, the study conducted in Ethiopia by MoFED (2012) employing consumption approach with the CBN and FGT methods, indicated that head count, poverty gap, poverty severity index were estimated and stood at 0.296, 0.078 and 0.031 respectively and which all indicators when disaggregated higher for the rural than urban sections. Besides, the finding on the food poverty revealed that food poverty head count, food poverty gap

and food poverty severity index stood at their respective estimates of 33.6, 10.5 and 4.6%. Moreover, NPC (2016) with same methodology showed that the poverty head count index was estimated to be 23.5%. The poverty gap index and poverty severity index were also estimated to be 6.7 and 2.8% respectively. Also, this study found respective food poverty incidence, depth and severity as 24.8, 6.7 and 2.7%; and the rural area measures are higher than its urban counterpart. Hence, the urgency of researching rural poverty is beyond doubt.

The available body of literature on rural poverty is not only scanty and up-to-date but also far from being exhaustive in addressing specific locality. The studies so far been studied in Ethiopia concentrate on and reflect the national picture which do not necessarily reflect the context-specific situation at grassroots levels such as the study area and this fact is strongly supported by Dercon and Krishnan (1998). And in addition, no research has been conducted on the same issue in the study area before. Therefore, this is the major knowledge gap that this research bridges by measuring poverty among rural households in Gedeo zone, southern Ethiopia.

Research questions

The research questions to guide the study include:

1) How much is the absolute poverty line for Gedeo Zone?
2) What are the extents (the incidence, depth and severity) of poverty in the study area?

Objectives of the study

1) To determine poverty line for Gedeo Zone.
2) To investigate the extents (the incidence, depth and severity) of poverty in the study area.

Significance of the study

Any intervention to alleviate and ultimately eliminate poverty needs a thorough understanding of the extents of poverty. Hence, such studies are beyond doubt important for the poverty reduction endeavor of the country, whose largest slice of population lives in abject poverty. Besides adding to the body of knowledge on the subject, the output of the study could also be informative for donors and non -governmental organizations interested to operate and make intervention in the study area. The study creates awareness for the rural households that in turn enable them design ways to escape poverty. Moreover, the study informs policy making for appropriate interventions and for assessing effectiveness of on-going poverty alleviation policies and strategies.

METHODOLOGY

Description of the study area

Gedeo zone is one of the zones in the Southern Nations, Nationalities and Peoples Region (SNNPR) of Ethiopia. It is located in the North-Eastern part of the region. It lies between 50.59'' N and 60.43''N latitude and 380.40'' E and 380.43'' E longitude. The zone has three agro-ecological zones: lowland (Kolla), mid-altitude (Woyina Dega) and highland (Dega) which accounts for 0.5, 70.7 and 28.8% respectively. It shares boundary with Oromia region in the south, southwest and east directions and Sidama zone in the north direction. Dilla town is the administrative capital of the Zone, 360 k.m from Addis Ababa. The zone has a total population of 1,040,829 with an area of 1,352.40 square kilometers with average population density of 774 persons per sq.k.m (Gedeo Zone Finance And Development Bureau, 2015).

Research design

Cross sectional survey design was employed in this study with quantitative approach. Survey methods are extremely efficient in terms of providing large amounts of data at relatively low cost in a short period of time (Smith, 1975). It entails the collection of data on more than one case and at a single point in time. Furthermore, the design for it requires only a snapshot, is less time consuming and cheaper than others(Ravallion and Bidani,1994) indicated how well a cross sectional study design works in identifying rural poor households.

Sampling techniques and sample size

The method of sampling technique applied in this study was multi-stage sampling and households were the sampling units. At the first stage, Wonago and Kochere woredas of Gedeo zone were selected purposively. This is because they are densely populated woredas and where a number of NGOs do provide aid for the people, implying that poverty prevails in the study area. This reality is witnessed by the pilot survey conducted by the researcher. In the second stage, six kebles were selected using simple random sampling (3 kebeles from each two woredas). In third stage, a probability proportional to sample size (PPS) sampling procedure was employed to determine sample households from each woreda and each kebele. Accordingly, a total of 334 sample households (186 from Wonago and 138 from Kochere) were selected. Finally, respondent households were identified using systematic random sampling from the list of the rural households. The sample size n for the study was determined using the following formula (Cochran, 1977) as:

$$n = \frac{\frac{Z^2 \alpha/2 P(1-P)}{d^2}}{1 + \frac{1}{N}\left(\frac{Z^2 \alpha/2 P(1-P)}{d^2} - 1\right)};$$

Where, d is the absolute precision, and $Z_{\alpha/2}$ is value of standard normal deviate at level of significance, α . The values taken are P = 0.5, (1-P) = 0.5, d =0.03, and $Z_{\alpha/2}$ =1.96 with α =0.05. And also

N= 64,920, as the total rural households in Wonago and Kochore woredas respectively were 30,599 and 34,321.

Accordingly, the sample size determined was; n= 334. And, the sample size of households for the randomly selected kebeles for the study was determined proportionally using probability proportional to sample size (PPS) technique. The six kebeles included in the study were Sugale, Tokicha and Mekonisa(from Wonago woreda) and Baya, Haniku and Biloya(from Kochore woreda).

Data sources and methods of collection

Both primary and secondary sources were used to collect data for the study. For the primary data, sample households were interviewed by using semi-structured survey questionnaire. This enables to ascertain both subjective and objective facts (Mayntz et al., 1976). The secondary data was also collected from secondary sources such as reports for triangulation purposes. White (2002) indicates that using triangulation approaches together yields synergy in research.

Model specification and estimation procedure

The poverty line was constructed using the Cost of Basic Needs (CBN) approach which is the most common method of constructing poverty line. In this approach, the predetermined normative nutritional requirement of calories was used. In line with this, the minimum requirement of 2,200 Kcal per adult per day of World Bank standard was used (World Bank, 2004). Allowance was given to the non-food expenditure component to estimate the absolute poverty line by dividing the food poverty line by the average food share for households that enabled a food consumption level equal to food poverty line.

The poverty measure is a statistical function that translates the comparison of the indicator of household well-being and the chosen poverty line into one aggregate number for the population. More precisely, these measures can be defined in terms of the well-known Foster et al. (1984), FGT Pα class of poverty measures. This class of poverty index is the most commonly applied to measure poverty. Given a vector of suitable measure of well-being, income(Y), in an increasing order, Y1, Y2, Y3,...,Yn, where n represents the number of households under consideration, the FGT poverty index (Pα) can be expressed as (Baffoe, 1992):

$$\mathbf{P\alpha} = \frac{1}{N} \sum_{i=1}^{q} \left(\frac{g^i}{Z}\right)^{\alpha} \quad ; \qquad \alpha \geq 0$$

Where, z is poverty line, q is the number of the poor, g_i is shortfall the i^{th} household in chosen indicator of wellbeing. If, for instance, x_i denote the per capita calorie intake of household i, then $g_i = z_i - xi$ if $x_i < z$; $g_i = 0$ if $x_i \geq z$, and α is the poverty aversion parameter (α ≥ 0) which reflects the policymaker's degree of aversion to inequality among the poor. The parameter α represents the weight attached to a gain by the poorest. The commonly used values of α are 0, 1, and 2. When we set α equal to 0, then above equation is reduced to the headcount ratio, FGT(0), which measures the incidence of poverty. When we set α equal to 1, we obtain FGT(1) or the poverty deficit.FGT(1) takes in to account how far the poor, on average, are below the poverty line; we also call it poverty gap and it measures depth of poverty. Setting α equal to 2 gives the severity of poverty or FGT(2) index. This poverty index gives greater emphasis to the inequality among the poor that calls for resource redistribution among the poor.

Data analysis

First poverty line was calculated using the cost-of-basic-needs (CBN) method. This method is based on the estimated cost of the bundle of goods adequate to ensure that basic needs are met. Establishing a line starts with defining and selecting a 'basket' of food items typically consumed by the rural poor. Based on the food consumption behavior and expenditure pattern of the rural community in the study area a basket of food items typically consumed by the poor was identified. The quantity of the basket is determined in such a way that the given bundle meets the predetermined level of minimum energy intake per day of 2200 kcal/day. The cost of the food bundle was calculated using local market prices to reflect actual food poverty line of the study area. Then after, a specific allowance for the non-food component consistent with the spending patterns of the poor is added to the food poverty line to reach at absolute poverty line. That allowance can be made in such way that the food poverty line is divided by the food share of the poorest 25 per cent of the population to arrive at the absolute poverty line. The value of minimum amount of consumed food items at an average price of the identified food items in the local markets plus the sum of estimated minimum amount of money needed to cover the non-food expenses per Adult Equivalent (AE) per annum were used as a threshold beyond which the household is said to be poor or non-poor. The Conversion factor used to estimate Adult Equivalent was adopted from Ravallion and Bidani (1994) and uses OECD scale as: AE = 1 + 0.7(Nadults –1) + 0.5N children.

After setting poverty line, it is easy to estimate poverty measures, which is an index that shows the magnitude of poverty in a society. Kimalu et al. (2002) pointed out that one poverty measure that has been found manageable in presenting information on the poor in an operationally convenient manner is the FGT measure developed by Foster et al. (1984). The first step taken has been distinguishing the poor and non- poor by constructing poverty line yardstick. Households are counted as poor when their measured standard of living is below this line, non-poor otherwise (Rath, 1996). This measure is used to quantify the three well-known elements of poverty: the incidence, depth (intensity) and severity. Among these measures, inequality among the rural poor was measured by poverty severity.

RESULTS AND DISCUSSION

Calculating poverty lines

The response rate of the questionnaire distributed was about 97%. Accordingly, to examine the levels of poverty in the study area, the calculation of poverty lines and indices of poverty was made using 325 sample households rather than 334 sample sizes. In the study, absolute poverty line is defined on the basis of the cost of obtaining the minimum calorie requirement for subsistence, which is 2200 kcal per adult per day (Ravallion and Bidani, 1994), taking the diet of the lowest income quartile households. The calorie share of the diets to the minimum calorie required for subsistence is calculated to arrive at the level of calorie and quantities

Table 1. Food poverty line based on food basket of 2200 Kcal per adult per day.

Food items	Mean Kcal/ 100 Gram/Litre	Food basket per adult per day in Kg/Litre	Kcal per day per adult	Kcal per adult per day needed to get 2200Kcal	Kcal share (%)	Food basket per adult per Month in Kg/Litre	Mean price per Kg/litre ETB)	Cost per month (ETB)	Value of poverty line per year (Birr)
Wheat	357.4	0.048	171.55	243.895	11.09	1.44	11	15.84	190.08
Barely	372.3	0.058	215.93	306.993	13.95	1.74	9	15.66	187.92
Teff	355.1	0.099	351.55	499.797	22.72	2.97	14.50	43.07	516.78
Maize	375	0.047	176.25	250.574	11.39	1.41	6.50	9.17	109.98
Beans	351.4	0.054	189.76	269.776	12.26	1.62	12.5	20.25	243.00
Peas	355.3	0.009	31.98	45.462	2.07	0.27	15.5	4.19	50.22
Onion	71.3	0.026	18.54	26.355	1.20	0.78	11	8.58	102.96
Tomatoes	30.7	0.013	3.99	5.674	0.26	0.39	12.33	4.81	57.70
Potatoes	89.7	0.024	21.53	30.606	1.39	0.72	6.5	4.68	56.16
Cabbage	23.7	0.009	2.13	3.032	0.14	0.27	5.50	1.49	17.82
Pepper	360.1	0.012	43.21	61.434	2.79	0.36	77.5	27.90	334.80
Coffee	110.3	0.008	8.82	12.545	0.57	0.24	58.60	14.06	168.77
Sugar	385	0.012	46.20	65.682	2.99	0.36	15.2	5.47	65.66
Salt	178	0.013	23.14	32.898	1.50	0.39	5.0	1.95	23.40
Oil	896.4	0.014	125.50	178.417	8.11	0.42	24.60	10.33	123.98
Milk	73.7	0.014	10.32	14.669	0.67	0.42	15	6.30	75.60
Enset	18.1	0.006	1.09	1.544	0.07	0.18	8.40	1.51	18.14
meat	197	0.033	65.01	92.425	4.20	0.99	107.5	106.43	1277.10
banana	87. 8	0.027	23.71	33.708	1.53	0.81	10.40	8.42	101.09
Carrot	42.0	0.018	7.56	10.748	0.49	0.54	9	4.86	58.32
Garlic	138.3	0.007	9.68	13.763	0.63	0.21	68.75	14.44	173.25
ETB 3952.74									

Source: Own computation based on the survey (2016).

of food group items that gives the 2200 kcal. Based on these methodological steps of the CBN model the food poverty line and the absolute poverty line that corresponds to the basket of food items was calculated by adopting from EHNRI (2007) and Dercon and Krishnan (1998). The quantities of the food item groups are valued using average local market prices in order to reflect the actual food poverty line in the locality (Table 1). The price of food items in the market during the survey was triangulated with secondary data on the price from trade and industry bureau of Gedeo zone. That is, the absolute poverty line can be obtained by adjusting for non- food expenditure using the average food share of the

lowest consumption quartile households. In this regard, the non-food expenditures include expenditures of clothing, medical, education, social obligations (like religious, idir, social contributions, etc.), housing, transportation, and other miscellaneous expenses. Dividing the food poverty line by the average food share of the lowest consumption quartile gives an absolute poverty line. In this regard, the Food basket composition used for poverty lines (per month) and nutrition (calorie) based equivalence scales for the food items were identified in the study area.

The food poverty line calculated from the data available was found to be ETB Birr 3952.74 [1] or 146.40 USD. Then this food poverty line is divided by the food share of the poorest 25 per cent of the population to arrive at the absolute poverty line. That is, the non-food expenditure component is calculated using the average food share of the lowest income quartile households. The food share of the lowest income quartile is found to be 88.56%. This figure is used to estimate an allowance of non-food expenditure and found to be 510.61 Birr. Therefore, the sum of food and non-food expenditures gives absolute poverty line of Birr 4463.35. Therefore, the food and absolute poverty lines for the study area were determined to be Birr 3952.74 and 4463.35, respectively (Table 1). Compared to the national level poverty lines in 2011, both the food and absolute poverty lines in this study were higher where their respective figures were calculated as ETB 1985 and 3781 (MOFED, 2012). And also according to NPC (2016), the food poverty and absolute poverty lines in Ethiopia were Birr 3772 and Birr 7184. Of course the deviation between national and study area figures can be due to that that national poverty line may not indicate the poverty line of a specific locality. This indicated the fact that a household in Gedeo zone with a household size of 4.82 adult equivalent units needs an income of Birr 3952.74 per annum which is Birr 820.071 per adult equivalent per annum to escape food poverty. Similarly, with an average household size of 4.82 adult equivalent units, a typical household in the zone needs an income of Birr 4463.35 per annum which is Birr 926.006 per adult equivalent per annum to escape absolute poverty.

Poverty measures and its magnitude

The poverty lines and the per adult consumption expenditure are used to aggregate consumption poverty indices. The per adult consumption is obtained by first dividing the total consumption expenditure by nutritional calorie based adult equivalence (AE) family size to arrive at per adult consumption expenditure. The per adult consumption expenditure includes both food and non-food consumption expenditures measured at current average prices in the study area. The study revealed that the mean consumption expenditure for the sample households is Birr 6904.38 /AE. The minimum and maximum consumption expenditure per AE during study period were Birr 1436.00 and 20776.00 respectively. The respective mean consumption expenditure for the poor and non-poor groups was Birr 4076.47 and 8125.23. This shows that there was a significant difference between the two means at 1% probability level (Table 2) in terms of distribution of consumption expenditure.

The poverty measure (Pα) developed by Foster et al. (1984) were used to explain the extent of poverty in the study area. Poverty indices were computed based on the consumption expenditures. The resulting poverty estimates for the study area (Table 3) shows that the percentage of poor people measured in absolute head count index (α = 0) was about 30.2%. This figure indicates that this proportion of the sampled households in Gedeo zone live below absolute poverty line. This implies that 30.2% of the population are unable to get the minimum calorie required (2200 kcal per day per adult) adjusted for the requirement of non-food items expenditure. Putting it differently, this proportion of rural community in Gedeo zone are unable to fulfill the minimum amount of income that is, Birr 4463 per adult equivalent per year and live under absolute poverty. The poverty gap index (α=1), a measure that captures the mean aggregate consumption shortfall relative to the poverty line across the sample population is found to be 0.085 which means that the percentage of total consumption needed to bring the entire population to the poverty line is 8.5%. Similarly, the FGT poverty severity index (the squared poverty gap, α=2) in consumption expenditure shows that 3.4 % fall below the threshold line implying severe inequality among the rural poor; it means that there is a high degree of inequality among the lowest quartile population. Nevertheless, these poverty profile figures have marked difference with that of the 2016 rural poverty indices that were reported in the poverty study (NPC, 2016). In this study, the rural poverty incidence, gap and severity estimated in Ethiopia were 25.6, 7.4 and 3.1% respectively. From this analysis, all measures are a significant and call for policy measure to alleviate poverty in the study area.

In addition to the absolute poverty indices, the food poverty measures are computed for the sample households. The food poverty index measures the proportion of food-poor people that fall below the food poverty line. The food poverty head count index in the study area was estimated to be 5.2% during the study period. The respective food poverty gap index and food poverty severity index stood at 2.1 and 1% in the study.

[1] *ETB=Ethiopian Birr (currency);it has an exchange rate with USD; 27ETB= 1 USD during the survey period.*

Table 2. Distribution of Sample Households Consumption Expenditure per year (in ETB).

Birr/AE	Poor (n = 98)		Non-Poor (n = 227)			Total (n = 325)	
	No	Percent	No	Percent	t- value	No	Cum. Percent
< 1,464	6	6.12				11	3.38
1,464 - 2,963	12	12.24				32	13.23
2,964 - 4,463	80	81.63				55	30.14
4,464 - 5,963			43	18.94		43	43.37
5,964 - 7,463			51	22.47		51	59.07
7,464 - 8,963			62	27.31		62	78.14
8,964 - 10,463			54	23.79		54	94.74
>10,463			17	7.49		17	100
Min (Birr/AE)	1436.00		4464.00			1436.00	
Max (Birr/AE)	4463.00		20776.00			20776.00	
Mean (Birr/AE)	4076.47		8125.23		25.488*	6904.38	
Std.Dev (Birr/AE)	825.85		2393.64			2768.36	

*Significant at 1% probability level.
Source: Own Survey Result (2016).

Table 3. Absolute Poverty Indices and Food Poverty Indices of rural Households.

Absolute poverty		Food poverty	
Poverty indices	**Index values**	**Poverty indices**	**Index values**
Head count index (α=0)	0.302	Head count index (α=0)	0.052
Poverty gap (α=1)	0.085	Poverty gap (α=1)	0.021
poverty severity (α=2)	0.034	poverty severity (α=2)	0.010

Sou*rce:* Own survey computation (2016).

The estimates in the study area have difference with the rural food poverty estimates at the national level (NPC, 2016); which were at 27.1, 7.4 and 3.0% for incidence, depth and severity of poverty respectively.

The results poverty measures of the study area showed that all kinds' food poverty indices (incidence, depth and severity) are lower than the absolute poverty measures (Table 3). As achievement of food self-sufficiency has been one of the key objectives of the Ethiopian government as articulated in its GTP and rural development policies and strategies, which is also consistent with the SDG goal of eradicating extreme poverty or hunger, such very low food poverty may be attributed to the wide-ranging and multi-faceted pro-poor programs of the government that have been implemented in rural areas such as intensification of agriculture, rural infrastructural development and food security programs.

Moreover, the food and non-food expenditure pattern and categories of rural sample households was analyzed. The results of the study showed that the poor in the study were found to spend larger proportion of their expenditure on food (about 88.56%) than the non-poor which (was about 85 percent). This is in line with Engel's law, which states that relative to the non-poor, the poor spend higher proportion of their income on food. This result is consistent with Metalign (2005).

Conclusion

Cost of basic needs (CBN) approach and FGT measures have been employed to set the poverty line (both food and absolute) and compute the magnitude (incidence, gap and severity) of rural poverty in the study respectively. The food and absolute poverty lines were calculated based on food basket of 2200 Kcal per adult per day. Accordingly, the food and absolute poverty lines for the study area are determined to be Birr 3952.74 and 4463.35, respectively. The food expenditure takes the lion's share accounting for about 88.56 %(relative to the non-food expenditure) in the consumption expenditure of the poor and thus this substantial expenditure was used for estimating the poverty line. Thereafter, the poverty

indices were computed using FGT indices. The incidence, depth and severity of food poverty stood at 0.052, 0.021, 0.010, while measures for absolute poverty were found to be 0.302, 0.085 and 0.034. These all indices confirm that food and absolute poverty have been problems and remain major concerns that need great attention of policy makers in designing strategies for rural development.

Recommendations

(1) The measures of poverty among the rural households in the study area indicates that the overall magnitude of poverty is quite significant and needs further attention from all stake holders working on rural development such as national and regional agricultural offices, civil society organizations, donors, the local community and financial institutions like micro finance institutions. The rural livelihoods particularly income of the rural community can improve and people can escape poverty when these stake holders synchronize their efforts to improve the production and productivity of agriculture, enable the local community to diversify their livelihoods to off-farm and non-farm activities.
(2) The agriculture of the study area is characterized by land scarcity and increasing fragmentation of already very small farms and low income from the sector. But agricultural income still remains a major income source and hence matters for rural poverty and inequality situations for the rural households. Thus, improving the income of the rural households through promoting livelihood diversification into farm, off-farm and non-farm activities should be considered by woreda agriculture and rural development office, rural cooperatives, safety net programs, micro finance institutions to help improve reduce poverty in the study area.
(3) Besides, government policies on overall rural livelihood improvements have to be implemented. In this regard evidence is mounting that Ethiopian government works aggressively and has shown progress in rural poverty reduction though the result of the study witnesses that much more work is required to address poverty and improve the living standards of the rural community. In addition, there is a need for redistribution of resources such as land and other resources among the rural poor to alleviate poverty severity among the poor.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Aigbokhan EB (2000). Poverty, Growth and Inequity in Nigeria: A Case Study. AERC Research Paper 102. Development policy Centre, Ibadan, Nigeria.
Baffoe JK (1992). Income Distribution and Poverty Profile in Ghana 1987, 1988. African Development Review 4(1):1.28.
Cochran WG (1977). Sampling techniques (3rd ed.). New York: John Wiley & Sons.
Dercon S, Krishnan P (1998). A Consumption-Based Measure of Poverty for Rural Ethiopia in 1989 and 1994. In Bereket K. and Mokonen T. (Eds.). The Ethiopian Economy: Poverty and Poverty Alleviation. Proceedings of the Fifth Annual Conference on the Ethiopian Economy. Addis Ababa.
Ethiopian Health and Nutrition Research Institute (EHNRI) (2007). Food Composition Table for Use in Ethiopia. Addis Ababa.
Foster J, Greer J, Thorbecke E (1984). A Class of Decomposable Poverty Measures. Econometrica: Journal of the Econometric Society pp. 761-766.
Gedeo Zone Finance And Development Bureau (2015). Report on socio economic Survey Report, SNNR State, Ethiopia. Dilla.
Kimalu P, Nafula N, Manda DK, Mwabu G, Kimenya SM (2002). A Situational Analysis of Poverty in Kenya. The Kenyan Institute for Public Policy Research and Analysis (KIPPRA) Working Paper Series. WP/6/2002.
Mayntz R, Holm K, Huebner R (1976). Introduction to Empirical Sociology. Penguin Books Canada Ltd. Ontario.
MEDaC (1999). Survey of the Ethiopian Economy: Review of post-Reform Development (1992/93-1997/98). Ministry of Economic Development and Cooperation (MEDaC). Addis Ababa.
Metalign A (2005). Rural poverty situation and determinants: The case of Kersa Kondalitity Woreda, South West Shewa. Unpublished Masters degree thesis at the Institute of Regional and Local development Studies, Addis Ababa University.
Ministry of Finance and Economic Development (MoFED) (2012). Ethiopia's Progress Towards Eradicating Poverty: An Interim Report on Poverty Analysis Study . Development Planning and Research Directorate. Ministry of Finance and Economic Development, Addis Ababa.
National Bank of Ethiopia (NBE) (2017). Annual Report 2017. Addis Ababa, Ethiopia.
National Plan commission (NPC) (2016). Ethiopia's Progress Towards Eradicating Poverty: An Interim Report on Poverty Analysis Study. National plan commission, FDRE, Addis Ababa.
National Plan commission (NPC) (2017). The 2017 Voluntary National Reviews on SDGs of Ethiopia: Government Commitments, National Ownership and PerformanceTrends.
Rath N (1996). Indian Journal of Agricultural Economics: Poverty in India Revisited. Indian Society of Agricultural Economics, Numbai pp. 76-109.
Ravallion M (1992). Poverty Comparison: A guide to Concepts and Methods. Living Standard Measurement Study. The World Bank, Washington, D.C.
Ravallion M, Bidani B (1994). How Robust is a Poverty Profile? World Bank Economic Review 8:1.
Smith HW (1975). Strategies of Social Research: The Methodological Imagination. Prentice-Hall, Inc, USA.
Todaro MP (1997). Economic Development, 6th edition, Third impression. New York.
White H (2002). Combining Quantitative and Qualitative Approaches in Poverty Analysis. World Development 30:3.
World Bank (2004). Rural Development Indicators Handbook. WBI, 2004.
World Bank (2017). Global Economic Prospects: Regional Overview, Sub –Saharan, 2017.

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Determinants of recommended agronomic practices adoption among wheat producing smallholder farmers in Sekela District of West Gojjam Zone, Ethiopia

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Development of the Ethiopian economy is directly related to the transformation of the agricultural sector which is manifested with low utilization of recommended agronomic practices, improved farm inputs, and dependency on traditional farming and rainfall. As a result, low production and productivity of agriculture were prevalent over the last years. This study aims to identify the factors influencing adoption of recommended agronomic practices of wheat farming. Two-stage sampling method was applied to select 204 smallholder wheat producing farmers. Simple descriptive statistics and econometrics model such as multivariate probit model were used. The result of the model indicates that formal education level, family size, farm size, distance to the input market, use of chemical fertilizers and the use of credit have negatively and statistically significant effect on adoption decision while off-farm income, access of social media, cultivated land size, and attitude towards risk have positively and statistically significant effect on adoption decision of agronomic practices among wheat producing farmers. Moreover, early planting has a negative effect on distance to input market, farm size, and use of chemical fertilizers. The study recommended that government and other concerned body should develop the supply of inputs provision mechanism, credit, land, awareness creation through media.

Key words: Adoption of agronomic practices, multivariate probit model, and Ethiopia.

INTRODUCTION

Agriculture still offers the leading source of livelihood, and contributes a major phase to national income for most developing countries including Ethiopia. Statistics from ILO (2007) suggests about 60% of Africa labour force still derive their livelihood from agriculture, making it the largest employer of labour in most developing countries. However, the performance of the agricultural sector has been less impressive than expected in most developing countries. Agriculture is the core sector of most developing countries in general and in particular for the Ethiopian economy. It accounts for about 35.8% of the Gross Domestic Product (GDP) and also industry provides 22.2% of the country's GDP whereas service sector contributes 42% (World Fact Book, 2018) and 68% of employment opportunity for our country (World Bank, 2018). The sector is dominated by smallholder farmers,

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whereas about 56% of the farmers possess less than one hectare of land (CSA, 2017).

Despite its contribution to the GDP, employment creation, source of food and export earnings, agriculture productivity is very low. In this regard, the research system, along with the other stakeholders, has to play a major role in improving technologies required to enhance agricultural productivity in the country. Efforts have been underway by the national agricultural research system since its establishment in 1956 and a number of technologies have been released in the farming community. In spite of these efforts, productivity gains are not as such adequate in the country as compared to the potential (Degefu et al., 2017).

Low levels of adoption of recommended agronomic practices, technologies are among the major reasons contributing to low productivity (CSA, 2015). Wheat is among the most important staple food crops grown in Ethiopia. In CSA (2017/2018)'s main season, the total area under wheat production was 1,696,082.59 ha while the total production in quintal was 45,378,523.39 and yield quintal/ha was 26.75. It is also one of the most important cereal crops in Amhara National Regional States of Ethiopia, representing sources of food, cash and wheat straw for livestock feed (Ather Mahmood et al., 2006). Ethiopian Government aims to increase the extent and intensity of wheat production by expanding the area planted to the crop and improving crop productivity. To this end over 100 high yielding, high quality, rust resistant bread and durum wheat varieties have been made available along with their production packages suitable for different agro-ecologies. Therefore, the research system has always been grappling with rusts and made replacement varieties timely available (Dawit et al., 2017).

Goal of increasing wheat productivity and production will be realized only if farmers adopt various agricultural technologies developed through research institutions. Despite the release of several technologies, particularly of improved crop varieties, there has been limited use of improved technology by the majority of farmers (CSA, 2010). Some previous studies done on the area attest that such as unavailability of quality inputs at the right place and time is one of the key factors accounting for limited use of recommended agronomic practices, which further contribute to low productivity (Mekuria, 2013). Moreover, there is about 60% yield gap in wheat, which needs to be narrowed (Mahmood et al., 2013).The reasons for low or no adoption of new agricultural technologies may be technical, socioeconomic, and institution factors (Musah, 2017). Late planting of wheat, non-availability of improved inputs like seed, inefficient fertilizer use, weed infestation, shortage of irrigation water, drought in rain fed areas, soil degradation, and inefficient extension services were other factors for low productivity (Phillis, 2007). Although the analysis of adoption of technology in general and recommended agronomic practices in particular is important, there are limited empirical studies in Ethiopia, particularly on adoption of recommended agronomic practices and its determinants among wheat farming system in Sekela District of West gojjam zone, Ethiopia. Understanding the types of recommended agronomic practices and their determinants will contribute a lot for enhancing production and productivity of wheat among smallholder farmers in the study area.

METHODOLOGY

Description of study area

The study area is located in Amahara Regional State, the North western Ethiopia. This study was under taken in Sekela District. This district is located between 10°59.25′N latitude and 36°55.30′E longitude .The district is bounded with the Mecha District in the north, Yilmana Densa District in the northeast, Burie District in the south, Jabi Tehinan District in the Southeast, Awi zone in the west and the Quarit District in the east, at 460 km from Addis Ababa and 178 km from Bihar Dar. The area is the origin of River Abay. Based on Ethiopian (CSA, 2014) National Census, the district has a total population of 138,691 of whom 69,018 are men and 69,673 women; 6,779 are urban inhabitants. A total of 29,908 households were counted in this district, resulting in an average of 4.64 persons in a household, and 29,093 housing units for thirty two kebeles (lowest administrative unit).

Data sources and method of collections

To collect data, both primary and secondary sources were employed in this study.

Primary data

The structured questionnaire was used to collect primary date from sample respondent smallholder farmers. To collect relevant data, a questionnaire which consists of both open and closed ended questions were applied and administered to the target respondents. Then, training was given for enumerators before the data collection was started and then appropriate correction taken. Finally the data were collected from 204 respondents in the study area.

Secondary data

Secondary data were collected by reviewing and careful examination of related documents, research reports, published and unpublished writings, different journals, and internet websites. It was also collected from agricultural and land office and central statistics agency and other governmental concerned bodies.

Sampling techniques and data

The study was conducted based on cross-sectional data that were collected from 204 sample respondents among wheat producing smallholder farmers. Two-stage sampling techniques that involve simple random sampling methods were deployed to select wheat producer farmers. In the 1st stage, simple random sampling techniques were used to select five kebeles (lowest administrative units) among wheat growing kebeles. In second stage, simple

random sampling proportion to their total population size was used to select households head from sample frame. As a result, a list of all wheat producer farmers in 2017/2018 production year was compiled with the help of the extension workers and leader of the respective kebeles. A total of 204 household head sample estimated based on sample size determination formula of Yamane (1967).

Analytical methods

Adoption of Recommended Agronomic Practices (RAPs) of particular technologies is not independent of other technological selections-on the same farm plot of land. Therefore multivariate Probit model (MVPM) were used because it accounts for error terms correlation (Priscilla et al., 2014). The MVPM simultaneously analyses the influence of a set of explanatory variables on each of the different agronomic practices, by allowing error terms to be freely correlated (Lin et al., 2005). Correlation between the different adoption decisions of RAPs may be due to technological positive correlation or negative correlation. If such correlation exists, estimates of simple Probit models would be biased and inefficient (Sied, 2015). Moreover, interdependence of technologies in both adoption and disadoption decisions could be tested by looking at the sign and significance of the off-diagonal elements of the variance-covariance matrix of MVPM explained by Teklewold et al. (2013) and Ndiritu et al. (2014)

Model specification of multivariate probit model

Specification assume that the decision to use recommended agronomic practices in improved wheat varieties adoption is simultaneously determined by vectors of demographic, socioeconomic, institutional and psychological factors. The interdependence between the statuses of adoption of recommended agronomic practices of adoption improved wheat varieties in 2017/18 production year in the study district is specified as:

$$\left.\begin{array}{l} Y^{*}i1 = X^{'}i1\beta 1 + \mathcal{E}i1 \\ Y^{*}i2 = X^{'}i2\beta 2 + \mathcal{E}i2 \\ Y^{*}i3 = X^{'}i3\beta 3 + \mathcal{E}i3 \\ Y^{*}i4 = X^{'}i4\beta 4 + \mathcal{E}i4 \\ Y^{*}i5 = X^{'}i5\beta 5 + \mathcal{E}i5 \end{array}\right\} \text{Univariate probit} \quad Y^{*}ijm = X^{'}ijm\beta m + \mathcal{E}ijm \tag{1}$$

The number of latent equations corresponds with the number of observed equations

$$Yijm = \begin{cases} 1 if Y^{*}ijm > 0 \\ 0\ otherwise \end{cases}, \text{ m=EP, RP, SR, H, \&TP} \tag{2}$$

This shows that: combination of univariate probit models give multivariate probit model .Where: m represents recommended agronomic practices choice for household i(i=1,..,N) i.e.m=Early Planting (EP), Row Planting (RP), Seeding Rate (SR), Herbicide (HC), and Timely Planting (TP) which is facing a decision on whether or not to adopt the available agronomic practices on plot j. Y*ijm is a latent variable which captures the unobserved preferences for technology m (applicable if net benefit that is benefit-cost >0).This latent variable is assumed to be a linear combination of observed plot and household characteristics (Xijm), and unobserved chacteristics captured by the stochastic error term(εijm).βm is the vector of parameters to be estimated. In multivariate model, the adoption of several agronomic practices is possible, in case of error terms jointly follow a multivariate normal distribution (MVND) with zero conditional mean and Variance normalized to unity (Haile et al*.,* n.d.) and (Mwebaze et al., 2017) where ($\mathcal{E}$EP, $\mathcal{E}$RP, $\mathcal{E}$SR, $\mathcal{E}$H &$\mathcal{E}$TP) ~MVND(0,Ω) and the symmetric covariance matrix.

The off-diagonal elements in the covariance matrix, which represent the unobserved correlation between the stochastic components of the different types of recommend agronomic practices. This assumption means that equation (B) gives a MVP model that jointly represents decisions to adopt a particular agronomic practice. This specification with non-zero off-diagonal elements allows for correlation across the error terms of several latent equations, which represent unobserved trait that affect the choice of alternative RAPs (Table 1).

RESULT AND DISCUSSION

Before running the model result appropriate model diagnostics test result were carried out and presented.

Multicollinearity test

The existence of Multicollinearity problems were checked among explanatory variables. The values of contingency coefficient (CC) for dummy variables and the value of variance inflation factor (VIF) for continuous variables were very low compared to their respective critical values (<0.75 for CC and <10 for VIF and tolerance was greater than 0.1 which is the inverse of VIF) that revealed the absence of a sever Multicollinearity problem among independent variables.

Heteroscedasticity test

Breusch-Pagan/Cook-Weisberg test was carried out for testing the existence of heteroscedasticity. The test result shows chi^2 value of 0.3918 was not significant implying there is no problem of heteroscedasticity on the model.

Multivariate probit model results

The chi-square (χ^2) distribution was used as the measure of overall significance of in Multivariate Probit Model (MVPM) estimation. As a result χ^2 (90) calculate greater than, the χ^2 (90) tabulated that is 122.61>69.93 at less than 5% significant level. So, this shows that, the variables included explaining well adoption decision of Recommended Agronomic Practices (RAP's) and fits the mvprobit model at less than 5% probability level. This implies that the joint null hypothesis of coefficients of all explanatory variables included in the model were zero should be rejected. Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: this implies null hypothesis (Ho), that is, there is no correlation for each equations error terms. HA: there is correlation for each equations error terms.

Table 1. Description of variables and expected hypothesis that were used in MVPM.

Variable	Unit	Nature	Descriptions	Expected sign
DV for RAPs:			Dependent variables for recommended agronomic practices adoption decision:	
Early planting	1 or 0	Dummy	1 for timely planting,0 otherwise	
Row planting	1 or 0	Dummy	1 for row planting 0, otherwise	
Seeding rate	1 or 0	Dummy	1 for recommended seed i.e kg/ha, 0 otherwise	
Herbicide	1 or 0	Dummy	1 for adopter ,0 otherwise	
Timely planting	1 or 0	Dummy	1 for timely tilling,0 otherwise	
IV			Independent variables	
Sex	1 or 0	Dummy	1for male,0 for female house hold head	-/+
Off income	Birr	Dummy	1 for off-farm, 0 other sources	+
Fedu.	Number of year	Continuous	year of formal education for household head in year	+
Excota	1 or 0	Dummy	1 for use of extension service, 0 otherwise	+
Useofcredit	1or 0	Dummy	use of credit 1,0 otherwise in Ethiopian birr	+
Farmsize	Hectare	Continous	Total land own by smallholder farmers.	+/-
Participation tech-evaluation	1or 0	Dummy	1 for Participation in technology evaluation ,0 otherwise	+
Family size	adult equivalent	Continous	Family size availability in small holder farmers in number.	$^{+}/_{-}$
tropical livestock	TLU	Continous	Number of livestock unit owned in the house hold.	+
HHexperi	Year	Continous	number of year house hold head use improved wheat varieties	+
DISTOMRT	Km	Continous	distance to impute market from small holder farmers residence	-
FPIWVS	Index	Perception	Small holder farmers' perception to the specific attributes of Recommended Agronomic practices of wheat	Favorable
Access oxen	1or 0	Dummy	1 for SHFs owns oxen ,0 other wise	+
AccessSM	1or 0	Dummy	1 for access to social media, 0 otherwise.	+
Wclaoship	1 or 0	Dummy	1 for well cultivated land ,0 otherwise	+/-
Risk	1 or 0	Dummy	1 if early adopter, 0 otherwise	+/-
Useche-ferti	Kilogram	Continous	User of chemical fertilizer by smallholder farmers.	+
Soil fertility status	1 or 0	Dummy	1 for fertile soil, 0 other wise	+

Since rho21 and rho41 were significant at 5 and 10% levels of significance (Table 2), we reject the Ho and accept the alternative hypothesis, meaning there is error terms correlation among each equation which implies the acceptance of the model.

The interaction between households' decision of choice rho21 and rho41 is positive and significant. This implies the households' decision to adopt rho21 does not alter the decision to adopt rho41 and the reverse is true. Moreover, this positive interaction will have a positive effect on activities done to promote row planting, early planting, and with the use of herbicide meaning they will take place at the same time by respondents. The joint probability of success showed that, if households are able to adopt all five agronomic practices (EP, RP, SR, HC & TP), their joint likelihood of adopting these technologies will be only 1% level of significance. This will justify simultaneous adoption of all the technologies is affordable for the smallholders. Moreover, the joint probabilities of failure in adopting all these five practices of the households are also 1% level of significance, implying that the households adopted at least one practice.

Formal education

The result of the model revealed that education of the household head has a negative influence on the participation in timely planting as opposed to the expected sign. Education is statistically significant at 1% probability level; as a unit increases in education every year, timely planting decreases by 0.068 holding constant other variables in the model. One more year in school for household head help increase his skill and minimize risk through diversification (by branching out income sources in off season). This leads to wastage of time to plough his land at the recommended time.

Table 2. Multivariate Probit model results.

Variable	Early planting	Row planting	Seeding rate	Herbicide	Timely planting
	Coeffi(St. error)	Coeffi(st.error)	Coeffi(st.error)	Coeffi(st.error)	Coeffi(st.error)
FEDUINYE	0.043(.033)	0.047(0.031)	-0.025(00.031)	-0.050(00.035)	-0.068(00.032**)
HHEXPERI	0.002(00.010)	0.007(00.010)	0.002(00.009)	-0.004(00.010)	-0.011(00.009)
FAMISI	-0.1003(00.068)	0.026(00.069)	-0.115(00.066*)	-0.057(00.073)	0.076(00.066)
SEXHH	-0.028(00.241)	-0.325(00.235)	0.152(00.232)	-0.026(00.245)	0.274(00.234)
TLU	0.082(00.076)	0.014(00.074)	0.078(00.072)	0.073(00.081)	0.034(00.072)
FARMSIZINHA	-0.201(00.118*)	-0.034(00.117)	-0.084(00.114)	0.192(0.121)	-0.160(00.115)
OFFFAIN	0.153(00.198)	0.484(00.192***)	-0.121(00.191)	0.157(00.209)	0.305(00.193)
AVAOXEN	-0.147(00.249)	-0.002(00.237)	-0.098(00.234)	0.110(00.260)	0.013(00.239)
EXCONTA	-0.0104(00.216)	0.038(00.208)	-0.121(00.204)	0.001(00.220)	-0.056(00.207)
DMRTKM	-0.073(00.018***)	0.013(00.017)	-0.033(00.017**)	0.011(00.018)	0.009(00.017)
USECHFKG	-0.001(00.001*)	0.0004(00.001)	-0.0004(00.001)	0.0005(00.001)	0.0017(00.001**)
USCREDIT	0.086(00.205)	-0.285(00.204)	-0.439(00.201**)	0.028(00.220)	-0.111(00.201)
PARTEVA	-0.012(00.227)	0.329(00.220)	0.347(00.217)	-0.073(00.235)	0.408(00.218**)
ACCESM	-0.108(00.215)	0.420(00.206**)	0.405(00.204**)	0.240(00.212)	0.0017(00.206)
WLANOSHIP	0.295(00.244)	0.410(00.235*)	0.160(00.236)	-0.647(00.243***)	-0.264(00.235)
ATITOWR	-0.095(00.206)	0.005(00.200)	0.128(00.198)	0.543(00.221**)	-0.156(00.199)
PHHIWV	-0.158(00.100)	-0.068(00.095)	0.027(00.095)	0.115(00.104)	-0.081(00.097)
SFS	0.2546(00.217)	0.031(00.209)	-0.063(00.208)	-0.119(00.228)	0.0213(00.213)
_cons	10.492019(00.611)	-10.021(00.578)	0.255(00.553)	-10.123(00.631)	-0.448(00.580)
rho21			0.237(0.106**)		
rho31			0.587		
rho41			0.204(0.118*)		
rho51			0.783		
rho32			0.184		
rho42			0.119		
rho52			0.722		
rho43			0.976		
rho53			0.506		
rho54			0.976		
Number of observation			204		
Wald chi2(90)			122.61		
Log likelihood			-608.857		
Prob > chi2			0.0127**		
Joint probability of success			0.000***		
Joint probability of failure			0.000***		

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: chi2(10) = 12.274, Prob > chi2 = 0.2671. Coeffi (Std. Error) in this table denote the coefficient for each equations and their p-value.
Note: ***, **, and * shows 1, 5 and 10% level of significant respectively.
Source: Own survey (2018).

Family size

This variable is measured by adult equivalent (Stork et al., 1991 as cited by Getaneh, 2003), and it has negative contribution to recommended seeding rate in line with the expected sign at 10% probability level. As family size increases by one individual, adoption of seeding rate decreases by 0.115, keeping constant other variables. Family size increase means there is high demand for consumption. This leads to reduction in recommended seeding rate adoption.

Farm size in hectare

Farm size affects early planting negatively at 10% probability level. As farm size increases by one hectare, early planting decreases by 0.201 holding other variables

constant. This implies that large farm size need plenty of time to cover vast area of land by seed at recommended planting time. That is why farm size in hectare and early planting have negative relationship.

Off-farm income

During slack periods many farmers earn additional income by engaging in various off-farm activities. This is believed to raise their financial position to acquire new inputs such as easy hire of labor because row planting is labor intensive activity. If off- farm income increases from zero to one birr it leads to increase in row planting of improved wheat varieties by 0.484 keeping other variables constant. Therefore, in this study, it is hypothesized that there is a positive correlation between the amount of off-farm income and row planting of improved wheat varieties at 5% probability level of significance and this relationship is in line with Mekuria (2013), that is access to off-farm employment had positively and significantly influence on the likelihood of adoption of improved maize seed production at 5% significant level. Hailu et al. (2014) said off-farm participation was positive in determining chemical fertilizer adoption decision.

Distance to the input market from farmers' residence

This variable has a negative influence on both early planting at 1% and seeding rate at 5% probability level of significance. A decrease in 1 km distance to the main market would increase the likelihood of participating in early planting and seeding rate by 0.073 and 0.033 respectively while holding all other variables constant. Hence, farmers nearest to the main market, infrastructure like main road and seasonal roads, use agricultural inputs both adequately and timely. Moreover, distance to main market is negatively correlated with participating because of the increased transaction costs associated with purchasing inputs. This agrees with the findings of Kidane (2001) that distance to the nearest market place has a negative influence on the extent of adoption of the farmers. Farmers who live in remote areas are reluctant to adopt improved agricultural inputs. This is possibly because they have limited access to modern agricultural inputs and market information. Ashenafi (2008) said market distance negatively influences triticale yield over Teff, wheat and barley; for Degefu et al. (2017) distance to the market negatively and significantly influenced the adoption of wheat technologies.

Use of chemical fertilizers

Use of chemical fertilizer is negatively correlated with early planting and positively correlated with timely planting at 1% probability level of significance for both. 1 kg decrease in use of chemical fertilizer increases early planting by 0.0018 other variables being kept constant. Logically chemical fertilizers could facilitate growth of plant as compared with plant without this input and lead to early maturation. So, farmers enforced early plant to persist maturation period of improved varieties as alternative to chemical fertilizers, and if use of chemical fertilizer increase by 1 kg timely planting increase by 0.00179 because farmers initiated to do more if they had got the input they want. Other variables hold constant, the later in line with Shemelis (2004) that is farmers who have better access to fertilizer credit has positive contribution to use modern agricultural inputs.

Use of credit

Credit has a negative contribution for adoption of seeding rate at 5% probability level of significance. Farmers who have access to credit can minimize the use of recommended seeding rate. Thus, it is expected that access to credit decreases the probability of adopting recommended seeding rate of improved wheat technologies. Moreover if credit increases from zero to one birr leads to decreased seeding rate by 0.439 amounts; other variables being equal (constant). This relationship is opposite to the expected sign. As access to credit increases, the household head will be established: new business venture to increase their income rather than adopting improved technology (particularly seeding rate); moreover nature is full of risk and uncertainty that is why farmers are enforced to start other business alternatives to reduce risk.

Participation in technology evaluation

Attending formal training such as field days, demonstration plots, and participating in formal agricultural training are expected to have a positive attitude for farmers to prepare their land timely. If participation in the above-mentioned activities increases from zero to one, timely planting increases by 0.408 ceteris paribus other variables. Training has positive contribution for land preparation at the required time by owners at 10% probability level of significant. The result is in line with Tesfaye and Alemu (2001), that is participating in on-farm demonstrations positively affect the adoption of improved varieties of bread and Tesfaye et al. (2014) report that field participation positively improved wheat technology adoption and is in line with the researcher prospect sign before.

Access to social media

Access to social media has positive influence on row

planting and recommended seeding rate at 5% probability level of significance for both. If access of social media increases from zero to one (from non-adopters to adopters), row planting, and seeding rate of wheat increase by 0.420 and 0.405 respectively keeping constant other variables. From this result we can understand that: Radio, television ownership develop the ability to receive broadcast agricultural programs and are expected to influence farmers' awareness and adoption. This is in line with Mesfin (2009) that higher access to information could increase adoption of triticale and Berhe (2014) that access to social media affects positively smallholder farmers' adoption of both row planting and improved wheat seed technologies.

Well cultivated land ownership

Well cultivated land positively affects row planting of improved wheat varieties (IWVs) and negatively influences the use of herbicide at 10% probability level for both. If the farmers have well cultivated land (well smoothed soil) they will be encouraged to adopt row planting of IWVs because the seed will germinate by penetrating the loam soil and if land is cultivated (if increases from zero to one then row planting increases by 0.410 and use of herbicide decreases by 0.647, it will be free from weeds. As a result the use of herbicide would decrease. This is in line with Hailu et al. (2014) and Musah (2017) that early adopters have 15% greater probability of participating in contract farming than late adopters.

Attitude towards risk

This variable positively affects the use of herbicide at 1% probability level of significance. If attitude towards risk changes from laggard to early adopter, the use of herbicide will increase by 0.543. The result is consistent with Musah (2017)'s that early adopters have 15% greater probability of participating in contract farming than late adopters.

CONCLUSION AND RECOMMENDATIONS

As the regression result indicate, distance from input market, farm size, and use of chemical fertilizers influence early planting of wheat negatively whereas off-farm income, access of social media, and well cultivated land size influence row planting of wheat positively; family size, distance to the input market, use of credit affect recommended seeding rate negatively. Moreover well cultivated land affects negatively use of herbicide whereas attitude towards risk influences positively use of herbicide. Finally participating in technology evaluation affects positively timely planting and in similar manner timely planting is affected negatively by use of chemical fertilizers and formal education. It is suggested that concerned bodies have to consider the supply of inputs to address the input demand of targeted farmers at the right time, with the right price, for the right person, to the right place to enhance development. Moreover it is better to give stress for methods of cultivation, income and information sources to reduce constraints faced by smallholder farmers and to open more opportunity than before. In the same situation, it is better to develop farmers' participation in social media to create strong awareness among those smallholder farmers in the study area and smallholder farmers should be motivated to use hand weeding system because hand weeding facilitates growth of crops than the use of herbicide. Finally, experience share should be conducted among laggards with that of late majority, early majority, early adopter and innovators to develop strong awareness for risk averse.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERRENCES

Ashenafi G (2008). Triticale production in Ethiopia its impact on food security and poverty alleviation in Amhara Region, Faculty of organic agriculture science of university of Kassel Thesis of Doctorial in Germany.

Ather Mahmood M, Sheikh AD, Abid H, Abbas M (2006). Recommended Technologies and Production Practices at Farm Level: Wheat Scenario Techno lo g y Transfer Institute. Pakistan Journal of Life and Social Sciences 4(1-2):52-57.

Awotide BA, Abdoulaye T, Alene A, Manyong VM (2014). Assessing the extent and determinants of adoption of improved cassava varieties in south-western Nigeria. Journal of Development and Agricultural Economics 6(9):376-385.

Central Statistical Agency (CSA) (2010). The federal democratic republic of Ethiopia central statistical agency agricultural sample survey. report crop and livestock product utilization, Addis Ababa.

Central Statistical Agency (CSA) (2014). Ethiopian population census during this year. The federal democratic republic of Ethiopia central statistical agency of population census of Sekela district in 2014.

Central Statistical Agency (CSA) (2015). The federal democratic republic of Ethiopia central statistical agency of, agricultural sample survey volume 1. report on area and production of major crops, Addis Ababa.

Central Statistical Agency (CSA) (2017). The federal democratic republic of Ethiopia central statistical agency of, agricultural sample survey volume 1. report on area and production of major crops, Addis Ababa.

Dawit A, Eshetu D, Getnet A, Abebe K (2017). Agricultural Research for Ethiopian Renaissance Challenges, Opportunities and Directions, Agricultural Research View project, The Bilateral, Ethiopian Netherlands Effort for Food, Income and Trade.

Degefu K, Mengistu K, Nigussie D, Feyisa H (2017). Determinants of Adoption of Wheat Production Technology Package by Smallholder Farmers: Evidences from Eastern Ethiopia. Turkish Journal of Agriculture - Food Science and Technology 5(3):267-274.

Hailu BK, Abrha BK, Weldegiorgis KA (2014). Adoption and impact of agricultural technologies on farm income: Evidence from Southern Tigray, Northern Ethiopia. International Journal of Food and Agricultural Economics (IJFAEC), 2(1128-2016-92058), 91-106.

ILO (2007). Employment by sector in Key, indicators of the labor market

KILM, 5th Edition.
Kidane G (2001). Factors influencing the adoption of new wheat and maize varieties in Tigray, Ethiopia: the case of Hawzien wereda, Degree of Masters of Science in Agriculture (Agricultural Economics), Alemaya University.
Lin CTJ, Jensen KL, Yen ST (2005). Awareness of food-borne pathogens among U.S. Consumers, Food Quality and Preference 16:401-412
Mekuria A (2013). Factors influencing adoption of improved maize varieties: the case of Goro Gutu Woreda of Eastern Hararghe, Ethiopia. M.Sc. Thesis, Haramaya University.
Mesfin A (2009). Environment and Social Assessment: Fertilizer Support Project. Ministry of Agriculture. Addis Ababa.
Musah AR (2017). Contract Farming And Adoption of Improved Technologies In Maize Production In The Northern Region of Ghana. Master of Philosophy Degree, University for Development Studies. Agricultural Economics.
Mwebaze P, McFadden S, Andy H, De Barro-CSIRO P, Australia AB, Chris O, Kalyebi-NACCRI A, Uganda Donald Kachigamba-DARS, Malawi Fred Tairo-MARI, Tanzania (2017). Modeling technology adoption decisions by smallholder cassava producers in East Africa. Oceania Stata Users Group Meeting, ANU, Canberra. https://www.stata.com/meeting/oceania17/slides/oceania17_Mwebaze.pdf
Ndiritu SW, Kassie M, Shiferaw B (2014) Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. Food Policy 49(1):117-127.
Mahmood N, Ali T, Bajwa MS, Shahbaz M, Chattha MB (2013). Analysis of the adoption of wheat sowing recommendations among small farmers using water saving interventions. Journal of Animal and Plant Sciences 23(1).
Priscilla W, Songporne T, Matin Q (2014). "Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya," Agricultural Economics, International Association of Agricultural Economists 47(3):351-362.
Sied H (2015). Disadoption, Substitutability, and Complementarity of Agricultural Technologies: A Random Multivariate Probit Analysis. Environment for Development Discussion Paper Series EfD DP 15-26. https://media.rff.org/documents/EfD-DP-15-26.pdf
Shemelis A (2004). Factors Influencing demand of Fertilizer in Ethiopia: A Case Study of in Oromia. Alemaya University, Agriculrure. UN published Master of science Thesis.
Techane A (2002). Determinants of fertilizer adoption in Ethiopia: the case of major Cereal producing area. M.Sc. Thesis, Alemaya University.
Teklewold H, Dadi L, Yami A and Dana N. (2006). Determinants of adoption of poultry technology: a double-hurdle approach. Livestock Research for Rural Development P 3.
Teklewold H, Kassie M, Shiferaw B (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. Journal of Agricultural Economics 64(3):597-623.
Tesfaye S, Tessema A, Bekele A (2014). Adoption of improved wheat varieties in Robe and Digelu Tijo Districts of Aris Zone in Oromia Region, Ethiopia: A Double hurdle Approach. African journal of, agricultural research., pp. 3692-3703.
Tesfaye Z, Alemu H (2001). Adoption of improved maize technologies and inorganic fertilizer in Northwestern Ethiopia. Ethiopian Agricultural Research Organization 40:51.
World Bank (2018). Employment in agriculture (% of total employment) (modeled ILO Estimates) international labour organization estimate). https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS
World Fact Book (2018). CIA World Fact Book of the United States Central Intelligence Agency (CIA) about Ethiopian Economy. https://theodora.com/wfbcurrent/ethiopia/ethiopia_economy.html
Yamane T (1967). Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.

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Slash-and-burn agriculture, the major cropping system in the region of Faradje in Democratic Republic of Congo: Ecological and socio-economic consequences

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The present study aims to explore smallholder's household living standard relevant to slash-and-burn agriculture, and determine trend of key crops grown with respect to their production and related generated average gross income in the region of Faradje, in the far northeastern region of the Democratic Republic of Congo (DRC). Surveys were conducted on agronomic and social economic characteristics prevailing in the area, in five localities, involving 50 farming households based on a questionnaire designed. Questions asked were about yield and gross income, considered as dependent variables as well as household size, farmland area, farming systems, crop types, distance between farms and home, farm task allocation, duration of fallowing, types of off-farm activities and number of reared animals taken as independent variables. Graphs were plotted using R statistic package (Version 3.6.1, 2019-07-05) and correlation analysis was conducted using Genstat 12th edition. The results showed that each household produced yearly on average 793.71 kg of paddy rice, 194.96 kg of maize grain, 175 kg of cassava chips, 70.50 kg of groundnut seeds and 8.60 kg of beans on an average of 0.81 ha of cropland in two cropping seasons. The results also showed that the total annual average income earned by one household was US $ 940.60 with individual average income of US $188.90. This was slightly higher than the national average real gross domestic product (GDP) in 2008 estimated at US $171; however, the figure was still unfortunately below the minimum of US $1 per day (0.52 US $/day) suggesting that slash-and–burn agriculture cropping system is far to achieve food security and accordingly improvement of economic situation in Faradje DRC. The household size and number of agricultural workers/households were weakly correlated with the average gross income (respectively, r = 0.29 and r = 0.35) whereas cropland surface area was moderately associated with the average gross income (r = 0.74). This demonstrates the importance of cropland surface in this cropping system in Faradje; suggesting that increasing farmers' gross average income through slash-and-burn cropping system requires cropland expansion. Consequently, much should be undertaken to mitigate adverse effects of the established cropping system over the overall environment.

Key words: Slash-and-burn agriculture, gross income, Faradje, DR Congo.

INTRODUCTION

Slash-and-burn agriculture is the most prevalent system used in the tropics and sub-tropics. It is estimated to be

used by 200 to 500 million people and supports life of billions of people worldwide (Andriesse and Schelhaas, 1987). However, despite enormous potential and large number of farm operators, shifting, swidden or slash-and–burn agriculture which is a current cropping system in poor economy countries is still not in measure to reverse food security and accordingly economic situation prevailing therein (Stefan and Norgrove, 2013).

Researchers are quite alienated as regards the definition to give to the concept and many interpretations are available depending on the number of factors such as physical, ecological, climatic and socioeconomic in which the system is practiced. Generally, whether shifting, swidden or slash-and–burn agriculture, all they refer to land uses where a cropping period is rotated with a fallow period that is long enough to enable the growing of dense, woody vegetation, and where the biomass is eliminated from the plot by cutting, slashing, and burning it, prior to the next cultivation cycle. It is generally considered as an extensive land use, maintained through time by expansion over uncultivated land following population growth (extensification), in contrast with more intensive land uses, where the biomass is incorporated to the soil through plowing or other practices (Stefan and Norgrove, 2013; Pollini, 2014).

Slash-and–burn agriculture is always reported of being associated with poor crop yields and rapid ecological degradation. ICRAF (2000), for instance, indicated that slash and burn agriculture caused 70% deforestation in Africa, 50% in Asia and 30% in America. The same source states that some governments and international organizations looking at themselves responsible for the inconsiderate natural resources destruction of nations attempted to put an end to the practice. Yet, it turned out to be easy to pass laws and adopt policies forbidding cut and incineration of forest, in contrast, stopping shifting agriculture was much less. It is therefore clear that, swidding agriculture is a reality and will continue to be so in the future. In this perspective, the Democratic Republic of Congo (DRC), one of resource rich countries, in order to build up sustainable management of its resources is committed in supporting the implementation of self-development policy based on rational use of natural resources especially the forest while focusing on their planning and sustainable use (Trefon, 2008). Given that shifting cultivation is one of the wide spread cropping systems across the tropics, the DR Congo is not exempted. For example, in the region of Faradje, located in the far northeast of the country, a woody savannah region, this system of agricultural land use is the most accessible and adapted to farm operators (Talaguma, 2013); while at the same time, shifting farmers are the first to be accused worldwide of deforestation in the tropics, raising fears of looming global warming resulting in climatic change (Roper et Robert, 1999; Cheryl et al. 2005; FAO, 2012).

It is then in this context that this study was set up with assumption that, similarly in the forest agricultural regions, slash-and-burn agriculture could also have negative impacts as well as on crop yield (translated into households' income) and on the environment. The hypotheses driving this study were: the balance between agricultural land use method and equipment used by farmers in the study area may not be adapted to optimal production conditions. Secondly, income generated through the practice of slash-and-burn agriculture may be the most important if not the only one, compared to that generated by other economic activities. Finally, this agricultural practice is likely imposed to farmers by socioeconomic conditions prevailing in the region. The purpose of the study was to collect information about slash-and-burn agriculture in this area, which is one of the remotest regions and isolated from the main universities and agricultural research centers in the country. The underlying rationale was to show the contribution of agriculture to the sustainable development of this rural area as well as related constraints and later constitute an actual database about slash-and-burn agriculture for the region. The research also aims at enabling the discovery of other cropping systems used in this area which would eventually help the understanding of local practice of slash-and-burn agriculture and in the choice of suitable production systems for the area. This study furthermore was susceptible to provide a general view to economic developers and policy makers to plan strategic responses to make shifting agriculture an income generating activity while promoting principles of rational and sustainable use of resources. To assess these hypotheses, several specific objectives were focused on namely, the characterization of crop types and reared animals as well as related motivation, the estimate of farmland sizes and the availability of labor force, the determination of key crop trends grown in the region with respect to their yield and total production (income derived) and the assessment of the sustainability of farming system.

MATERIALS AND METHODS

Geographic location of the study area

The study was carried out in the region of Faradje (Figure 1); it is a

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"Territory[1]" with a surface area of 13,138 km^2 and where reside an estimated 576, 861 inhabitants of whom 299,968 are women (52%) and 276,892 are men (48%), with a density average of 26.22 persons/km^2 (CAID, 2016). This area was selected by the fact that it was one of the remotest regions and isolated from the main universities and agricultural research centers in the country.

Faradje's Territory is one of the 124 administrative entities named "territories" that possess the DR Congo. It is situated in the far northeast of the country (Former Eastern province now called Haut-Uele or Upper Uele), at the boundary of South Sudan (in the North) and the neighbouring territory of Aru bordering Ugandan Republic (in the East). The geographic coordinates of the region are: 3° 44' 0'' latitude N, 29° 43' 0'' longitude E; an altitude varying between 700 and 1500 m with some mountain ranges in the eastern part of the Territory (Maps of world.com, 2009).

According to Makondambuta (1997), the climate of Faradje belongs to the AW type according to Koppën-Geiger's classification. It is a climate characterized by two seasons: one dry season (the longest) from November to March and a rainy one, from April to October. However, there exists a short dry period between June and July. The average annual temperature revolves around 23°C, with a precipitation ranging from 900 to 1500 mm. The vegetation ranges from forest galleries to small shrubby savannas (Lisingo, 2009). The main groups of soil found in the region belong to the tropical ferruginous soils rich in iron (ferralsols on rocks undifferentiated), dominated by clay-type 1/1 (kaolinite). However, there may also be found some soils with the fraction of clay-like 2/1 (montmorillonite) and clayey-silt soils mainly in the south part of the territory (Landa et al., 2013). The territory is one of the mining areas of DR Congo (gold mining of Kilo-Moto, Kibali Gold mining) and includes one of the most important nature reserve of the country (Garamba Park) where are kept the last white rhinoceros (*Ceratotherium simum cottoni*) of the world. In contrast, the majority of people are engaged in smallholder agriculture.

Data collection timing and process

The fieldwork covered the period ranging from 20th May to 20th June 2011. It involved a descriptive survey using semi-structural questionnaire containing both open-ended and closed-ended questions, (Kibwika, 2015) and completed by some interviews and observations. In fact, as stated by Shukla in 2007, pragmatism endorses the idea that research questions should guide methods and paradigms that underlie the methods. Consequently, this study mainly followed a quantitative method approach including standardized measurements of data collection even though some data with qualitative characteristics (that are not analyzed in this paper) intervened across the collection process, in order to be more practical and find workable solutions for data collection and analysis. Therefore, due to some on ground practical issues, the study had to do with experimentally accessible samples failing to access theoretically targeted samples (Kyazze, 2016).

The research target population covered farming households of five villages living in one of the eight rural counties that the territory of Faradje encompasses. The units of the study included responsible persons of farming households of all gender. Other analysis units included farmland area, crop types, cropping system, yields, gross income, distance between farms and home, farm task allocation, duration of fallowing, types of off-farm activities as well as rearing types. Surveyed households were selected using combined sampling methods by probability and non-probability, namely by convenience, purposively and also using snow ball technique (Kibwika, 2015; Kyazze, 2016).

[1] Territory: Congolese administrative entity right below the province but above the county according to the new national layout put in place since 2016.

The questions asked were about yield and gross income taken as dependent variables whereas the independent variables comprised household size, farmland area, farming systems, crop types, distance between farms and home, farm task allocation, duration of fallowing, types of off-farm activities as well as number of reared animals. The gross income was evaluated using the most simple formula based on the quantity of production intended to the market, that is, gross income = production times current market price. Given some concerns such as the absence of available sampling frame of farming households and clue on the accurate number of households per surveyed village as well as the insufficiency of resources, the study decided to consider a unique number of ten farming households per each surveyed village (Table 1), instead of using the mathematical formula suggested by Nassiuma (2000). In total, 50 farming households were surveyed in 5 villages. Farmland areas were measured and estimated in ha; the production was weighed and converted in yield terms into ton/ha. Furthermore, the yields were estimated at the local market cost and converted into US $. As for data processing and analysis, mainly descriptive statistics were used to analyze and present results. R statistical package (Version 3.6.1, 2019-07-05) was used to plots the graphs. Pearson's correlation was used between the number of agricultural workers per household, the cultivated surface area in ha, size of surveyed farming households, field surface area/agricultural worker and gross income was carried out using Genstat 12th edition. Means were separated with least significant difference at 5% (Ibanda et al., 2018). Pearson's correlation was given by the formula:

$$\frac{N\sum xy - (\sum x)(\sum y)}{\sqrt{[N\sum x^2 - (\sum x)^2\,]\big[\,N\sum y^2 - (\sum y)^2\,\big]}}$$

Where: N= number of pairs of scores, $\sum xy$ = Sum of the product of paired scores, $\sum x$ = Sum of the x scores, $\sum y$ = Sum of the y scores, $\sum X^2$ = Sum of squared x scores, $\sum y^2$ = Sum of squared y scores.

RESULTS AND DISCUSSION

Opportunities for slash-and-burn agriculture implementation

Households' composition and number of agricultural workers

The results related to household composition showed that the surveyed farming households were composed of 4.1; 6; 5.5; 5 and 4.3 for Awago, Watu, Karisia, Zoro and Angwande respectively (Figure 2a). Numbers of agricultural workers per household were 2.6; 3; 2.9; 2.7 and 2.5 for Awago, Watu, Karisia, Zoro and Angwande respectively (Figure 2b). On average, the surveyed households consisted of 5 persons (4.98 exactly) of whom an average of 3 were agricultural workers (2.74) who constituted familial labor force. In a total of 50 surveyed households (Table 1), there were 137 agricultural workers out of 248 persons making up the whole sample (55.2%). This average household size and the number of familial labor force were slightly lower than the national average, ranging from respectively 5.4 to 7

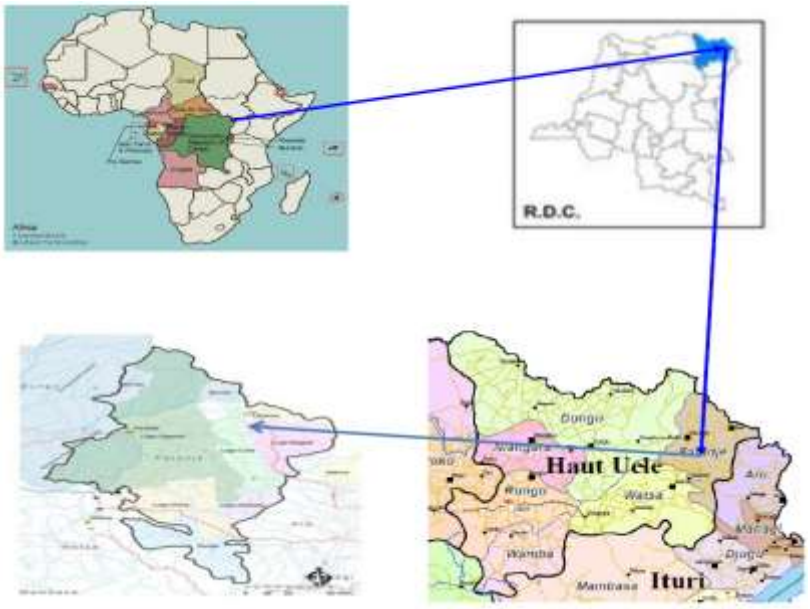

Figure 1. Territory of Faradje in the far Northeast of DR Congo.
Origin: Congo autrement[2] (2017).

Table 1. Number of surveyed farming households per village.

Name of village	Potential number of farming households noticed while surveying	Number of surveyed farming households/village
AWAGO	158	10
WATU	109	10
KARISIA	102	10
ANGWANDI	34	10
ZORO	152	10
TOTAL	**525**	**50**

Source: Authors.

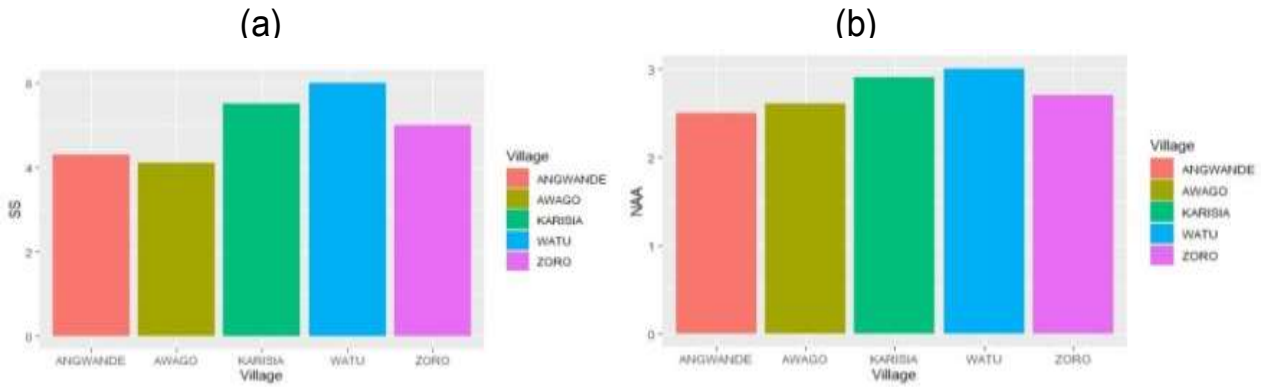

Figure 2. (a) Size of farming households; (b) Number of agricultural workers per household. SS =Size of Surveyed household; NAA = Number of Agricultural Workers.

[2] Congo autrement: Reference website for different view about Economic, Sportive, Cultural, Artistic, Scientific, Technological , Social and Leisure activities in DR Congo. URL: https://www.congo-autrement.com/

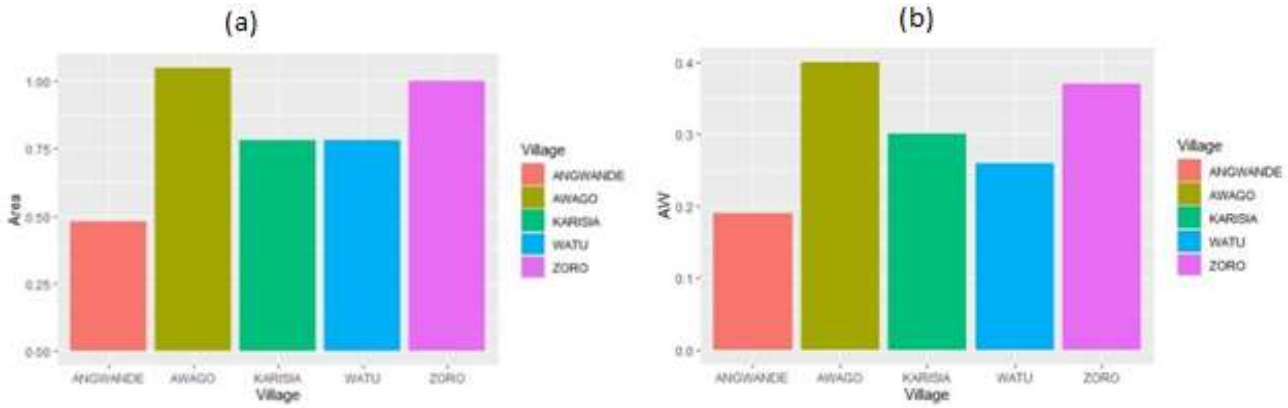

Figure 3. (a) Size of cultivated land/household, (**b)** slash-and-burn agriculture average surface area/agricultural worker in ha.

persons/household and 4 familial farm laborers (Angongolo et al., 2005; Tanzito, 2009; Kamara et al., 2010; Kankwanda et al., 2014). However, the figures found in this study fitted in the average size of sub-Saharan African countries which was reported to range between 4 individuals per household and 9 in Senegal for example (UNDESA, 2017).

Average number of fields per households

These results showed that the average number of fields per household was 3. About 40% of respondents stated to have 3 fields (20 households); 28% had respectively 4 and 2; 2% had respectively 1 and 5. Several factors explained this multiplicity of fields number namely for example, the will of minimizing risks such as pests and other crop enemies, the lack of consolidated land and declining soil fertility. This average number of 3 fields per household was almost similar to that found by Gafsi et al. (2007) in their survey conducted on family farms in western and central African region, who found an average of 3.3 fields / smallholder household.

Average size of cultivated surface area and average surface area/agricultural worker

The results showed that the size of cultivated area was 1.05, 0.78, 0.78, 1 and 0.48 ha for Awago, Watu, Karisia, Zoro and Angwande respectively (Figure 3a). According to these figures, one household cultivates on average 0.81 ha of land for one season. Nevertheless, the village Awago showed more than 1 ha average size of cultivated area (1.05 ha). Lowder et al. (2016) stated that slash-and-burn agriculture land area in sub Saharan Africa ranged from 0.5 to 5 ha per smallholder household with a large number of sizes less than 1 ha (60%). In Cameroon for example, Ntumu people cultivated around 1.5 ha/household (Dounias, 2000).

Besides, assessments made by Hurault (1965); Grenand (1981); Tsayem-Demaze et al. (2002); Tsayem-Demaze acd Fotsing (2005) and Tsayem-Demaze and Manusset (2008) reported an average size of 0.5 ha of slash-and-burn agriculture surface area varying from one community to another: 0.8 ha for instance in Aluku people of upper Maroni (Surinam, Guyana), 0.3 ha in Kali'na and Palikur people in the region of Mana and Oyapock, 0.5 ha in Wayapi people and 0.4 in Wayana people (Guyana). Their results showed that these averages were continuously increased and tended currently towards 1 ha. Gely, 1984 suggested that this surface area variability highlighted diverse agricultural purposes underpinning land clearing depending on communities, while emphasizing that the minimal indispensable surface area to satisfy daily needs for example in cassava flour was 0.6 ha. The cultivated surface area/number of agricultural worker was 0.40 for Awago, 0.26 for Watu, 0.30 for Karisia, 0.37 for Zoro and 0.19 for Angwande as shown in Figure 3b. This suggests that the average cultivated surface area/number of agricultural worker is around 0.3 ha.

Farm activity allocation

The results of farming task allocation and sharing among members of the household in the study area showed that, men were involved in heavy tasks in high percentage, such as land clearing (96%), tree felling (96%) and tillage (96%) (Figure 4).

Contrariwise, women accomplished slight tasks such as collection of lops and weeding in high percentage (94 and 98% respectively), compared to men and children. The results also showed that harvest and sowing were done by females and males at almost the same level. In general, the average of farming task allocation and sharing among members showed that in the studied

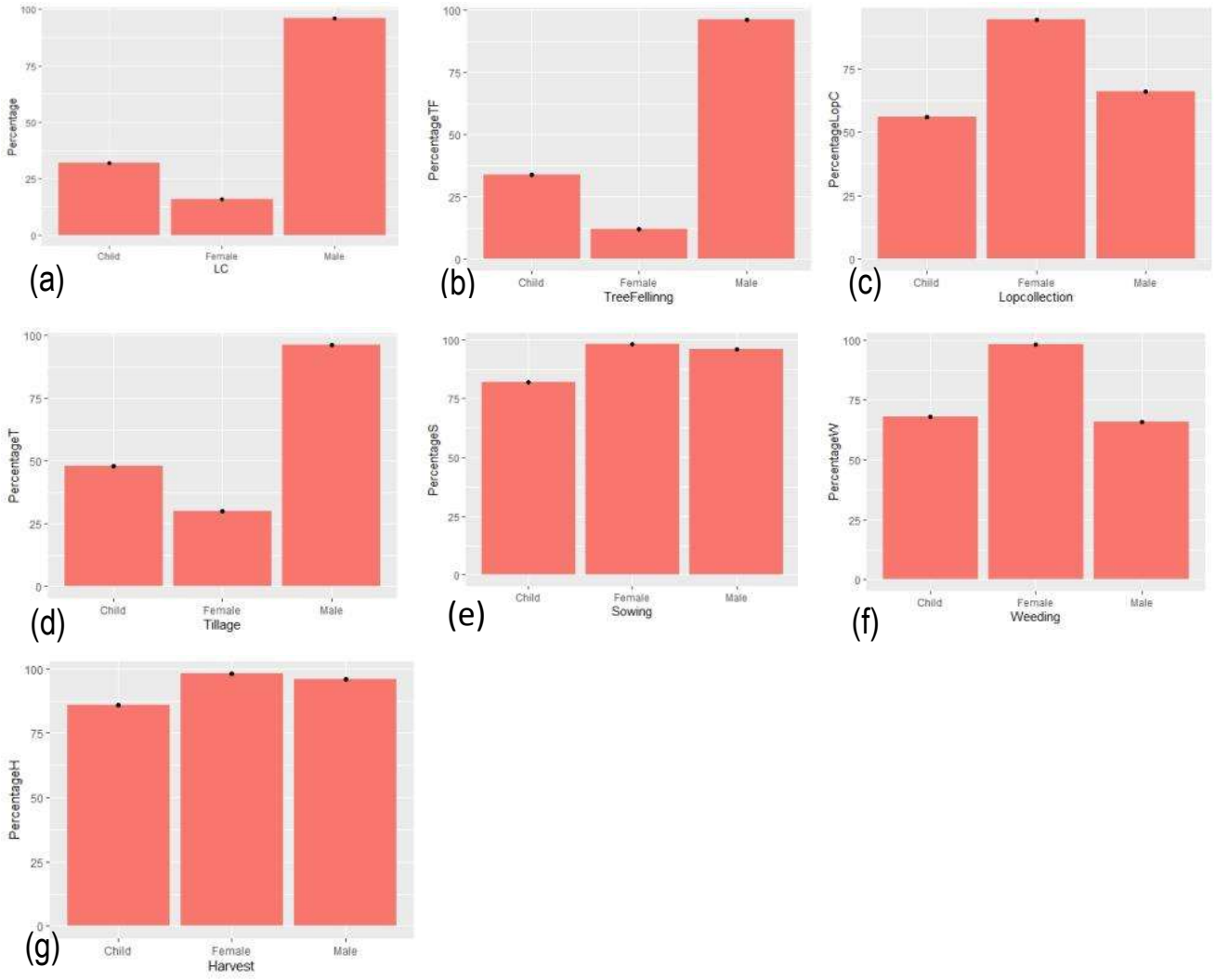

Figure 4. (a) Land clearing or slashing; (b) Tree felling; (c) Lop collection; (d) Tillage; (e) Sowing; (f) Weeding; (g) Harvest.

region, men participated in about 87.48% of the whole farm works, against 63.71% for women and children were involved up to 58% in farm works. These results suggested that there were no strictly speaking gender-based tasks depending on crops, growing periods and work intensity implying that works were almost implemented collectively by the members of households in the region of Faradje. Mushagalusa et al. (2015) reported in contrast that women's participation in farming activities amounted to 48.40% in the southwest of DR Congo, which is quite lower than the rate found in this study area (Figure 5).

In other developing countries women's participation in farming activities ranged from 20% in the Americas, around 35% in south Asia and up to slightly fewer than 50% on average in east and Southeast Asia. In sub Saharan Africa, the average percentage was between 40 and 50% with some exceptions such as Nigeria, Togo, Ethiopia and Niger (with respectively 37, 29 and 24%). Besides, the figures ranged from 67 to 77% in certain regions of Cameroon. However, they varied considerably across the same country, between and within regions and were changing rapidly in many parts of the world, where economic and social forces were transforming the agricultural sector (FAO, 2011; Palacios-Lopez et al., 2015).

Duration of cropland exploitation and fallowing

According to the results of the survey, cropland fallowing was a common practice for the majority of farm operators in the region of Faradje (88% of surveyed households). About 48% of households declared that they set their farms aside for about 3 years against 40% who leave their fields uncultivated for 10 years. 12% of households

Figure 5. (a, b, c, d, e and f): Slash-and-burn agriculture pictures in the region of Faradje.
Source: Authors' survey.

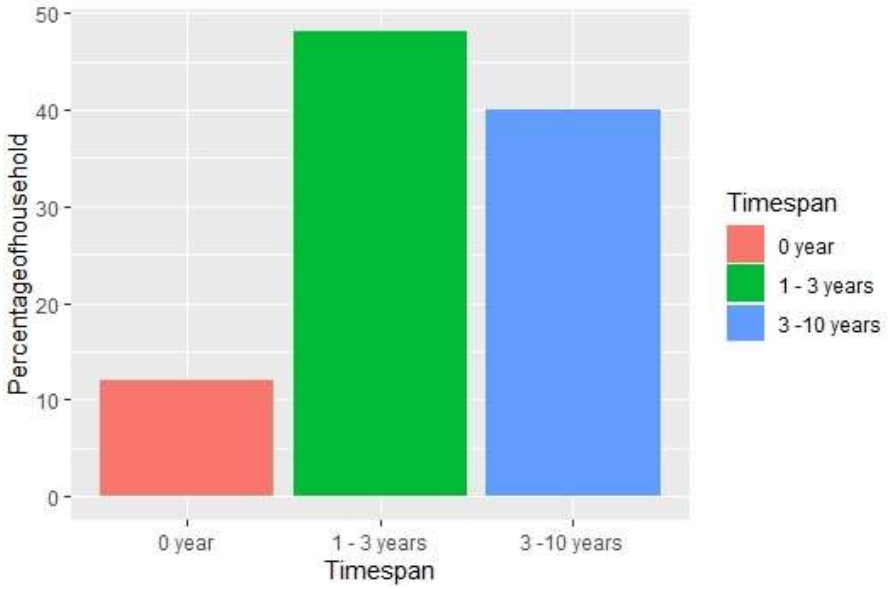

Figure 6. Average timespan of fallowing.

did not resort to fallowing due to land availability issue (Figure 6).

On average, the duration of the continuous running of a given cropland across the surveyed villages approximated almost three years and the average fallowing timespan was shown to be around 3.3 years; despite the low educational level of some farmers in the field of agriculture. This could be explained by the fact that although the technique of crop rotation was not well known by some, several farming households declared that the most common crop succession comprised rice followed by intercropping associating maize with

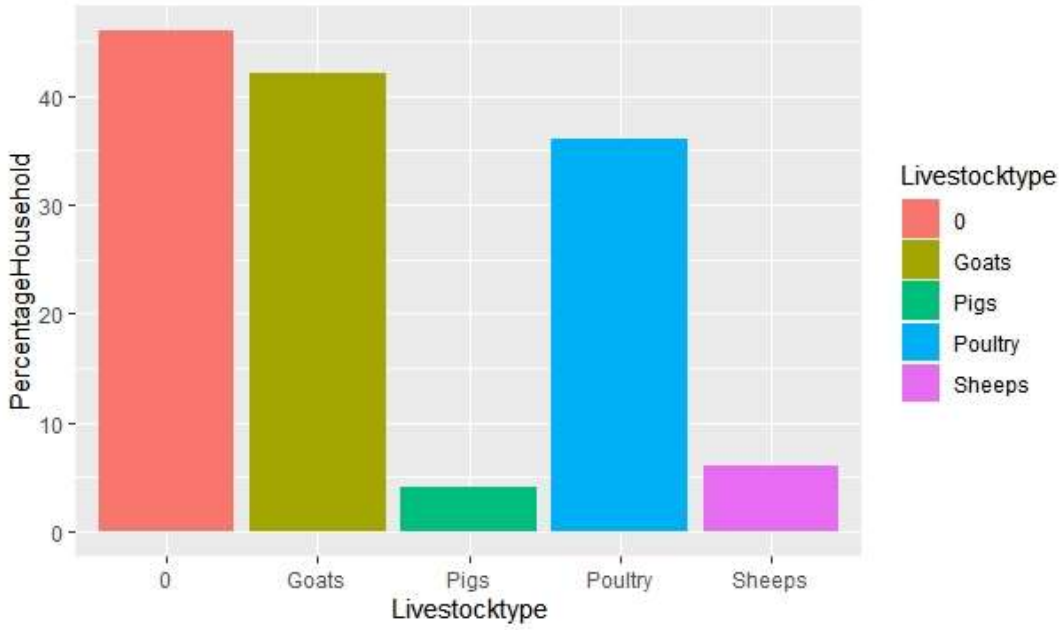

Figure 7. Type of livestock and average number per household.

groundnut or beans and finally cassava. This was quite acceptable from agronomic perspective. It is relevant to notice that, rice, groundnut and beans were sown mainly for the market; whereas, maize and cassava were intended for self-consumption because of their low commercial value. Furthermore, households stated that this fallowing timespan was getting increasingly shorter due to an invasive plant species (*Chromolaena odorata*) which enabled a fast soil fertility recovery. Studies by Hurault (1965); Grandisson (1997); Fleury (2000); Tsayem-Demaze and Manusset (2008) reported that the average timespan of successive land use was about 2 to 3 years (with in-between burn) in Guyana (Central America) and the fallowing period covered from 2 to 5 years which was correspondent to the exploitation of one to two croplands.

Synergism between crop production-livestock

The results showed that the practice of animal rearing in the studied area comprised mainly small livestock namely, goats, pigs, sheeps and poultry (Figure 7). However, this livestock rearing was conducted traditionally, that is small scale (Figure 7) without any zootechnic standards and accordingly was less productive (Kazybayeva et al., 2006). Generally, it was not associated to crop production given that the livestock system was unable to provide enough manure for soil amendment even though animal are usually in kind of stalling.

The results in the Figure 7 indicate that in general, 54% of 50 surveyed households practiced livestock rearing against 46% who did not have livestock. Among 54% of household who had livestock, 42% of surveyed households practiced goat rearing followed by poultry rearing with 36%. Sheep and pigs were reared at 6 and 4% respectively. This figure (46%) of rural households with no livestock was quite higher compared to the prevailing context in other African countries. The range of rural households with livestock varied from 67 to 85% in Senegal (Kazybayeva et al., 2006) and 42.9% on average in South Africa (Lehohla, 2016). The low proportion of farmers keeping animals in the study area indicated that farmers had no livestock keeping culture and remained mainly crop producers (Table 3).

Average distance between households' homes and farms

The results showed that the relative distance separating farmers' residential area from their fields was 1.6 km with a majority of 60% of households (30) who had their farms located between 0 and 1 km. However, 16% had to walk up to 2 to 5 km to find their fields. The neighborhood of fields around the residential areas (around 1 km) could be related to the security issue prevailing in the region (Lord's Resistance Army, from the neighboring Uganda) at the time of the survey that forced the majority of small farm operators to move closer to residential areas. This situation also had an impact on the average fallowing period as well as on the average cultivated surface area which tended to decline (respectively 3.3 years and 0.82

Table 2. Overall average field number/farming household.

Field number	1	2	3	4	5	Overall average	Total Percentage (%)
Number of households	1	14	20	14	1	3	
Percentage against total number of surveyed households (50)	2	28	40	28	2		100

Table 3. Average distance between farms and residences of surveyed households.

Range of distance	0-1 km	1-2 km	2-5 km	Total	Overall estimated average distance
Number of households per range (out of 50)	30	12	8	50	1.6 km
Percentage (%)	60	24	16	100	

ha). On the other hand, the positive impact of this regretful situation was noticed on the general surrounding vegetation which was less and less cleared during the survey period.

Socio-economic aspect of slash-and-burn agriculture system in Faradje

Average gross yield in kg of main crops grown per household and related market values in US$ and total average gross income in US$ per household and per head

The results of Table 4 revealed that one household produced on average 194.96 kg of maize grain, 70.50 kg of groundnut seeds, 793.71 kg of paddy rice, 175 kg of dried cassava chips and 8.62 kg of beans. It is important to remark that the very poor bean production occurring during the investigation time was completely atypical given that the region is traditionally an area producing this commodity. According to the respondents, it was related to unfavorable seasonal conditions (high precipitations) which caused production destruction on field. Besides, the results also showed that the average household income generated by those main crops was US $ 726.62. Paddy rice was the most valuable crop to the households which generated US $ 496.30 against US $ 141.50 for cassava, US $ 42.90 for groundnut, US $ 33.90 for maize and US $ 12.10 for beans. The almost higher value earned from paddy rice was related to the large surface area given to the crop compared to others, because of its market value. Households reported that commonly bean comes after the rice in terms of income generation although its poor production during the specific season is due to seasonal climatic perturbation. The lowest value of the generated income through slash-and-burn agriculture system in this region was US $ 69.47 against US $ 4269.47 which was the highest. However, when adding to this above mentioned average income, those generated through other agricultural commodities such as palm oil (an average of 242.39 Kg of oil that is, 116.40 L / household/year) not shown in table 4 and the income from small livestock rearing, the average annual rises up to US $ 940.60 /household. The total annual average income earned by one household was shown to be US $ 940.60 and the individual average income was US $ 188.90 (Table 4). This figure was slightly higher than the national average real GDP in 2008 (IMF, 2010; WHO, 2010) which was estimated at US $ 171. However, with national average growth rate of around 5% over the period 2009 to 2012 (2.8% in 2009, World Bank), the national average real GDP was projected to reach US $ 188.10 in 2011 against US $ 207.70 in the study area and US $ 256.50 against US $ 283.30 by the end of 2018. It can be seen that slash-and-burn agriculture in Faradje participated consequently in the development of the national real GDP despite its much-maligned ecological impacts. Besides, it is worth noticing that the sector of agriculture contributed up to 40.30% to the national GDP (against 13% for mining industry) and hired the three quarts of active population in 2006 (World Bank, 2010). In contrast, these figures are well below the minimum of US $1 per day (US $ 0.52/day in Faradje in 2011). Hauser and Norgrove (2013) reported that most slash-and-burn farmers are poor. Often the only resource available to them is land. Thus, farming, whether subsistence or market oriented, might be their only option. Therefore, much efforts are required if one needs a fast and durable income growth in the region through diverse supports for example by educating farmers to use conservation agriculture, a more sustainable alternative to slash-and-burn, which could contribute to alleviating food insecurity, and fight poverty while being ecologically sustainable and providing financial supports (Mulimbi et al., 2019).

Correlation analysis of gross income with other parameters

The results of Person's correlation between the number

Table 4. Average gross yield in kg of main crops grown and related market value in US$ and the total average gross income in US$ per household and head.

Village	Maize	Gnut	Rice	Cassava	Beans	Total kg	Gr Total US$
Awago	1487	1104	4963.64	490	88	8132.64	9328.56
Watu	2090	720	8694	560	84	12148	7449.01
Karisia	2219	486	7392	3500	71.80	13668.80	12574.42
Zoro	2736	1044	14064	3920	153	21917	14643.10
Angwande	1216	171	4572	280	34	6273	3033.28
Total	9748	3525	39685.64	8750	430.80	**6470.64**	
Aver./vill.	1949.60	705	7937.13	1750	86.16	12427.89	
Aver./hh	194.96	70.50	793.71	175	8.62	**1242.80**	
Total US$	1694.70	2143.21	24814.10	7073.64	605.23	36330.84	47028.37
Aver./hh $	33.9	42.9	496.30	141.47	12.10	**726.62**	**940.60**
Aver./head	6.81	8.61	99.70	28.41	2.43	**145.32**	**188.90**

Aver. = Average, Gunt = Groundnut, hh= Household, Vill. = Village.

Table 5. Correlation matrix for different factors.

Parameter	FS	HH_size	NAW	S/AW	GTotal_US
FS	-				
HH_size	-0.04	-			
NAW	0.14	0.96*	-		
S/AW	0.98**	-0.25	-0.08	-	
GTotal_US	0.74	0.29	0.35	0.67	-

**, *Significant at P<0.01, 0.05, FS= Field size ha, HH_size= Household size, NAW= Number of agricultural workers per household, S/AW= Surface area/ number of agricultural worker, GTotal_US= gross income.

of agricultural workers per household, the cultivated surface area in ha, size of surveyed farming households, field surface area/agricultural worker and gross income showed that there was significant (P≤0.0104) correlation between the number of agricultural workers per household and the size of farming households. This implies that the increase in the number of agricultural workers per household would inevitably lead to the increased size of farming (Table 5). The cultivated surface area in ha was also significantly (P≤0.0038) correlated to the field surface area/number of agricultural worker indicating linear relationship among them. A very low negative correlation (r= - 0.04) was also found between cultivated surface area and the size of households. This means that the increase in size of households negatively impacts the total cultivated surface area while it could be thought that a bigger size of household is supposed to hold a proportional cultivated area.

This may be related to the financial situation within those smallholder households (average income per head to be invested in agricultural activities) and may eventually impact the living standard of the households in question. In contrast, the average number of agricultural workers had also a very low positive correlation with field expanse (r= 0.14). This means the number of familial laborer is not the only factor in that area susceptible to expand the cultivated surface area. Several parameters such as the quality of work tools (always rudimentary) and other sources of labor force are necessary in order to extend the cultivated area to meet satisfactory threshold of households' needs.

Household size and the number of agricultural workers/households were weakly correlated to the average gross income (respectively, r = 0.29 and r = 0.35) whereas cropland surface area was moderately positively associated with the average gross income (r = 0.74). This demonstrates the importance of cropland surface in this slash-and-burn cropping system in the region. This suggests that the increase in cropland size would inevitably lead to increased farmers' gross average income, confirming the expanding characteristic of the cropping system. However, much should be done, to mitigate associated ecological adverse effects of the cropping system.

Conclusion

The present study aims to explore smallholders' households' living standard relevant to slash-and-burn

agriculture, and determine key crops grown trend with respect to their production (yield) and related generated average gross income in the region of Faradje, far northeast of the D R of Congo. After analysis, results showed that the total annual average income earned by one household was US $ 940.57 with individual average income of US $ 188.87. This was slightly higher than the national average real GDP in 2008 estimated at US $171; however, the figure was still unfortunately far below the minimum of US $ 1 per day. Consequently, this confirmed the whole hypotheses set for this study. This suggests that slash-and-burn agriculture cropping system is a limitation to food security and accordingly improvement of economic situation in this study region. Thus, in view of the above results found, it could be recommended that, policymakers and developers involved in human promotion by the means of agricultural activities need to explore other cropping systems, such as integrated cropping system, in order to achieve the sustainable development goal in this remotest rural region of the DR of the Congo. It is also recommended that policy makers and developers emphasize on providing institutional support to the farmers in the form of financial help.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Andriesse JP, Schelhaas RM (1987). A monitoring study of nutrient cycles in soils used for shifting cultivation under various climatic conditions in tropical Asia. II. Nutrient stores in biomass and soil-results of baseline studies. Agriculture, Ecosystems & Environment 19:285-310. https://doi.org/10.1016/0167-8809(87)90058-2

Angongolo K, Kalambaie B, Ngoy IN (2005). Etude de la vulnérabilité de la population de Kisangani face à la sécurité alimentaire. Kisangani, CRIDE-UNIKIS, RDC 3(1)107-117.

Cellule d'Analyse des Indicateurs de Developpement (CAID) (2016). Rapport annuel de l'Administration du Territoire de Faradje. Résidence FikHuss, 65, Boulevard Tshatshi, Kinshasa / Gombe, DR Congo.

Cheryl AP, Stephen AV, Pedro AS, Polly JE (2005). Slash-and-Burn Agriculture the search for alternative. Columbia University Press, New York Chichester, United States of America, pp. 1-488.

Dounias E (2000). La diversité des agricultures itinérante sur brûlis. In Bahuchets S., (Cord), les peuples des forêts aujourd'hui. APFT-ULB 2:65-106.

Food and Agriculture Organization (FAO) (2011). The role of women in agriculture. ESA Working Paper 11-02, Rome, Italy.

Food and Agriculture Organization (FAO) (2012). State of the World's Forests. Rome,Italy. copyright@fao.org

Fleury M (2000). L'agriculture wayana : une transition viable. In : Grenand P., (dir). Les Peuples des Forêts Tropicales Aujourd'hui, vol. IV, Région Caraïbes. Brussels*:* APFT-ULB.

Gafsi M, Dugué P, Jamin J-Y, Brossier J (2007). Exploitations agricoles familiales en Afrique de l'Ouest et du Centre. Enjeux, caractéristiques et éléments de gestion. CTA, Éditions Quæ, RD 10, 78026 Versailles Cedex, France.

Gely A (1984). L'agriculture sur brûlis chez quelques communautés d'Amérindiens et de Noirs Réfugiés de Guyane française. Journal D'agriculture Traditionnelle et de Botanique Appliquée*,* Paris (1-2):43-71. DOI:10.3406/jatba.1984.3912

Grandisson M (1997). Gestion des systèmes d'agriculture itinérante sur brûlis dans l'ouest Guyane : contribution à l'étude de la reproductibilité de la fertilité. Thèse, Université des Antilles et de la Guyane.

Grenand P (1981). Agriculture sur brûlis et changements culturels : le cas des Indiens Wayapi et Palikur de Guyane. Journal D'agriculture Traditionnelle et de Botanique Appliquée 28(1):23-31.

Hauser S, Norgrove L (2013). Slash-and-Burn Agriculture, Effects of. CABI, Encyclopedia of Biodiversity 6:551-562. http://dx.doi.org/10.1016/B978-0-12-384719-5.00125-8

Hurault J (1965). La vie matérielle des noirs réfugiés Boni et des Indiens Wayana du Haut-Maroni (Guyane française): Agriculture, Économie Et Habitat.

Ibanda AP, Karungi J, Malinga GM, Tanzito GA, Ocan D, Badji A, Mwila N, Odong TL, Tukamuhabwa P, Rubaihayo PR (2018). Influence of environment on soybean [Glycine max (L .) Merr .] resistance to groundnut leaf miner, *Aproaerema modicella* (Deventer) in Uganda. Journal of Plant Breeding and Crop Science 10(12): 336–346. https://doi.org/10.5897/JPBCS2018.0764

ICRAF (2002). Alternatives to slash-and-burn. ASB Programme, ICRAF, P. O. Box 30677, Nairobi, Kenya.

International Monetary Fund (IMF) (2010). Democratic Republic of the Congo: Staff Report for the 2009 Article IV Consultation, Request for a Three-Year Arrangement Under the Poverty Reduction and Growth Facility, and Request for Additional Interim Assistance Under the Enhanced Initiative for Heavily Indebted Poor Countries. MF Country Report No. 10/88, Washington, pp. 1-121.

Kamara AB, Anyanwu JC, Aly HY, Rajhi T, Vencatachellum D (2010). Analyse de la pauvreté en République démocratique du Congo. In Salami A., Moummi A., (Eds), Banque Africaine de Développemt, N^0 112, Angle des l'avenue du Ghana et des rues Pierre de Coubertin et Hédi Nouira, BP 323 -1002 TUNIS Belvédère, Tunisia.

Kankwanda G, Makabu MT, Nilsson B, Roubaud F, Torelli C, Wachsberger JM (2014). Le marché du travail en République Démocratique du Congo en 2012 : Principaux résultats de la Phase 1 de l'Enquête 1-2-3. Document de travail IRD, Paris, France.

Kazybayeva S, Otte J, Roland-Holst D (2006). Livestock Production and Household Income Patterns in Rural Senegal. Pro-Poor Livestock Policy Initiative, RR Nr. 06-13

Kibwika P (2015). Qualitative research method. PhD class course, College of Agricultural and Environmental Sciences (CAES), PARI 4, Makerere University, Kampala, Uganda.

Kyazze F (2016). Research design. PhD course in Agricultural and Rural Innovation, Department of Extension and Innovation Studies, College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.

Landa BRZ, Nyongombe U, Monzambe M (2013). Evaluation de la gestion des plantes fourragères résistantes pendant la saison sèche en zone de savane par les communautés locales (cas du basin de l'Uele). Congo Sciences 1(1):14-22.

Lehohla PJ (2016). Community survey 2016 agricultural households. Statistics South Africa, Report No. 03-01-05, Pretoria, South Africa.

Lisingo WL(2009). Typologie des forêts denses des environs de Kisangani en RDC par une méthode d'analyse phytosociologique multistrate. Diplôme d'études approfondies (DEA) en gestion de la biodiversité et aménagement forestier durable. Memoire Online https://www.memoireonline.com/12/12/6641/m_Typologie-des-forts-denses-des-environs-de-Kisangani-en-RDC-par-une-methode-danalyse-phytosoci0.html Accessed on 6th / 2/ 2020

Lowder SK, Bertini R, Karfakis P, Croppenstedt A (2016). Transformation in the size and distribution of farmland operated by household and other farms in select countries of sub-Saharan Africa. 5th International Conference of the African Association of Agricultural Economists, September 23-26, Addis Ababa, Ethiopia.

Maps of world.com (2009). Zaire Latitude and Longitude. http://www.mapsofworld.com/lat_long/zaire-lat-long.html

Makondambuta E (1997). Les types de climat. *Congonline.* Afriqu'Info asbl, Bruxelles, Belgique.

Mulimbi W, Nalley L, Dixon B, Snell H, Huang Q (2019). Factors influencing adoption of conservation agriculture in the Democratic Republic of the Congo. Journal of Agricultural and Applied Economics, pp. 1-24.

Mushagalusa BA, Baraka SP, Lenga NA, Madi MD, Ilunga KF, Nkulu MFJ (2015). Gender and family farms in rural area in Katanga, DR Congo: case study of Kipushi. International Journal of Innovation and Applied Studies 11(2):367-375.

Nassiuma DK (2000). Survey Sampling; Theory and Methods. Nairobi: Nairobi University Press.

Palacios-Lopez A, Christiaense L, Kilic T (2015). How much of the labor in African agriculture is provided by women? World Bank, JEL Codes: J16, J22, O13, Q12

Pollini J (2014). Slash-and-burn agriculture. Synonyms: shifting cultivation, swidden cultivation. In: Thompson P. B. and Kaplan D. M., (Eds). Encyclopedia of Food and Agricultural Ethics - Springer Reference, Illinois, USA

Roper J, Roberts RW (1999). Deforestation: tropical forests in decline. Hull, CIDA, CFAN, Quebec, Canada.

Stefan H, Norgrove L (2013). Slash-and-Burn Agriculture, Effects of. In: Levin S.A. (ed.). Encyclopedia of Biodiversity, second edition 6:551-562. DOI:10.1016/B978-0-12-384719-5.00125-8

Shukla S (2007). Interconnections among community-based conservation, local knowledge and environmental education: Case studies from India. PhD thesis dissertation, Natural Resources Institute, University of Manitoba, Winnipeg, Canada.

Talaguma NR (2013). L'Agriculture itinerante sur bruli comme pratique agricole majeur: Conséquences ecologique et socio-economiques dans la région de faradje en RD Congo. Monographie, 3e graduat, IFA-Yangambi, Kisangani, DR Congo.

Tanzito G (2009). Contribution à l'essai de domestication et de l'intégration de Gnetum africanum Welw. Dans les systèmes agricoles des paysans de la région de Kisangani en RDC. Mémoire de DES, GRAVMT, Fusagx, Gembloux. 60p.

Trefon T (2008). La réforme du secteur forestier en Republique Democratique du Congo: defies sociaux et faiblesses institutionelles. Afrique Contemporaine (227):81-93. http://doi.org/10.3917/afco.227.0081

Tsayem-Demaze M, Fotsing JM, Huynh F (2002). La déforestation dans la région de Saint-Georges de l'Oyapock (Guyane française). Les Cahiers d'Outre-Mer (218):197-222.

Tsayem-Demaze M, Fotsing JM (2005). Évaluation quantitative des défrichements agricoles en forêt amazonienne de Guyane française et du Brésil. In : Taabni M. and Dupuy F., (Eds). La forêt : enjeux comparés des formes d'appropriation, de gestion et d'exploitation dans les politiques environnementales et le contexte, d'urbanisation généralisée, Poitiers: Université de Poitiers-MSHS.

Tsayem-Demaze M, Manusset S (2008). L'agriculture itinérante sur brûlis en Guyane française : la fin des durabilités écologique et socioculturelle ?, *Les Cahiers d'Outre-Mer*. DOI:10.4000/com.3173

United Nations Department of Economic and Social Affairs (UNDESA) (2017). Household size and composition around the world. POPFACTS, N02, NY, USA.

World Health Organisation (WHO) (2010). The global financial crisis: implications for the health sector in the African region. Regional committee for Africa, report of the regional director, sixtieth, afr/rc60/12, Malabo, Equatorial Guinea 1-9. https://apps.who.int/iris/handle/10665/1678

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Spatial price transmission between white maize grain markets in Mozambique and Malawi

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The objective of this study was to measure white maize grain price transmission among markets in Mozambique and Malawi. Our analysis included two major deficit markets (Maputo in Southern Mozambique and Blantyre in Southern Malawi) and two major surplus markets (Chimoio in Central Mozambique and Nampula in Northern Mozambique). We used monthly wholesale white maize grain prices covering the period 2000 through 2016 to test for and quantify the magnitude of short- and long-run price transmission. To do so, we employed a combination of methodological approaches: Johansen cointegration test, Granger causality test and error correction model (ECM). Our findings revealed that Chimoio market has joint long-run relationship with Maputo, Nampula and Blantyre markets. All three Mozambique market pairs (Maputo and Chimoio; Maputo and Nampula; and Chimoio and Nampula) exhibited bidirectional causality in the long run. However, price changes in Maputo, Chimoio and Nampula are transmitted to Blantyre, but not the reverse. In the short run, only two Mozambique market pairs (Maputo and Chimoio, and Chimoio and Nampula) show bidirectional causality. Blantyre appeared to not exhibit short-run causality with Maputo, Chimoio nor Nampula.

Key words: Market integration, white maize grain, causality, price transmission

INTRODUCTION

Maize is among the most important commodities in terms of production and consumption in both Malawi and Mozambique. Data from the nationally representative Integrated Household Survey (IHS), administrated by the Malawi National Statistics Office (NSO) in 2016, administrated by the Malawi National Statistics Office (NSO), show that 70.8% of the 3.8 million households grew maize in the 2015/2016 agricultural season in Malawi. Similarly, data from the nationally representative Integrated Agricultural Survey (IAI), conducted by Mozambique Ministry of Agriculture and Food Security (MASA) in 2015, conducted by the Mozambique Ministry of Agriculture and Food Security (MASA), indicate that 67.2% of the about 4.0 million households grew the crop in the 2014/2015 agricultural season in Mozambique. These two nationally representative surveys also reveal that the shares of the total cultivated area accounted for by maize in each country averaged 56.2% in Malawi and

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33.2% in Mozambique. On the other hand, sizeable proportions of households consume maize in both countries: 98.2% in Malawi computed from data from IHS in 2016 and 74.0% in Mozambique computed from the nationally representative National Budget Survey (IOF) administrated by Mozambique National Institute of Statistics (INE) in 2015. During the period between 2003 and 2013, data from FAOSTAT indicate that maize contributes on average to 50.7% of the total daily caloric intake in Malawi and to 21.7% in Mozambique. This makes maize rank undoubtedly first in Malawi and second only to cassava (with 29.3%) in Mozambique in terms of contribution to total daily caloric intake. FAOSTAT data also reveal that maize consumption per capita is higher in Malawi than in Mozambique (132 versus 56 Kg per capita).

Malawi is on aggregate a maize grain surplus country, whereas Mozambique is on aggregate a white maize grain deficit country. Between 2005 and 2015, data from United State Department of Agriculture (USDA), Foreign Agriculture Service (FAS) indicate that white maize grain production is greater than maize consumption on average by about 170 thousand metric tons (MT) in Malawi, while maize production is smaller than maize consumption on average by about 100 thousand MT in Mozambique. However, whether white maize grain production outweighs maize consumption varies across regions within both Malawi and Mozambique. According to Cirera and Arndt (2008) and Myers (2013), Southern Malawi and Southern Mozambique are white maize grain deficit regions; whereas Central Malawi and Northern and Central Mozambique are white maize grain surplus regions. Moreover, Northern Malawi is a white maize grain surplus region in some years and deficit in others depending on weather patterns. These authors also document that white maize grain surpluses generated in Northern and Central Mozambique flow to Southern Mozambique and Southern Malawi.

White maize grain supply flows from Mozambique to Malawi and vice-versa, although Mozambique is a net exporter of white maize grain to Malawi. This bidirectional flow of white maize grain between Mozambique and Malawi depends to a large extent on seasonality and the relatively small difference between white maize grain production and consumption within each country. Between 2010 and 2015, data from Famine Early Warming Systems Network (FEWS NET) reveal that Mozambique exported a total of 125,000 MT of white maize grain to Malawi through informal channels; while Malawi exported a total of 97.7 thousand MT of white maize grain to Mozambique; suggesting that Mozambique is a net export of white maize grain to Malawi. During the same period, informal white maize grain export from Mozambique to Malawi outweighed that from Malawi to Mozambique in 5 out of 6 years, with an annual average of 15.9 thousand MT. Furthermore, data from FEWS NET show that Malawi accounted for 82.6% of the total white maize grain exported from Mozambique between 2010 and 2015; making Malawi rank first, followed by Zambia and Zimbabwe with shares of 16.2 and 1.2%, respectively, of Mozambique white maize grain exports. This suggests that markets in Malawi are more important in contributing to price determination in Mozambique than those in Zambia and Zimbabwe.

Two major existing studies have investigated price transmission among white maize grain markets in Mozambique. First, Tostao and Brorsen (2005) measured spatial arbitrage efficiency in white maize grain markets in Mozambique. Their findings showed that price spreads between white maize grain markets in Northern and Southern Mozambique generally fell below transport costs during the period between July 1994 and Abril 2001; suggesting that it was not profitable to ship white maize grain from surplus markets in Northern Mozambique to deficit markets in Southern Mozambique. This finding was mainly associated with poor roads connecting Northern to Southern Mozambique coupled with the lack of a bridge over the Zambezi River and traders' limited access to capital. Prior to August 2009, there was no bridge over the Zambezi River; which created a natural barrier to trade – especially for low-value commodities like white maize grain – by physically isolating markets in Northern Mozambique from those in Central and Southern Mozambique. A modern bridge was built over the Zambezi River in August 2009, facilitating trade between Northern and Southern regions.[1]

Second, Cirera and Arndt (2008) assessed the impact of road rehabilitation on spatial maize market efficiency in Mozambique between February 1992 and June 2005 and found that road rehabilitation increased spatial market efficiency but not as robust as one would expect due to substantial fuel prices increases after the road-rehabilitation period. The lack of a bridge over the Zambezi River could also explain this not robust impact of road rehabilitation especially between maize markets in Northern and Southern Mozambique.

Both of the above-mentioned studies assessed maize market efficiency prior to the construction of the bridge over the Zambezi River. We are not aware of a study that investigated white maize grain market efficiency in Mozambique after the construction of the bridge by also measuring whether the bridge contributed to white maize grain market efficiency. This study aims at filling this knowledge gap. Furthermore, unlike the studies by Tostao and Brorsen (2005); and Cirera and Arndt (2008), this study also attempts to take into account spatial market efficiency between white maize grain markets in Mozambique and those in Southern Malawi. The main

[1] The bridge was named after Armando Emilio Guebuza who was Mozambique's president between 2005 and 2015 and inaugurated the bridge.

Table 1. Maize production and sales in the 2014/2015 agricultural season.

Item	Region			Total
	Northern	Central	Southern	
% maize growers	73.3	83.6	45.9	67.2
Maize production (thousand MT)	441.2	445.0	114.4	1,000.6
Share of production (%)	44.1	44.5	11.4	100.0
Sales (thousand MT)	83.6	53.3	2.9	139.7
Share of sales (%)	59.8	38.1	2.1	100.0
Share of production sold (%)	18.9	12.0	2.5	14.0

Source: Authors' calculation using data from IAI 2015

objective of this study was to measure white maize grain price transmission among markets in Mozambique and Malawi.

MAIZE PRODUCTION AND MARKETING IN MOZAMBIQUE

Maize is among the main staple and cash crop in Mozambique. The crop is grown during the rainy season spanning October through March, harvested between March and July, and commercialized between July and September. White maize grain production and sales are concentrated in Central and Northern Mozambique where farmers cultivating small plots dominate. Farmers cultivating less than 1.5 ha accounted for 93.5% of the total number of maize growers in the 2014/2015 agricultural season. Table 1 summarizes maize production and sales in the 2014/2015 agricultural season. This table shows that maize is grown by 67.2% of smallholder farmers in Mozambique. Central Mozambique with 83.6% and Northern Mozambique with 73.3% are undoubtedly the regions with the largest shares of maize grower; followed by Southern Mozambique with 45.9%. This is to a large extent because Central and Northern Mozambique are endowed with way more favorable biophysical conditions for growing maize compared to Southern Mozambique. Table 1 also illustrates that Central (44.5%) and Northern (44.1%) regions accounted together for 88.6% of the total white maize grain production in the 2014/2015 agricultural season. Northern Mozambique, accounting for 59.8%, ranks undoubtedly first in terms contribution to the total white maize grain sales in the 2014/2015 agricultural season; followed by Central Mozambique with share of 38.1% and Southern Mozambique with a share of only 2.5%.

Table 1 reveals that a small share of total white maize grain production is sold (less than 15%), but the share varies across regions; ranging from 18.9% in the Northern region to 12.0% in the Central region to only 2.5% in the Southern region. The proportion of maize growers who sold their production follows a pattern similar to that of share of white maize grain production sold, including the magnitude. These findings suggest that a considerable share of white maize grain production goes to own consumption. Moreover, data from IAI (2015) show among maize growers, 16.6% of smallholder farmers sold their maize production in the 2014/2015 agricultural season; Northern Mozambique with 21.1% stands out as the region with the largest share of smallholder farmers who sold their maize production, followed by Central Mozambique with 17.7% and Southern Mozambique with 3.1%.

In addition to shipments to Southern Mozambique, white maize grain surplus generated in Northern and Central Mozambique is traded across the border especially to Southern Malawi. Figure 1 shows monthly average white maize grain export to and import from Mozambique over the period 2010 through 2015. This figure illustrates that white maize grain export to Malawi outweighs white maize grain imports from Malawi between March and July; while the opposite is true between November and February. This is consistent with seasonal pattern of white maize grain production in Mozambique: The harvesting season for white maize grain runs from March to July, while the lean season runs from November to February. Seasonal white maize grain index is also consistent with both this finding and harvest pattern as Seasonal white maize grain price index is below annual average white maize grain price between March and September (reaching seasonal lowest) and above it between November and February (reaching seasonal peak).

South Africa is another important channel through which white maize grain is sourced to meet deficit Southern Mozambique's requirements. Between 2010 and 2015, Mozambique imported 454.5 thousand MT of white maize grain from South Africa; making Mozambique the fourth most important destination of the South African

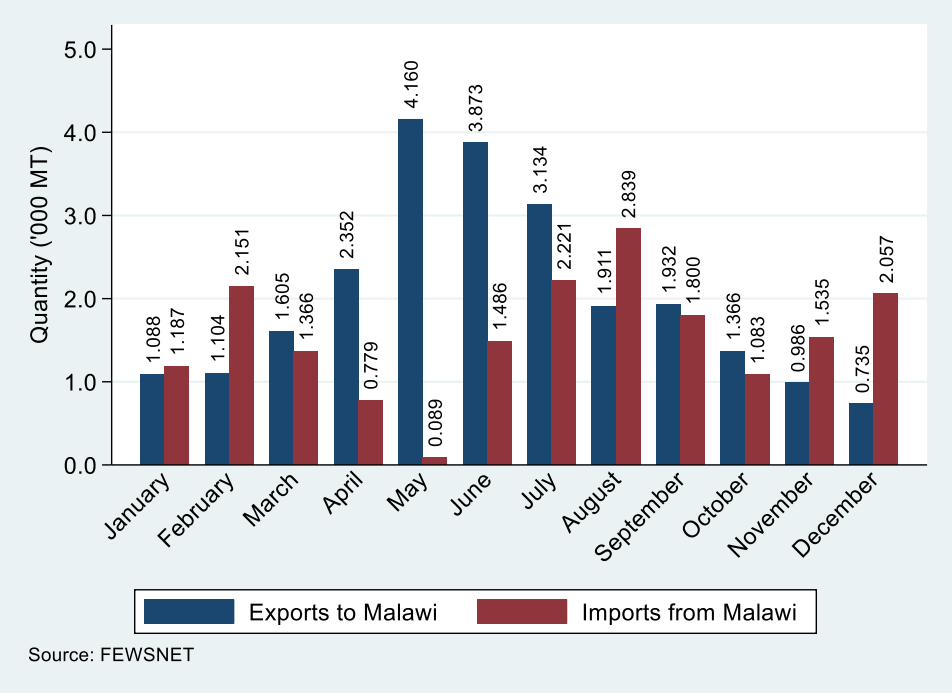

Figure 1. White maize grain export from and import to Mozambique from 2010 to 2015.

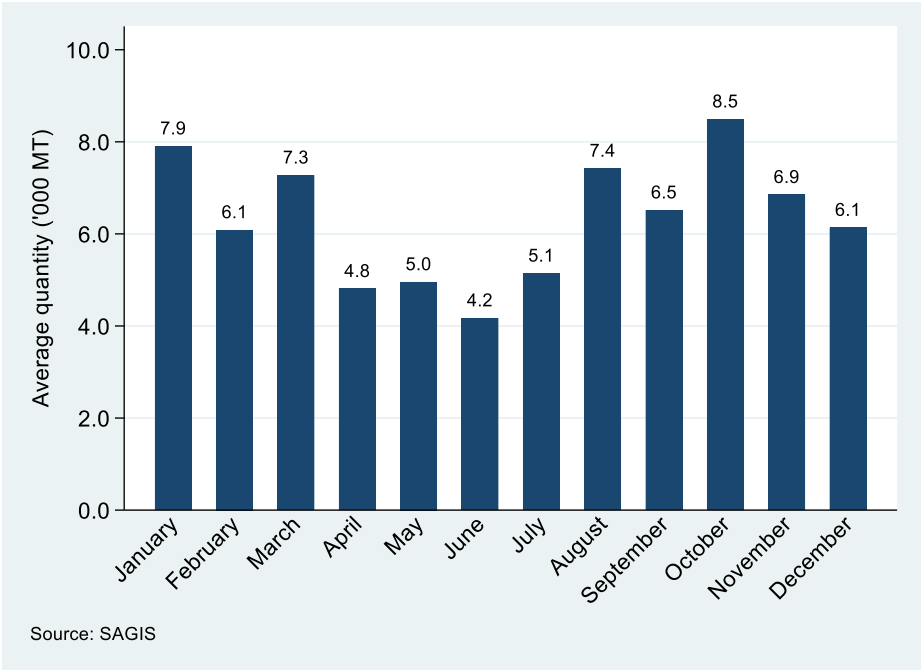

Figure 2. White maize grain imported from South Africa between 2010 and 2015.

white maize grain export to the African continent in terms of the total volume imported; following Botswana with 958.5 thousand MT, Lesotho with 629.2 thousand MT, and Namibia with 528.3 thousand MT. Figure 2 summarizes monthly average white maize grain import from South Africa during the period 2010 through 2015.

This figure shows that average quantity of white maize grain imported from South Africa is lowest between April and July and largest between October and March; consistent with seasonal pattern of white maize grain production in Mozambique. Anecdotal evidence reveals that the sizable share of white maize grain imported from South Africa is taken up by large-scale maize meal processors in Maputo; while white maize grain sourced from Central and Northern Mozambique is purchased by consumers who hand pound it or take it to small-scale hammer millers. This suggests that South African white maize grain goes through different market channels compared with white maize grain coming from Central and Northern Mozambique.

In addition to availability of white maize grain, road conditions connecting white maize grain markets affects the flow of white maize grain from surplus to deficit markets. This is because transport costs are among the key impediments to smallholder farmers' input and output market participation. Data from National Road Administration (ANE) illustrate that Mozambique had 30.5 thousand kilometers of classified roads in 2017; of which 74.2% were classified as unpaved and the remaining as paved. Northern Mozambique with 38.1% and Central Mozambique with 36.3% are the regions accounting for the largest share of the total extension of unpaved roads in the country. Data from ANE show that of the 30.7 thousand kilometers of the total classified road in 2013, 48.2% are classified as being in bad conditions.[2] As in the case of unpaved roads, the largest share of the total extension of roads in bad conditions are accounted for by Central Mozambique (39.9%) and Northern Mozambique (35.9%). This sizable share of poor road infrastructure especially in Central and Northern regions – which are maize surplus regions – limits maize trade between surplus and deficit regions, as also highlighted by Tostao and Brorsen (2005), and Cirera and Arndt (2008).

Maritime transport could be an alternative to road transport given that Mozambique is endowed with about 2.4 thousand kilometers of coastline linking Southern to Central to Northern Mozambique and with three largest ports (one in each region).[3] However, extremely low vessel availability and frequency lead to prohibitively high ocean transport costs (vessel rental price). This coupled with low volumes of white maize grain trade make maritime transport inefficient and out of reach for small-scale maize traders who are the majority. Railway transport could be another alternative to move white maize grain from surplus to deficit markets. Mozambique has three main railway systems namely Maputo railway corridor connecting Maputo port to Swaziland and South Africa, Beira railway corridor connecting Beira with Malawi and Zimbabwe, and Nacala corridor connecting Nacala port to Malawi. No railway connects Southern to Central to Northern Mozambique regardless of existing small railway networks scattered through the country. This makes railway transport very inefficient for white maize grain traders except those trading white maize grain between South Africa and Mozambique in the Southern region and those trading between Mozambique and Malawi in certain parts of the Central and Northern Mozambique.

METHODOLOGICAL APPROACH

Conceptual framework

Prices, trade volumes or both are used to describe spatial market relationships between spatially separated markets; however, neither on its own can inform us whether actual trading behavior are efficient. Spatial market integration means transfer of Walrasian excess demand between geographically distinct markets manifested in three ways: physical flow of commodity between markets or transmission of price signals or both. Price transmission – one of forms in which market integration is manifested – occurs when a price change in one market leads to a price change in another market (Barrett and Li, 2002; Kabbiri et al., 2016). This suggests that price signals are not transmitted from a deficit market to a surplus market when the two markets are not spatially integrated.

Market integration could also be vertical rather than spatial. Vertical market integration occurs when price signals are transmitted between distinct marketing channels for a given commodity. We consider price transmission for white maize grain across spatially separated markets. Let p_t^i denote white maize grain price in market i at time t, r_t^{ij} represent transaction costs – such as transport cost, negotiation, etc. – of spatial arbitrage associated with the physical movement of white maize grain between markets i and j at time t, and q_t^{ij} denote white maize grain trade flow from market i to market j at time t. Following Barrett (2001), and Negassa and Myers (2007), competitive spatial equilibrium can be specified as follows:

$$p_t^i - p_t^j \begin{cases} \leq r_t^{ji} & \text{if } q_t^{ji} = 0 \\ = r_t^{ji} & \text{if } q_t^{ji} \in \left[0, q_t^{ji*}\right] \\ \geq r_t^{ji} & \text{if } q_t^{ji} = q_t^{ji*} \end{cases} \quad (1)$$

Equation (1) suggests that we could have three possible equilibrium regimes. The first regime occurs when the price differential between two spatially separated markets is smaller or equal to the transaction costs associated with the movement of white maize grain between

[2] ANE categorizes classified roads into four groups in terms of road conditions: Good, fair, bad and very bad. We grouped roads in very bad and bad conditions, according to ANE classification, into one category referred to as "bad condition". For classification in terms of road conditions, we used data for 2013 because this is latest year for which ANE classification is available.

[3] The main ports in Mozambique include Maputo in Southern Mozambique with a cargo capacity of 2.5 million MT per year, Beira in Central Mozambique with a cargo capacity of 2.3 million MT per year and Nacala in Northern Mozambique with a cargo capacity of 2.4 million MT per year. These three main ports account for about 95% of the total tonnage of commodities handled in all ports.

the two markets (the first weak inequality in Equation 1 above), implying that no white maize grain trade between the two markets occurs because no profitable arbitrage opportunities exist between the two markets. However, if trade between the two markets occurs under this regime, then traders make losses. In the second regime the price spread between the two geographically distinct markets is equal to the transaction costs (the strict equality in Equation (1) above), implying that the volume of white maize grain trade between the two markets will lie between zero and some trade flow ceiling $\left(q_t^{ji*}\right)$ if the ceiling exists. Under the second regime, the two markets are said to be in a competitive spatial equilibrium assumed under the law of one price (LOP).

This equilibrium condition suggests that competitive spatial equilibrium could occur with or without physical transfer of white maize grain between the two geographically separated markets because when transaction costs between two markets are fully exhausted, traders are indifferent between trading and not trading. If two markets are in the competitive spatial equilibrium, perfect price transmission occurs when a price change in one market stemming from local supply or demand shocks results in an identical price change in the other market.

The third regime occurs when the price spread between two spatially distinct markets is greater than or equal to the transaction costs (the last weak inequality in Equation (1) above), implying that the white maize grain trade between the two markets will be equal to some trade flow ceiling. Under this regime, the markets are not efficient regardless of whether white maize grain trade between the two markets occurs. Conditions that could lead to this regime include restrictions on the volume that could be traded between two geographically separated markets, government price support, licensing requirements, among others.

Empirical strategy

Our empirical strategy could be grouped into three categories. First, we perform unit root tests to assess whether white maize grain price series for each market is stationary as a crucial initial step for the following steps. This is because we should use stationary white maize grain price series in the following steps to avoid spurious regression. Second, we tested cointegration and direction of causality to assess whether current and lagged white maize grain prices for a given market help to predict future white maize grain price for another market. Third, we measured degree of market integration and price transmission between white maize grain markets.

Unit root test

Following Gujarati (2003), the augmented Dickey-Fuller (ADF) unit root test is specified as follows:

$$\Delta p_t^i = \beta_1 + \beta_2 T + \delta p_{t-1}^i + \sum_{s=1}^{m} \alpha_s \Delta p_{t-s}^i + \varepsilon_t^i \quad (2)$$

where p_t^i denotes white maize grain price in market i at time t; p_{t-1}^i represents lagged white maize grain price in market i; Δp_{t-s}^i is the price difference where $\Delta p_t^i = p_t^i - p_{t-1}^i$, $\Delta p_{t-1}^i = p_{t-1}^i - p_{t-2}^i$ and so on; T denotes time trend; ε_t^i is the independently and identically distributed error term; and β_1, β_2, δ and α_s are unknown parameters to be estimated. A white maize grain price series for market is nonstationary (or has a unit root) if $\delta = 0$; if we reject this null hypothesis (against the alternative hypothesis that δ is less than zero) then the white maize grain price series is stationary. If a white maize grain price series is nonstationary, we differentiate it until it becomes stationary based on the ADF test. The number of times (d) a white maize grain price series has to be differenced to become stationary gives the order of integration of the price series denoted as $I(d)$. As a robustness check, we also tested for stationarity using Phillips-Perron (PP) unit root test. Unlike the parametric ADF test that adds lagged difference terms to deal with serial autocorrelation in the error term, PP test is a nonparametric approach that takes care of serial autocorrelation without adding lagged difference terms.

Cointegration test

For spatially separated markets with white maize grain price series that are integrated of the same order using the appropriate unit root test, we investigated whether those price series are cointegrated, implying that they exhibit a long-run relationship and interdependence. Absence of cointegration among geographically separated markets suggests that those markets are segmented. Two price series that are integrated of the same order are said to be cointegrated if their linear combination is stationary. Consider the following long-run relationship between white maize grain prices in two geographically separated markets i and j:

$$p_t^i = \gamma_0 + \gamma_1 p_t^j + \nu_t \quad (3)$$

where p_t^i denotes white maize grain price in market i at time t; parameter γ_0 captures the price differential between the two markets (such as transportation cost, quality differences, processing costs, sales tax, etc.); γ_1 denotes the cointegrating parameter, and ν_t is the random error term. According to Engle and Granger (1987), if the two white maize grain price series have the same order of integration, testing for cointegration is equivalent to testing whether ν_t is stationary using the ADF test after estimating Equation (3) by ordinary least square (OLS). This approach implies pairwise testing of the long-run cointegrating relationship. However, long-run relationship between prices could happen for more than two markets jointly. Hence, we also employed the Johansen approach to test for cointegration. Enders and Siklos (2001) argued that unlike the Engle and Granger approach, the Johansen approach allows for more than one cointegrating relationships and is more robust to the choice of the dependent variable.

Following Johansen (1988, 1991), cointegration can be tested from the following specification

$$\Delta \mathbf{p}_t = \boldsymbol{\pi} \mathbf{p}_{t-1} + \boldsymbol{\nu}_t \quad (4)$$

where Δ denotes the first difference operator; $\mathbf{p}_t$ is a $n \times 1$ vector of white maize grain price series all integrated of the same

order; $\mathbf{p}_{t-1}$ is a $n\times 1$ vector of lagged white maize grain price series; $\boldsymbol{\pi}$ is a $n\times n$ matrix of unknown parameters to be estimated; and $\mathbf{v}_t$ is a $n\times 1$ vector of normally distributed error terms. Johansen approach consists in estimating matrix $\boldsymbol{\pi}$, determining its rank, and making use of the trace Eigen value and maximum Eigen value statistics given, respectively, by

$$\lambda_{trace}\left(r\right)=-T\sum_{i=r+1}^{n}\ln\left(1-\lambda_i\right) \quad (5)$$

$$\lambda_{\max}\left(r,r+1\right)=-T\ln\left(1-\lambda_{r+1}\right) \quad (6)$$

where λ_i denotes the estimated values of the characteristics roots obtained from the estimated matrix $\boldsymbol{\pi}$; n denotes the number of price series for which we would like to test for cointegration; r is the rank of matrix $\boldsymbol{\pi}$ and represents the number of cointegrating vectors; and T represents the number of observations.

Granger causality test

For stationary price series for two geographically separated markets, we performed Granger causality test to assess whether white maize grain price changes in market i affect white maize grain price changes in market j and vice-versa. This provides an indication of the extent of integration between two geographically separated markets. For two markets with white maize grain price series that are integrated of the same order, say $I\left(d\right)$, the model to test for Granger causality is specified as follows:

$$p_t^i=\alpha^i+\tau^iT+\sum\nolimits_{s=1}^{a}\eta_s^i p_{t-s}^i+\sum\nolimits_{r=1}^{q}\varphi_r^i p_{t-r}^j+u_t^i \quad (7)$$

$$p_t^j=\alpha^j+\tau^jT+\sum\nolimits_{r=1}^{q}\varphi_r^j p_{t-r}^j+\sum\nolimits_{s=1}^{a}\eta_s^j p_{t-s}^i+u_t^j \quad (8)$$

where p_t^i denotes white maize grain price in market i at time t; p_{t-s}^i represents lagged white maize grain price in market i; T is the unit-step (monthly) time trend; u_t^i is the independently and identically distributed error term for market i where u_t^i and u_t^j are assumed to be uncorrelated; α, τ, η, and φ are unknown parameters to be estimated; and a and q denote the number of lagged white maize grain prices to be included in the regression specification. We used several statistical tests to select the number of lags. These statistical tests for selection of number of lags include Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike's Information Criterion (AIC), Hannan and Quinn Information Criterion (HQIC), and Schwarz's Bayesian information criterion (SBIC).

Two directions of causality are possible: Unidirectional where white maize grain price changes in market i affects white maize grain price change in market j and not the reverse, and bidirectional where white maize grain price changes are transmitted in both ways between markets i and j. Using Equations (7) and (8), three hypotheses of causality could be tested:

a) Unidirectional causality: white maize grain prices in market j Granger cause white maize grain prices in market i if at least one of the coefficients φ_1^i to φ_q^i in Equation (7) are statistical different from zero and all coefficients η_1^j to η_a^j in Equation (8) are not statistically different from zero; and similarly, white maize grain prices in market i Granger cause white maize grain prices in market j if at least one of the coefficients η_1^j to η_a^j in Equation (8) are statistically different from zero and all coefficients φ_1^i to φ_q^i in Equation (7) are not statistical different from zero;

b) Bidirectional causality: white maize grain prices in markets i and j Granger cause one another if at least one of the coefficients φ_1^i to φ_q^i in Equation (7) and at least one of the coefficients η_1^j to η_a^j in Equation (8) are statistically significant;

c) Independence: markets i and j are independent if all coefficients φ_1^i to φ_q^i in Equation (7) and all coefficients η_1^j to η_a^j in Equation (8) are not statistically different from zero.

Vector auto-regression (VAR)

To assess adjustment process in both short-run and long-run responsiveness to price changes between spatially separated markets which usually reflects arbitrage and market efficiency, we used vector autoregression (VAR) technique to examine endogenous and dynamic structural relationship between white maize grain price series for markets in Mozambique and Malawi. VAR technique is widely used in the literature for this purpose. For instance, Pierre and Kaminski (2019) employed VAR framework to analyze maize market integration and price transmission among global and local markets in twenty-seven Sub-Saharan Africa (SSA) countries; while Gitau and Meyer (2019) investigated spatial price transmission under different policy regimes in maize markets in Kenya, also using the VAR approach. In our application, the reduced-form VAR of the dynamic structural relationship between white maize grain price series can be specified as follows

$$\mathbf{p}_t=\sum_{k=1}^{q}\boldsymbol{\Phi}_k\mathbf{p}_{t-k}+\boldsymbol{\Gamma}\mathbf{X}_t+\boldsymbol{\varepsilon}_t \quad (9)$$

where $\mathbf{p}_t$ is a $n\times 1$ vector of stationary white maize grain price series; $\mathbf{p}_{t-k}$ is a $n\times 1$ vector of lagged white maize grain price series; $\mathbf{X}_t$ is a $m\times 1$ vector of exogenous variables including the intercept; $\boldsymbol{\Phi}_k$ and $\boldsymbol{\Gamma}$ are matrices of unknown parameters to be estimated; and $\boldsymbol{\varepsilon}_t$ is a $n\times 1$ vector of independently and normally

distributed error terms with zero mean and variance $\boldsymbol{\Omega}$.

We estimated a system with four equations (white maize grain price series from three markets in Mozambique plus another one from Malawi). For the sake of exposition, easy of understanding and simplicity, considering only two markets and adding an exogenous variable to the system of equations, the structural relationship between white maize grain prices can be written as

$$p_t^i = \alpha_0^i + \sum_{k=1}^{q} \alpha_k^i p_{t-k}^i + \sum_{k=1}^{q} \beta_k^i p_{t-k}^j + \gamma^i DB_t + \varepsilon_t^i \quad (10)$$

$$p_t^j = \alpha_0^j + \sum_{k=1}^{n} \alpha_k^j p_{t-k}^i + \sum_{k=1}^{n} \beta_k^j p_{t-k}^j + \gamma^j DB_t + \varepsilon_t^j \quad (11)$$

where DB_t is an exogenous dummy variable equal to one starting in August 2009 onward and zero otherwise (before August 2009). This dummy variable capture whether construction of the bridge over the Zambezi River had an impact on long-run white maize grain price relationship. As discussed before, absence of the bridge over the Zambezi River created a natural barrier to trade especially between Northern and Southern Mozambique and between Northern and Central Mozambique.

Error correction model (ECM)

For cointegrated white maize grain series, we can describe their short-run dynamics consistent with their long-run relationship through an error correction model (ECM) representation. It has also been widely shown in the literature that every stationary VAR can be expressed as an ECM representation and that VAR and ECM are observationally equivalent (Engle and Granger, 1987; Gujarati, 2003). One of the advantages of ECM over VAR is that ECM allows direct estimation of the short-run and long-run relationships, making their interpretation easier. For the VAR represented in Equation (9), the corresponding ECM can be specified as

$$\Delta \mathbf{p}_t = \boldsymbol{\Pi} \mathbf{p}_{t-1} + \sum_{k=1}^{q-1} \boldsymbol{\Lambda}_k \Delta \mathbf{p}_{t-k} + \boldsymbol{\Gamma} \mathbf{X}_t + \boldsymbol{\varepsilon}_t \quad (12)$$

where Δ denotes the first difference operator, $\boldsymbol{\Pi} = \sum_{j=1}^{q} \boldsymbol{\Phi}_j - \mathbf{I}_n$, and $\boldsymbol{\Lambda}_k = -\sum_{j=k+1}^{q} \boldsymbol{\Phi}_j$. The VAR representation is called cointegrated of rank r (where $0 < r < n$) if matrix $\boldsymbol{\Pi}$ has rank r and thus can be decomposed as $\boldsymbol{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$ with $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ being of dimension $n \times r$ and of rank r. The matrix $\boldsymbol{\beta}$ is called cointegration matrix, while matrix $\boldsymbol{\alpha}$ is called loading matrix. We tested for short-run and long-run relationships among markets using estimates from the ECM.

Data

This study focuses on two countries, namely Mozambique and Malawi. For both countries, the study employed white maize grain price series covering the period from January 2000 through December 2016. We gathered monthly white maize grain prices at wholesale levels from the Market Information Systems from both Mozambique Ministry of Agriculture and Food Security (MASA) and the Malawi Ministry of Agriculture, Irrigation and Water Development (MOAIWD). Our VAR specification consisted of price series from four markets: Three markets from Mozambique (Maputo, Chimoio and Nampula) and one from Malawi (Blantyre). Chimoio in Central Mozambique and Nampula in Northern Mozambique are key white maize grain surplus markets in Mozambique; while Maputo in Southern Mozambique and Blantyre in Southern Malawi are main white maize grain deficit markets being the capital cities in the respective countries and consequently major consumption hubs. Price series in two markets included in our VAR specifications had missing observations for certain months: Two missing observations for Nampula market and one for Chimoio market. We used annual average price for the corresponding year and market to fill in these missing observations.

We averaged weakly white maize grain prices measured in domestic currencies – Mozambican Metical (MZN) for Mozambique and Malawian Kwacha (MWK) for Malawi – per kilogram (Kg) to obtain monthly white maize grain prices. We then calculated monthly white maize grain prices measured in United States Dollars (USD) per kg by dividing monthly white maize grain prices measured in domestic currencies by the corresponding monthly exchange rates. These price conversions were made because our VAR specification comprised of white maize grain prices from markets from both countries; and also, to allow price comparisons among markets in both countries. For consistency, monthly exchange rates employed in the price conversions from domestic currencies to US Dollars were obtained from the International Monetary Fund (IMF)'s International Financial Statistics.

RESULTS

Descriptive statistics

Table 2 summarizes descriptive statistics for white maize grain prices in the four markets included in our VAR specifications. This table shows that between January 2000 and December 2016, the white maize grain prices averaged 0.33 USD/kg in Maputo, 0.26 USD/kg in Blantyre, 0.24 USD/kg in Nampula and 0.23 USD/kg in Chimoio. This price pattern (higher prices in Maputo, followed by Blantyre, Nampula and Chimoio) is observed in every single year between 2000 and 2016 and is consistent with the marketing positions for those four markets: Relatively higher white maize grain prices are registered in the deficit markets of Maputo and Blantyre and relatively lower prices in surplus markets of Chimoio and Nampula.[4]

With these price differentials, price signals could potentially be transmitted between any two geographically separated markets. These price differentials could create profitable arbitrage opportunities for traders to move white maize grain from surplus markets (Chimoio and Nampula) to deficit markets (Maputo and Blantyre) if the price differentials cover at the least the transaction costs associated with the movement of white maize grain between any two physically separated markets. We

[4] We tested whether the price differentials were statistically significant for all possible market pairs and the findings revealed that the price differentials are indeed statistically significant at one-percent significance level for all market pairs except one that was significant at 10 percent significance level.

Table 2. Descriptive statistics for white maize grain prices (USD/kg).

Market	Observations	Mean	Standard Deviation	Minimum	Maximum
Maputo	204	0.33	0.12	0.11	0.72
Chimoio	204	0.23	0.10	0.06	0.57
Nampula	204	0.24	0.11	0.06	0.50
Blantyre	204	0.26	0.12	0.08	0.66

Table 3. Augmented Dickey-Fuller and Phillips-Perron unit root tests.

Parameter	H_o: Unit root H_1: Stationary process p-value for Z(t)		H_o: Unit root H_1: Stationary process with trend p-value for Z(t)	
	Dickey-Fuller	Phillips-Perron	Dickey-Fuller	Phillips-Perron
		Level		
White maize grain price in Maputo	0.4183	0.0388	0.0608	0.0000
White maize grain price in Chimoio	0.0947	0.0285	0.0024	0.0006
White maize grain price in Nampula	0.1198	0.0239	0.0090	0.0006
White maize grain price in Blantyre	0.0018	0.0025	0.0065	0.0059
		First difference		
White maize grain price in Maputo	0.0000	0.0000	0.0000	0.0000
White maize grain price in Chimoio	0.0000	0.0000	0.0000	0.0000
White maize grain price in Nampula	0.0000	0.0000	0.0000	0.0000
White maize grain price in Blantyre	0.0000	0.0000	0.0000	0.0000

investigate with more details whether spatial price transmission occurs among two markets in the successive parts of this paper, starting with the next where stationarity is tested.

During the period between January 2000 and December 2016, price variability, measured by the coefficient of variation which is given by the ratio of the standard deviation to the mean, is relatively higher in deficit markets (Chimoio with 0.44 and Nampula with 0.44) than in surplus market (Maputo with 0.35), with the exception of Blantyre market (0.45). This higher variability in deficit markets in Mozambique could be associated with higher dependence on seasonality of production coupled with almost nonexistence storage conditions in deficit markets compared with surplus markets.

Stationarity

Cointegration test, Granger causality, and VAR models require that price series included in the model be stationary. To determine whether each white maize grain price series is stationary in the time series sense, we tested for unit roots using Augmented Dickey Fuller (ADF) and Phillips Perron (PP) tests. For the ADF test, we chose the optimal lag lengths based on five statistical tests, namely Likelihood Ratio (LR); Final Prediction Error (FPE), Akaike's Information Criterion (AIC), Hannan and Quinn Information Criterion (HQIC), and Schwarz's Bayesian information criterion (SBIC). These statistical tests suggested that the optimal lag lengths would be: Six for Maputo, Chimoio and Nampula markets and seven for Blantyre market.

Table 3 summarizes the results of ADF and PP unit root tests. This table suggests that based on both ADF and PP tests at five-percent significance level, the price series for all four markets do not have unit roots with a deterministic time trend included in the specification. However, without a deterministic time trend included, we found mixed results depending on whether we consider ADF or PP tests. Given that it is more sensible to include a deterministic time trend in this context, we consider that all price series are stationary in levels.

Cointegration

We tested for cointegration using the Johansen cointegration test. This cointegration test is based on the number of lags on the underlying VAR specification.

Table 4. Johansen cointegration test for Mozambique and Malawi markets.

Maximum rank	Eigenvalue	Statistic	Critical value 5%	Critical value 1%
		Trace test		
0		72.88	47.21	54.46
1	0.147	41.63	29.68	35.65
2	0.112	18.28	15.41	20.04
3	0.077	2.67	3.76	6.65
4	0.014			
		Max test		
0		31.25	27.07	32.24
1	0.147	23.35	20.97	25.52
2	0.112	15.61	14.07	18.63
3	0.077	2.67	3.76	6.65
4	0.014			

Hence, prior to testing for cointegration, we determined the optimal lag length for the underlying VAR specification using five statistical tests, namely LR, FPE, AIC, HQIC, and SBIC. The LR test selected a VAR with specification with eight lags, while the FPE and AIC tests indicated that three lags are required. On the contrary, the HQIC and SBIC tests selected specifications with two and one lags, respectively. Given these inconsistent findings regarding the optimal lag length, we employed the Lagrange multiplier (LM) test to verify whether residuals from each suggested VAR specification (VAR with one, two, three and eight lags) exhibited serial autocorrelation. Findings from the LM test revealed evidence of serial autocorrelation for residuals from the VAR specifications with three, two and one lags; while the VAR specification with eight lags did not exhibit serial autocorrelation. Hence, we chose the VAR specification with eight lags for our analysis and this specification was also employed to test for cointegration.

Table 4 summarizes the results of the Johansen cointegration test for the set of four markets included in our analysis. This table shows that the null hypothesis of no cointegration between white maize grain prices in Mozambique and Malawi is rejected at one percent significance level for the Trace test and at five percent significance level for the max test. The table also illustrates that the null hypothesis of having two cointegration relationships is reject for both trace and max tests at five percent significance level. However, no evidence exists to reject the null hypothesis for three cointegration relationships at one percent significance level for both the trace and max tests. These findings suggest that there exist three cointegration relationships which can be interpreted as the presence of long-run cointegrating relationships among white maize grain prices in Mozambique and Malawi markets. Furthermore, these findings demonstrate that white maize grain markets in Mozambique and Malawi are linked, implying that estimation of ECM for Mozambique and Malawi is important to test for the evidence of price transmission among markets in Mozambique and Malawi.

This presence of long-run cointegration relationships is consistent with findings presented earlier in this paper and showing the presence of trade of white maize grain between Mozambique and Malawi (Figure 1). As discussed earlier, white maize grain flow from Mozambique to Malawi and vice-versa throughout the year. White maize grain export to Malawi outweighs white maize grain imports from Malawi between March and July; while the opposite is true between November and February. This is consistent with seasonal pattern of white maize grain production in Mozambique: The harvesting season for white maize grain runs from March to July, while the lean season runs from November to February.

Granger causality

We tested for short-run causality among markets for white maize grain in Mozambique and Malawi using Granger causality test. Table 5 summarizes results of the Granger causality test. This table suggests that white maize grain prices in Chimoio Granger cause white maize grain prices in Maputo, implying that prices in Chimoio help improve forecasting of prices in Maputo. This table also reveals that prices in Maputo Granger cause prices in Chimoio. Hence, Maputo and Chimoio markets have bi-directional Granger causality. Moreover, bi-directional Granger causality was also found between Chimoio and Nampula markets. White maize grain prices in Maputo market provide further information to forecast

Table 5. Granger causality test for white maize grain prices in Mozambique and Malawi.

Null hypothesis	Chi-squared	p-value
Chimoio does not Granger cause Maputo	22.76	0.0040
Nampula does not Granger cause Maputo	12.31	0.1380
Blantyre does not Granger cause Maputo	6.90	0.5470
Maputo does not Granger cause Chimoio	28.66	0.0000
Nampula does not Granger cause Chimoio	34.33	0.0000
Blantyre does not Granger cause Chimoio	10.00	0.2650
Maputo does not Granger cause Nampula	15.48	0.0500
Chimoio does not Granger cause Nampula	15.41	0.0520
Blantyre does not Granger cause Nampula	7.49	0.4850
Maputo does not Granger cause Blantyre	13.84	0.0860
Chimoio does not Granger cause Blantyre	8.21	0.4130
Nampula does not Granger cause Blantyre	10.08	0.2600

Table 6. Long-run white maize grain price causality in Mozambique and Malawi.

Market	Maputo	Chimoio	Nampula	Blantyre	Constant	Cointegrating term
Maputo	1.000	-2.178(0.0000)	0.696(0.0080)	0.187(0.1450)	-0.037	0.039(0.5480)
Chimoio	-0.459(0.0000)	1.000	-0.319(0.0080)	-0.086(0.1430)	0.017	-0.543(0.0000)
Nampula	1.438(0.0010)	-3.132(0.0000)	1.000	0.270	-0.053	0.045(0.2240)
Blantyre	5.334(0.0010)	-11.618(0.0000)	3.710(0.0090)	1.000	-0.196	0.001(0.9360)

p-values are in parentheses.

white maize grain prices in Nampula in the Granger causality test, but not vice-versa. This suggests unidirectional Granger causality between prices in Maputo and Nampula markets.

Table 5 shows that white maize grain prices in Blantyre market do not Granger cause white maize grain prices in Maputo, Chimoio and Nampula markets; however, white maize grain prices in Maputo market do help forecasting of white maize grain prices in Blantyre markets, suggesting unidirectional Granger causality between Maputo and Blantyre markets.[5] These findings demonstrate some extent of integration among geographically separated markets for white maize grain in Mozambique and Malawi and are consistent with the findings for the Johansen cointegration test. This reinforces that white maize grain markets in Mozambique and Malawi are linked, opening the way for estimating ECM for Mozambique and Malawi to evaluate short-run (and long-run) price transmission among markets in Mozambique and Malawi.

Short- and long- run price relationships

Since white maize grain prices in Mozambique and Malawi are co-integrated, we estimated an ECM model. Johansen cointegration test presented earlier suggests that presence of three long-run cointegration relationships among markets for white maize grain in Mozambique and Malawi. For sake of parsimony and simplicity, we considered only one cointegrating term in the estimation of ECM model. Table 6 summarizes results from the ECM model testing for long-run price transmission among markets in Mozambique and Malawi. This table illustrates that only Chimoio market have joint long run price transmission with Maputo, Nampula and Blantyre markets because the coefficient for the error correction term is negative and statistically significant at one percent level for only Chimoio market. This is expected because Chimoio, located in Central Mozambique, is among the largest surplus markets in Mozambique supplying white maize grain to markets in Southern Mozambique (including Maputo market) and Southern Malawi (including Blantyre market). Table 6 suggests that Chimoio market

[5] Findings from the Granger causality test revealed that white maize grain prices in Chimoio, Nampula and Blantyre markets combined Granger cause white maize grain prices in Maputo markets and that white maize grain prices in Maputo, Nampula and Blantyre markets combined provide information to help forecast white maize prices in Chimoio market. We found similar results for Nampula market. These findings are available from the authors upon request.

Table 7. Short-run white maize grain price causality in Mozambique and Malawi.

Null hypothesis	Chi-square	p-value
No causality from Chimoio to Maputo	17.20	0.0161
No causality from Nampula to Maputo	3.08	0.8771
No causality from Blantyre to Maputo	5.17	0.6390
No causality from Maputo to Chimoio	32.45	0.0000
No causality from Nampula to Chimoio	20.36	0.0048
No causality from Blantyre to Chimoio	7.88	0.3429
No causality from Maputo to Nampula	12.67	0.0850
No causality from Chimoio to Nampula	13.89	0.0532
No causality from Blantyre to Nampula	5.03	0.6558
No causality from Maputo to Blantyre	9.98	0.1899
No causality from Chimoio to Blantyre	7.81	0.3500
No causality from Nampula to Blantyre	5.91	0.5502

has the speed of convergence towards the long run equilibrium of 54.3%. This indicates that a sizable long-run price spreads (45.7%) exist among Chimoio, Maputo, Nampula and Blantyre markets.

As suggested by the law of one price (LOP), price spread for the same commodity in geographically separated markets is related with transaction costs associated with the movement of the commodity among those markets. The sizable long-run price spread is consistent with empirical evidence (Tostao and Brorsen, 2005; Cirera and Arndt, 2008) suggesting that sizable transaction costs exist in Mozambique. As mentioned earlier, 48.2% of classified roads in Mozambique are in bad conditions; and Central Mozambique with 39.9% and Northern Mozambique with 35.9% are the regions that account for the largest share of the total classified roads in bad conditions in Mozambique. This sizable share of roads in bad conditions constrains profitable arbitrage opportunities to trade white maize grain among markets in Mozambique.

Although the findings suggest that Chimoio market exhibited joint long-run causality with Maputo, Nampula and Blantyre markets, Table 6 shows that pairwise long run price transmission exists among all four markets (Maputo, Chimoio, Nampula and Blantyre). This table illustrates that in the long run, changes in the white maize grain prices in Chimoio has a positive impact, while those in Nampula has a negative impact, on the white maize grain prices in Maputo, as the coefficients for Chimoio and Nampula are statistically significant at one percent level. This suggests that Chimoio and Nampula have asymmetric effects on Maputo in the long run. Similarly, our findings suggest that in the long run at one percent significance level, changes in the white maize grain prices in Maputo have positive impact on those in Chimoio and negative impact on those in Nampula. At one percent significance level, changes in prices in Chimoio have positive long-run impact on those in Nampula and vice-versa. These findings imply that the long run causality between white maize grain prices is bidirectional among markets in Mozambique.

Table 6 also shows that change in white maize grain prices in Blantyre have no long-run impact on white maize grain prices in Maputo, Chimoio and Nampula. On the contrary, in the long run, price changes in Maputo and Nampula have negative impact while price changes in Chimoio have positive impact on price changes in Blantyre. This suggests that the direction of long run causality goes from markets in Mozambique to those in Malawi and not vice-versa.

Table 7 summarizes short-run causality based on findings from the ECM model. Findings presented in Table 7 are consistent with those presented in Table 5 for the Granger causality test. Table 7 shows white maize grain prices in Maputo and Chimoio have bi-directional short-run causality at one percent significance level. Similar pattern is revealed for the short-run causality of white maize grain prices in Chimoio and Nampula. Table 7 illustrates that changes in white maize grain prices in Maputo have a significant influence on white maize grain prices in Nampula at ten percent significance level, but not the reverse. This table also shows that changes in white maize grain prices in Blantyre do not have a significant short-run effect on white maize grain prices in Maputo, Chimoio and Nampula; neither do the findings suggest significant short-run causality from Maputo, Chimoio and Nampula to Blantyre.

Conclusion

Our findings show that markets for white maize grain in Mozambique and Malawi exhibit both short- and long-run relationships. These findings are supported by both

Granger causality test and ECM test for price transmission. The results of this study revealed that Chimoio is the only market that showed joint long-run relationship with Maputo, Nampula and Blantyre markets. Our findings revealed that several market pairs have bidirectional long run causality: Maputo and Chimoio; Maputo and Nampula; and Chimoio and Nampula. On the contrary, our findings indicate unidirectional causality from Maputo, Chimoio and Nampula to Blantyre in the long run. In the short-run, only two market pairs in Mozambique (Maputo and Chimoio, and Chimoio and Nampula) exhibited short-run causality; while we found unidirectional causality between Maputo and Nampula going from Maputo to Nampula. Findings from ECM showed that Blantyre does not have short-run causality with Maputo, Chimoio and Nampula.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Barrett CB (2001). Measuring Integration and Efficiency in International Agricultural Markets. Applied Economic Perspectives and Policy 23(1):19-32.

Barrett CB, Li JR (2002). Distinguishing between Equilibrium and Integration in Spatial Price Analysis. American Journal of Agricultural Economics 84(2):292-307.

Cirera X, Arndt C (2008). Measuring the Impact of Road Rehabilitation on Spatial Market Efficiency in Maize Markets in Mozambique. Agricultural Economics 39(1):17-28.

Enders W, Siklos PL (2001). Cointegration and threshold adjustment. Journal of Business and Economic Statistics 19(2):166-176.

Engle RF, Granger CW (1987). Cointegration and error correction: Representation, estimation, and testing. Econometrica 55(2):251-76.

Gitau R, Meyer F (2019). Spatial price transmission under different policy regimes: A case of maize markets in Kenya. African Journal of Agricultural and Resource Economics 14(1):14-27.

Gujarati DN (2003). Basic Econometrics. 4th Edition, McGraw-Hill, New York.

Johansen S (1988). Statistical analysis of cointegration vectors. Journal of Economic Dynamics and Control 12(2-3):231-254.

Johansen S (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. Econometrica: Journal of the Econometric Society 59(6):1551-1580.

Kabbiri R, Dora M, Elepu G, Gellynck X (2016). A Global perspective of food market integration: A review. Agrekon 55(1-2):62-80.

Myers RJ (2013). Evaluating the Effectiveness of Inter-Regional Trade and Storage in Malawi's Private Sector Maize Markets. Food Policy 41:75-84.

Negassa A, Myers RJ (2007). Estimating Policy Effects on Spatial Market Efficiency: An Extension to the Parity Bounds Model. American Journal of Agricultural Economics 89(2):338-352.

Pierre G, Kaminski J (2019). Cross country maize market linkages in Africa: integration and price transmission across local and global markets. Agricultural Economics 50(1):79-90.

Tostao E, Brorsen BW (2005). Spatial Price Efficiency in Mozambique's Post-Reform Maize Markets. Agricultural Economics 33(2):205-214.

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Assessing the likelihood of adoption of orange-flesh sweet potato genotypes in Sierra Leone

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The adoption of research outputs to bring the desired impacts is a major factor of any research work. Based on this premise, adoption likelihood analysis was used to determine the maximum likelihood of adoption of orange flesh sweet potato (OFSP) in Sierra Leone. The study was conducted in Western Area, Moyamba, Bo, Kenema and Bombali districts. A multi-stage sampling procedure was employed to select the study samples. Data was collected from 200 sweet potato farmers using android devices programme with the Census and Survey Processing System (CSPro 6.3) software package. Descriptive statistics was used to analyze the awareness and level of cultivation of OFSP genotypes and inferential statistics to determine the maximum likelihood (rate) of adoption. From the results, there is a high level of awareness (57.7%) of OFSP genotypes by sweet potato farmers within the treatment communities as opposed to farmers in the control communities (19.2%). The high level of awareness of OFSP genotypes by the farmers within the treatment communities is as a result of the establishment of SLARI trials and with frequent discussions taking place between farmers, research scientist and technicians. The results of the adoption likelihood analysis showed that different maximum adoption rates can be achieved by combining different dimensions in the three-function adoption likelihood model. Based on the farmer's category, production goals and environments model, OFSP genotypes are likely to be adopted by farmers in the study area (MAR = 98.04%). However, the adoption rate is likely to be higher for farmers who prefer improved varieties, mainly cultivating for income, and have access to both upland and lowland ecologies. Therefore, those recommended factors should be considered in the future planning for OFSP interventions in Sierra Leone.

Key words: Adoption, likelihood analysis, orange flesh sweet potato (OFSP) genotypes, treatment communities, control communities.

INTRODUCTION

Sweet potato (*Ipomoea batatas* L. Lam) is currently ranked among the most tenth important crop in the world

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with a total production of 103 million tonnes in 2013. It also ranked as the 3rd largest cultivated root crop (7.9 million ha) after potato and cassava worldwide (Sugri et al., 2017). In the area of cultivation, the crop has a good adaptive ability due to the short growth cycle and ability to survive in diverse agro-ecologies, marginal lands and water stress soils (Sugri et al., 2017).

Sweet potato is an important food crop in sub-Saharan Africa (SSA) providing an affordable source of energy and nutrients. In many countries in sub-Saharan Africa (SSA) the preferred types of sweet potato are those that are higher in dry-matter content (28 - 30%) and have little to no sweetness (Mwanga et al., 2007). The leaves are a source of protein, containing 2.7 to 3.4 g/100 g of raw fresh leaves (Kanju, 2000) and it also contains a substantial amount of beta-carotene (-800 mg/100 g) contributing as much as 86% of the daily dietary requirement in Asia and 80% in Africa (Oke, 1990). The leaves can be used as vegetable and roots utilize in various forms for consumption which will also contribute towards food security.

Sweet potato has become the second most important root crop after cassava in Sierra Leone. About 4.2% of agricultural households in the entire country is involved in sweet potato cultivation scattered all over the 14 districts and can thrive in all the five agro-ecological zones and cultivated, both upland and lowland. This was made up of 2% in the Northern region, 1% in the Eastern region, 0.9% in the Southern region and 0.3% of agricultural households in the Western region (Gboku et al., 2017). The importance of sweet potato in Sierra Leone cannot be overemphasized. It has been a poor man's food and substitute food crop especially where the first (rice) and second staple (cassava products) are not available. The roots can be consumed in different forms: boiled, fried as chips, roasted, and often made into porridge in Sierra Leone. On the other hand, the leaves are widely used in traditional dishes and are also rich in micro nutrients.

Currently, Sierra Leone produces 132,214 tonnes in 30,656 ha from 1995 to 2016 (FAOSTAT, 2018). This production level shows that sweet potato production in Sierra Leone is very low as less than 10% of the total 5.4 million ha of land cropped in every year compared with cassava and rice. This is because women farmers are the primary producers and suppliers of sweet potato planting materials, as well as the custodians of sweet potato knowledge in the local sweet potato system in Sierra Leone. Most of the smallholders' farms are between 0.1 and 2 ha with less use of inputs (Agrochemicals and Machineries) and recommended agronomic practices.

In Sierra Leone, breeding efforts on sweet potato at Njala Agricultural Research Canter (NARC) in past several years was focused mainly on white flesh sweet potato varieties. Orange Flesh Sweet Potato genotypes were only introduced at NARC in the late 2013 that have high levels of β-carotene and have the potential to alleviate vitamin A deficiency (VAD) in children and lactating mothers. These genotypes were characterized and evaluated during the 2014 and 2015 cropping seasons at the on-station research site at Njala before multi-locational evaluation during the 2016 cropping season in all the agro-ecological zones in Sierra Leone. After evaluation, 3 elite OFSP genotypes were selected based on their resistance to pest and disease, root yield, organoleptic quality and carotenoid content and other desirable consumers' characteristics. These genotypes with the popular white fleshed sweet potato (as checks) were further evaluated through farmer-led participatory on-farm trials under fertilized and non-fertilized conditions in the 2017 cropping seasons.

Sierra Leone has the fifth highest child mortality rate and malnutrition in the world, and 17% of children aged six months to five years of age suffer from VAD (R). Lack of VAD can lead to blindness, and also increase the risk of illness and death from malaria and measles (R). Therefore, OFSP has been proven to combat VAD, malnutrition, and many other illnesses in under-five children, pregnant women and lactating mothers (NBS, 2011; CIP and HKI, 2014). In Sierra Leone, sweet potato is widely eaten by almost every household; hence, having a variety with such nutrient component could be a double advantage. It is a situation where a food-based vitamin A supplement is compared to capsule based; where the latter is becoming more expensive. Moreover, cost-effectiveness is based on the fact that it can be grown in all agro-ecological zones within Sierra Leone and can easily be accessed and utilized by poorest households who are mostly affected by VAD due to poor dietary intake. The adoption of OFSP genotypes for production and consumption is seen as the opportunity which could not only provide the significant micro nutrients of vitamin A but also more cost-effective compared to the VAS programme (Utoni, 2016).

Despite the desirable characteristics of OFSP, competition with white fleshed sweet potato (WFSP) varieties that farmers are already growing will be obvious when introduced. Adoption of research outputs to bring the desired impacts is a major factor of any research work (Knowler and Bradshaw, 2007).

However, the level of adoption of agricultural technologies in most developing countries is low and depends on the number of factors. Even though there are studies on adoption of agricultural technologies, but Socioeconomic characteristics associated with adoption do vary with time and space (De Graaff et al., 2008). Hence, circumstances in the target research areas, farmer's practices, resources availability and uses need to be thoroughly analyzed to minimize incidences of low adoption. According to Tenge et al. (2013), most adoption studies have been done after the introduction of the technology (ex-post). The value of such studies can be added if factors for adoption of a certain technology can be identified before introduction (ex-ante), as it will be

possible to take necessary measures and increased adoption.

For appropriate and sustainable agricultural innovation, it is essential that efforts be made to ensure that recommended agricultural technologies will be adopted by the intended farmer categories within the recommendation domains. The eventual adoption of the recommended technologies should be the constant concern of the research in all its various phases. Based on this premise, adoption likelihood analysis was the tool used to determine the maximum likelihood of OFSP genotypes adoption in Sierra Leone. The objectives were awareness and source of information of OFSP genotypes, level of cultivation of OFSP genotypes, dissemination of OFSP genotypes to other farmers and analysis of maximum possible adoption rate of OFSP genotypes.

METHODOLOGY

Description of study locations

The study was conducted in five (5) districts in Sierra Leone such as Western Area, Moyamba, Bo, Kenema and Bombali districts (Figure 1). The criterion for selecting those districts was based on the Njala Agricultural Research Centre (NARC) on-station and on-farm research activities on the OFSP genotypes. Due consideration was also given to the delimitation agro-climatic zone in the country during the establishment of the on-station and on-farm trials. Within those districts, we have both the treatment and control communities where the focus group discussions (FGDs) and individual interviews were conducted.

Sampling procedures

The sampling scheme designed for this study by the team was economical, easy to operate and provide unbiased estimates with small variance. The sampling frame consists of sweet potato producers in Sierra Leone (Table 1).

Sweet potato producers were selected using a multi-stage sampling procedure. The first stage involved the selection of districts and chiefdoms for both the treatment and control communities using the purposive sampling technique. The selection of the treatment communities was based on NARC research activities on OFSP genotypes within the country and the control communities, based on volume of sweet potato production and their proximity to the treatment communities, but at different chiefdoms. A total of five (5) districts and 30 communities (15 for the treatment and 15 for control communities). Purposive sampling technique has been recommended in social research as it focuses directly to the area intended to be studied (Kothari, 2004).

The second stage involved the selection of respondents from the selected communities. A total of 200 respondents were sampled (100 respondents for the treatment and 100 for control communities) for individual farmer's interview, and a total of 10 communities for the FGDs. Two (2) communities were randomly selected for individual interviews and the one (1 community selected for FGD in both the treatment and control communities within each of the five districts). Listing of sweet potato producers was done in each community and the individual interviews were held. Ten respondents were randomly selected from the list of producers for individual interviews using structured questionnaires in each community.

Data collection

This study entails primary and secondary data. Primary data involves both qualitative and quantitative which was collected through conducting field interviews: focus group discussions, individual interviews, personal observation, while secondary data was collected from scientific reports, maps and statistical abstracts used as additional sources of data (Saunders et al., 2004). The individual interviews were conducted with android devices programme with the Census and Survey Processing System (CSPro 6.3) software package. The process is called electronic data capture. The total number of 15 team members was involved during the data collection process. The type of data collected includes awareness and level of cultivation, source of information, willingness, and means of disseminating and maximum likelihood (rate) of adoption of OFSP genotypes.

Data analysis and presentation

Qualitative data from FGDs was analyzed using non-statistical methods. This involved extracting the information and clustering it into themes and sub-themes and ranking according to priorities, weights or proportional of responses in a certain category to support the individual interviews (Bryman, 2012). Quantitative data from household individual interviews was exported from CSPro to various statistical packages such as Statistical Analysis Systems (SAS 9.3), Microsoft Excel 2010 and Statistical Package for the Social Sciences (IBM SPSS Statistics 2) for analysis using different analytical tools in statistics.

Descriptive statistics (frequency and percentages) in the form of tables and charts was used to analyze quantitative data related to the respondent's awareness and level of production, source of information, willingness, and means of disseminating OFSP genotypes. Inferential statistics (maximum adoption rate) was used to predict the likelihood or rate of OFSP adoption.

Based on the characteristics of targeted sweet potato growers, it is possible to calculate and predict their maximum adoption rate before any action is undertaken to test or diffuse it. This priority estimation needs a good understanding of the producers' population, and the production goals for which the genotypes are meant to be. Likelihood to adopt the OFSP genotypes was analyzed using a three functions adoption model (Sheikh et al., 2006). The adoption model assumed that technology adoption is a function of the relationship between farmer's category, production goals and production environment and summarized in the following equation:

$$MAR = \frac{\{cf(i,n) * gf(i,n) * ef(i,n)\}}{10000}$$

where MAR = Maximum adoption rate (%) $cf(i,n)$ =Frequency of farmer categories (%), $gf(i,n)$ =Frequency of Production goals (%), and $ef(i,n) = \text{Frequency of production envrionment}$ (%).

Two categories of farmers were identified based on the type of sweet potato variety preferred (local and improve), three production environments based on the ecologies for sweet potato cultivation (upland only, IVS only, and both upland and IVS) and two production goals based on the reasons for growing sweet potato (food security and income generation) were identified in the study

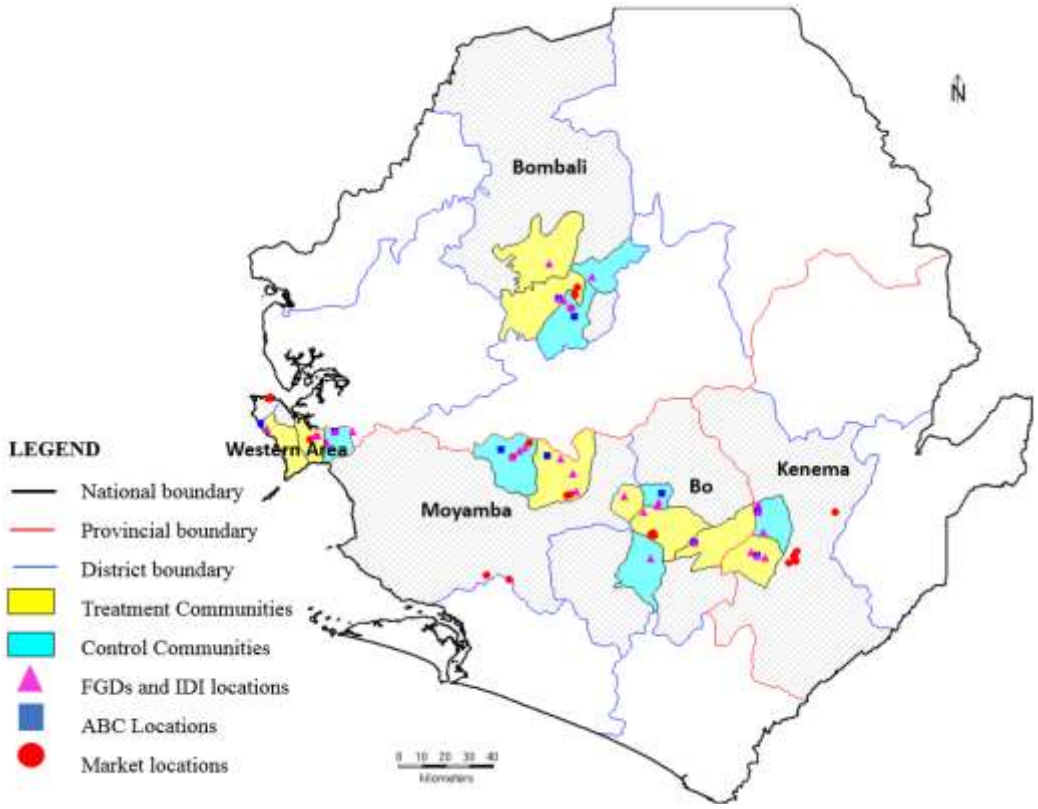

Figure 1. Map of Sierra Leone showing study locations.

Table 1. Sample size of the study.

Data collection method	Sweet potato actor	District					Total
		Moyamba	Bo	Kenema	Bombali	Western Area	
Individual interviews	Producer	40	40	40	40	40	200
FGDs	Producer	2	2	2	2	2	10

Source: Survey Data (2018).

area.

RESULTS

Awareness and source of information of OFSP genotypes

The level of awareness and source of information of OFSP varieties is illustrated in Figure 2. Majority (57.7%) of the farmers in the study area are aware of OFSP genotypes. 70% were aware of Chipka, 65% aware of Kaphulira and 60% aware of Mathuthu. In the control area, 19.2% of sweet potato farmers are aware of OFSP varieties. Twenty-five percent (25%) of these farmers are aware of the three OFSP genotypes. The major source of information for OFSP varieties of the treatment areas is from Research Institutions (75%). In the control areas, 15% access information from Research Institutions, followed by family/friends (5%) and other sweet potato growers (5%).

Level of cultivation of OFSP genotypes

The result in Figure 3 indicates that 50% of the farmers in the treatment areas have planted OFSP genotypes whilst 15% within the control area. Within the treatment, 53.9% of the farmers planted Mathuthu, 46.2% planted Chipka and 23.1% planted Kaphulira whilst 23.1% planted each of the OFSP genotypes in the control area. 38.5% of respondent planted at least one of the OFSP genotypes

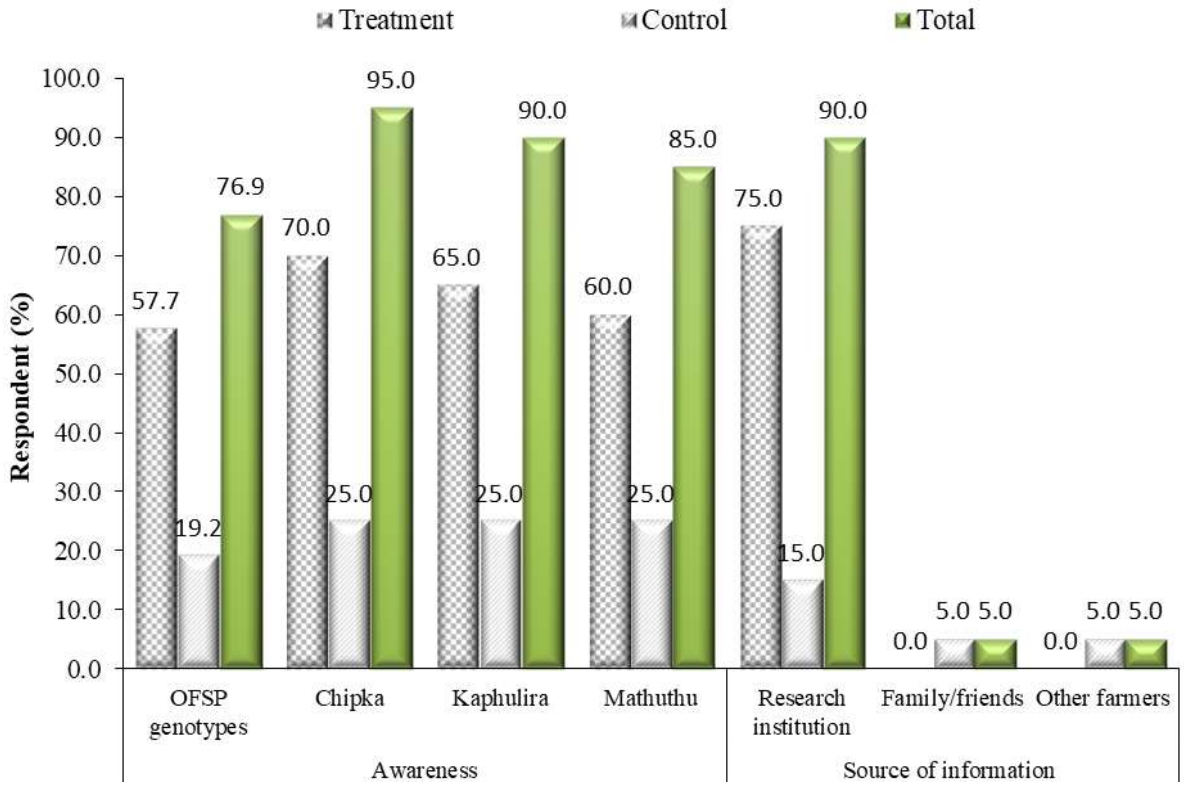

Figure 2. Awareness and source of information of OFSP genotypes.
Source: Survey Data (2018).

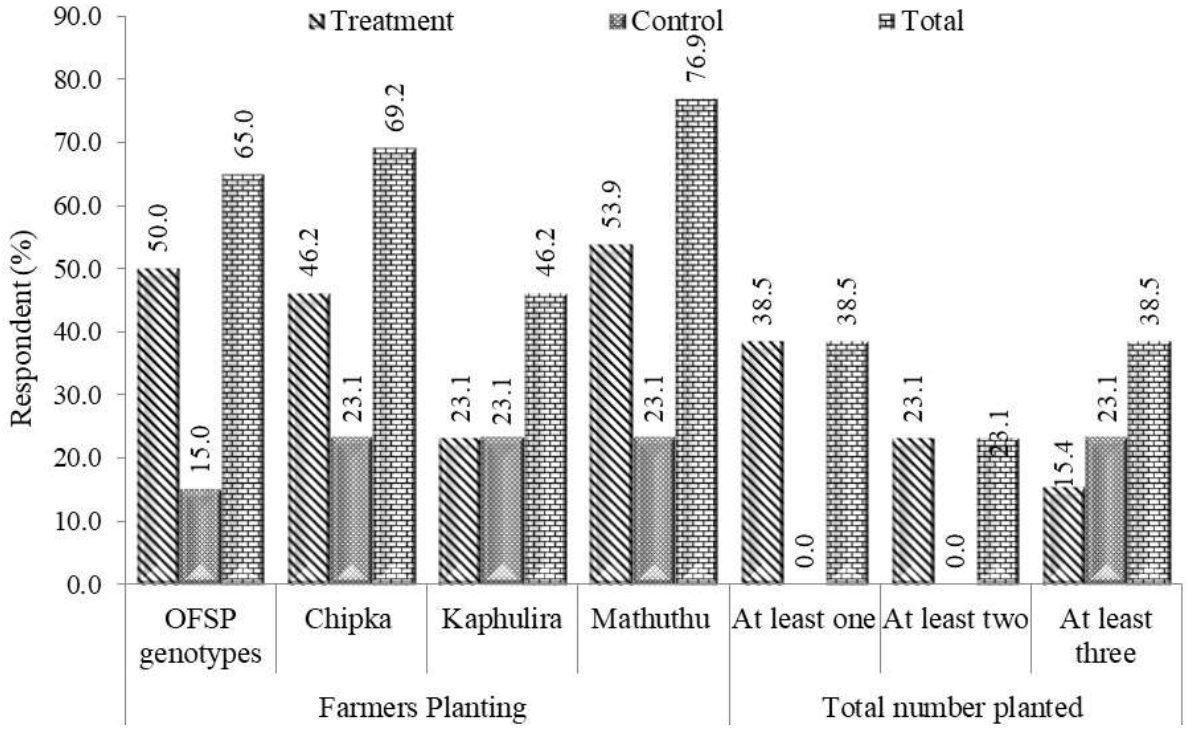

Figure 3. Level of cultivation of OFSP genotypes.
Source: Survey Data (2018).

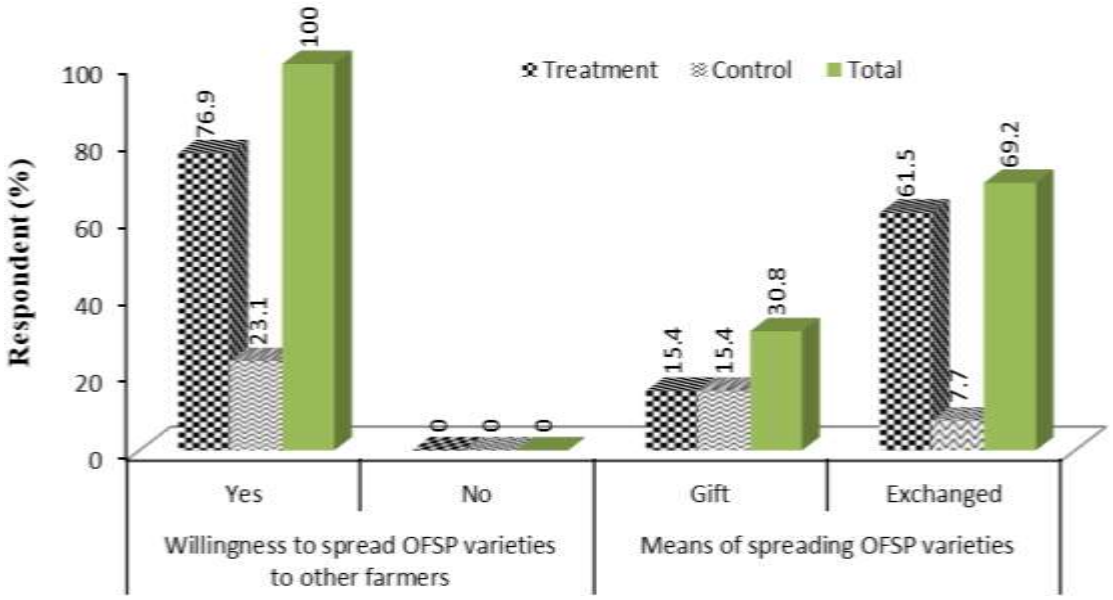

Figure 4. Dissemination of OFSP genotypes between farmers.

(Treatment areas only), 23.1% planted at least any two of the OFSP genotypes (Treatment areas only) and 38.5% planted all the three varieties (23.1% for control and 15.4% treatment areas).

Dissemination of OFSP genotypes between farmers

The total number of farmers who have already planted the OFSP genotypes during the 2017 cropping seasons in both the treatment (76.9%) and control areas (23.1%) are willing to spread the OFSP genotypes to other farmers through the exchange of materials (69.2%) and gift (30.8%). All the farmers who have not planted any of the OFSP genotypes will be willing to plant the OFSP genotypes if they have access to the vines (Figure 4).

Maximum likelihood (rate) of adoption of OFSP genotypes

The result of the maximum adoption rates for different scenarios that are based on the farmer's category, production goals and environments is illustrated in Table 2.

Scenario 1

Using farmers' category (Type of preferred variety for planting), sweet potato varieties which are applicable for two production goals (1 and 2) and two production environment (1 and 3) will have a maximum adoptions rate of 4.45% by category A farmers and 93.59% by category B farmers. This accumulates to a total maximum adoption rate of 98.04%.

Scenario 2

Using farmers' category (type of preferred variety for planting), sweet potato varieties which are applicable for production goal two and production environment three will have a maximum adoptions rate of 1.63% by category A farmers and 47.18% by category B farmers. This accumulates to a total maximum adoption rate of 48.81%.

Scenario 3

Using farmers' category (type of preferred variety for planting), sweet potato varieties which are applicable for production goal two and two production environment (1 and 3) will have a maximum adoptions rate of 2.94% by category A farmers and 71.13% by category B farmers. This accumulates to a total maximum adoption rate of 74.07%.

DISCUSSION

The high level of awareness (57.7%) of OFSP genotypes by farmers within the treatment communities is as a result of the establishment of SLARI trials and with frequent discussions taking place between farmers and research

Table 2. Maximum possible adoption rate of OFSP varieties.

There are two categories of farmers with two production goals and three production environments					
Category A = 4.5%			**Category B = 95.5%**		
G_1 = 34%	G_2 = 66%		G_1 = 24%	G_2 = 76%	
E_1 = 44%	E_2 = 1%	E_3 = 55%	E_1 = 33%	E_2 = 2%	E_3 = 65%
$C_AG_1E_1$ rate = (4.5 × 34 × 44) / 10000 = 0.67%			$C_BG_1E_1$ rate = (95.5 × 24 × 33) / 10000 = 7.56%		
$C_AG_1E_2$ rate = (4.5 × 34 × 1) / 10000 = 0.02%			$C_BG_1E_2$ rate = (95.5 × 24 × 2) / 10000 =0.46%		
$C_AG_1E_3$ rate = (4.5 × 34 × 55) / 10000 = 0.84%			$C_BG_1E_3$ rate = (95.5 × 24 × 65) / 10000 = 14.90%		
$C_AG_2E_1$ rate = (4.5 × 66 × 44) / 10000 = 1.31%			$C_BG_2E_1$ rate = (95.5 × 76 × 33) / 10000 = 23.95%		
$C_AG_2E_2$ rate = (4.5 × 66 × 1) / 10000 = 0.03%			$C_BG_2E_2$ rate = (95.5 × 76 × 2) / 10000 = 1.45%		
$C_AG_2E_3$ rate = (4.5 × 66 × 55) / 10000 = 1.63%			$C_BG_2E_3$ rate = (95.5 × 76 × 65) / 10000 = 47.18%		
If the technology is applicable to production goals 1 and 2 and for production environments 1 and 3, then MAR = 98.04% (4.45 + 93.59)					
If the technology is applicable to production goal 2 and production environment 3, then MAR = 48.81% (1.63 + 47.18)					
If the technology is applicable to production goal 2 and production environment 1 and 3, then MAR = 74.07% (2.94 + 71.13)					

C_A = Farmer category 1 (% of farmers that preferred to plant local varieties); C_B = Farmer category 2 (% of farmers that preferred to plant improved varieties); G_1 = Production goal 1 (% of farmers for Consumption/Food security); G_2 = Production goal 2 (% of farmers for Market/Income); E_1 = Production environment 1 (% of farmers that cultivate upland); E_2 = Production environment 2 (% of farmers that cultivate lowland); E_3 = Production environment 3 (% of farmers that cultivate both upland and lowland).
Source: Survey Data (2018).

scientist and technicians (75%). From the data and FGDs, the 25% of farmers that are aware of those newly introduced genotypes from the control communities are as a result of high family and friend connection existing between farmers (Figure 2). Therefore, the frequent contact between research officers or extension agents increased the probability of being aware of the newly introduced genotypes. This is in consonance with Simtowe et al. (2012).

Most (65.0%) of the farmers are currently planting or adopting at least one of the OFSP genotypes from those that are aware (76.9%). This indicates that, there is a high tendency of OFSP adoption if farmers are aware or planting materials available because, only 11.9% of farmers are aware but not planting. According to Mbanaso et al. (2012), Bouis and Islam (2012) and Amengor et al. (2018), dissemination efforts should include effective awareness creation about the improved sweet potato varieties across the country for enhanced adoption which is in support of these results. Among the three OFSP genotypes distributed to farmers, Mathuthu (76.9%) is the highest genotype cultivated followed by Chipka (69.2%). The high number of farmers cultivating Mathuthu is as a result of its field performance during the field trails. The agronomic data and FGDs also support why the farmers preferred cultivating Mathuthu (Figure 3).

All (100%) the farmers that has planted at least one of the OFSP genotypes are willing to give to other farmers through exchange (69.2%) and others as form of gift (30.8%) (Figure 4). This is an indication of the weak formal seed systems in Sierra Leone and hence most farmers source their planting material (vines) through the informal seed systems and the strong social ties existing among our farmers which facilitate majority of planting materials (vines) acquisitions/distributions through exchange and gift without cash payment (Adam et al., 2018). The FGDs result also confirms the most common way on how sweet potato farmers obtained their planting materials between themselves which is through exchange and gift. Therefore, the findings provide entry points both for entities that seek to enhance small-scale farmers' access to improved, high quality sweet potato genotypes, as well as broader efforts to strengthen research and development strategies for integrating formal and informal seed systems.

From Table 2, in scenario one (where we have two production goals and two production environment), the total maximum adoption rate is 98.04%; scenario two (where we have one production goal, and one production environment), the total maximum adoption rate is48.81% and scenario three (where we have one production goal and two production environment), the total maximum adoption rate is 74.07%. The

results of the adoption likelihood analysis showed that, in situations where there is an interaction between different production environments, goals, and farmer categories, blanket recommendations have low maximum adoption rates. Therefore, to increase the maximum adoption rates, flexible recommendations that combine several-dimensions of the technology are needed. This is clearly shown in the analysis for the different scenarios.

CONCLUSION AND RECOMMENDATION

There is a high level of awareness (57.7%) of OFSP genotypes by sweet potato farmers within the treatment communities as opposed to farmers in the control communities (19.2%). The high level of awareness of OFSP genotypes by the farmers within the treatment communities is a result, the establishment of SLARI trials and with frequent discussions taking place between farmers, research scientist and technicians. Majority of those that are aware and have access to the planting materials are cultivating at least one of those genotypes. The farmers are also willing to give those planting materials (Vines) to other farmers through exchange and gift which is a good indication of high level of OFSP genotypes adoption if disseminated.

The results of the adoption likelihood analysis showed that, different maximum adoption rates can be achieved by combining different dimensions in three function adoption likelihood model. Based on the maximum adoption rate calculations (MAR) between farmer's category, production goals and environments, OFSP genotypes are likely to be adopted in the study area (MAR = 98.04%). However, adoption rate is likely to be more for farmers who prefer improve varieties (MAR = 93.59%) than those who preferred local varieties (4.45%), mainly cultivating for income and have access to both upland and lowland ecologies. Adoption of OFSP genotypes is likely to increase and be sustainable with flexible recommendations that address farmer's criteria, production goals and environments. Therefore, those recommended factors should be considered in the future planning for OFSP interventions in Sierra Leone.

Therefore, SLARI, the National Seed Board and other partners should facilitate the official release of the three OFSP genotypes (Mathuthu, Chipka and Kaphulira) that have been evaluated and selected by the farmers. After the release, development partners and the government agencies working on OFSP to combat VAD among under five children should develop robust promotion and dissemination strategies for out-scaling OFSP genotypes.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Amengor NE, Owusu-Asante B, Adofo K, Acheampong PP, Nsiah-Frimpong B, Nimo-Wiredu A, Adogoba D, Haleegoah J, Adu-Appiah A, Baafi E, Sagoe R (2018). Adoption of Improved Sweetpotato Varieties in Ghana. Asian Journal of Agricultural Extension, Economics and Sociology. DOI: 10.9734/AJAEES/2018/39874. http://www.sciencedomain.org/review-history/23796

Bouis HE, Islam Y (2012). Delivering Nutrients Widely through Biofortification: Building on Orange Sweet Potato. In: Linn JF (editor). Scaling up in Agriculture, Rural Development, and Nutrition: Focus 19. Washington, D.C.: International Food Policy Research Institute.

Bryman A (2012). Social Research Methods (4th ed.). Oxford University Press.

De Graaff J, Amsalu A, Bodner F, Kessler A, Posthumus H, Tenge AJ (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. Applied Geography 28:271-280.

FAOSTAT (2018). Food and agriculture data. http://www.fao.org/faostat/en/#home.

Gboku MLS, Davowa SK, Gassama A (2017). Sierra Leone 2015 Population and Housing Census -Thematic Report on agriculture, STATISTICS SIERRA LEONE (SSL). file:///C:/Users/USER/Desktop/reference_1/sl_2015_phc_thematic_report_on_agriculture.pdf

International Potato Center and Helen Keller International (CIP and HKI) (2014). The Reaching Agents of Change (RAC) Project in Tanzania (2011-2014).

Kanju EE (2000). Inheritance of agronomic and quality characteristics in sweet potato. PhD thesis, University of Orange Free State, South Africa.

Knowler D, Bradshaw B (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. Food Policy 32:25-48.

Kothari CR (2004). Research Methodology-Methods and Techniques, 2nd Edition, K.K. Gupta for New Age International (P) Ltd. New Delhi P 288.

Mbanaso EO, Agwu AE, Anyanwu AC, Asumugha GN (2012). Assessment of The Extent of Adoption of Sweetpotato Production Technology by Farmers in The Southeast Agroecological Zone of Nigeria. Journal of Agriculture and Social Research 12:1.

Mwanga RO, Odongo M, Niringiye BC, Kapinga R, Tumwegamire S, Abidin PE, Carey EE, Lemaga B, Nsumba J, Zhang D (2007). Sweetpotato selection releases: lessons learnt from Uganda. African Crop Science Journal 15:11-23.

National Bureau of Statistics (NBS) (2011). Micronutrients: Results of the 2010 Tanzania Demographic and Health Survey: USAID and Unicef.Dares Salaam Tanzania 73p.

Oke OL (1990). Nutritive value in Roots, Tubers, Plantains and Bananas in Human Nutrition. FAO Food and Nutrition Series, No. 24. Food and Agriculture Organization of the United Nations (FAO):

Rome. pp. 37-58, 129-130
Saunders M, Lewis P, Thornhill A (2004). Research Methods for Business Students. 2nd Edition, Prentice Hall, New York.
Sheikh AD, Mohamed MA, Bashir A, Kashif M (2006). Adoption of rice technological package by farmers of irrigated Punjab. Journal of Agricultural Research 44(4):341-353.
Simtowe F, Muange E, Munyua B, Diagne A (2012). Technology Awareness and Adoption: The case of improved pigeonpea varieties in Kenya. Selected paper prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.
Sugri I, Kissinger BM, Kusi F, Gaveh E (2017). Quality and Shelf-life of Sweet Potato as Influenced by Storage and Postharvest Treatments. Trends in Horticultural Research 7(1):1-10
Tenge A, Ley G, Hella J, Kinyau M, Opio F, Rwomushana I (2013). Options to Increase Adoption of Lowland Rice – Legume Technologies in Morogoro, Tanzania Journal of Sustainable Development 6:7.
Utoni N (2016). Consumer acceptability and willingness to pay for selected processed orange fleshed sweet potato products in Morogoro municipality. A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural and Applied Economics of Sokoine University of Agriculture, Morogoro,Tanzania.http://www.suaire.sua.ac.tz:8080/xmlui/bitstream/handle/123456789/1715/UTONI%20NKOKELO.pdf?sequence=1&isAllowed=y

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Full Length Research Paper

Evaluation of technical efficiency of edible oil production: The case of canola production in Kieni West Constituency, Kenya

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Globally, the vegetable oil demand is growing due to rising food consumption in emerging countries such as China and due to the high demand for biofuels. The current world vegetable production estimates stand at 187 million tons for the year 2016/2017. Of the estimated vegetable oil production, 70.3 million tons (37.6%) comes from palm and palm kernel, 55 million tons (30%) arise from soybean while the remaining 32.5% are supplied by canola, sunflower, peanut and cottonseed oils. Canola production is becoming an important crop in Kenya due to the high demand for edible oils, with the current production not meeting the current demand. This study evaluates canola production efficiency in Kieni West Constituency and its determinants using a stochastic production frontier approach and a sample of randomly selected 46 canola farmers. The output and input variables measured included the total amount of canola produced, land size under canola production, quantity of canola seeds, labour quantity engaged, and fertilizer quantity. The total input costs and income from canola farming were also evaluated. The mean technical efficiency score was 0.97 with 50% of the farms being efficient. The determinants of canola production included gender of the farmer, age of the farmer, years of schooling of the farmer and number of household members. Canola production was found profitable with the farmers earning an average income of Kshs. 96532.61 (965.32 US$) and a profit of Kshs. 76413.04 (764.13 US$) per season. Thus, the study recommends that there is need for policy makers to promote the crop as an alternative to other crops grown commonly in the area such as maize and coffee which have less return than canola. Measures should specifically be put in place to popularize the crop especially among the younger canola farmers who were found to be more efficient than the older farmers. Seed is also not readily available in Kenya, hence measures that would help farmers' access high quality canola seeds should be put in place.

Key words: Canola, technical efficiency, determinants, Kieni West Constituency.

INTRODUCTION

Globally, the vegetable oil demand is growing due to rising food consumption in emerging countries such as China and due to the high demand for biofuels. The current world vegetable production estimates stand at187 million tons for the year 2016/2017. Of the estimated vegetable oil production, 70.3 million tons (37.6%) comes from palm and palm kernel and 30% (55 million tons) arise from soybean while the remaining 32.5% are

supplied by canola, sunflower, peanut and cottonseed oils (USDA, 2017). Canadian Oil which is often referred to as CANOLA originated from Canada which was the first country to produce canola for commercial purposes. The term canola is an abbreviation of two words, that is, “CAN” for Canada and “OLA” for oil and it originated from the Rapeseed Association of Canada (Wrigley et al., 2016). Canola has since been grown worldwide; ranks only second to soybeans in world oilseed crop production, constitute an important source of edible oil, source of biodiesel and are processed into feed for livestock (USDA, 2012). United States Development Agency estimates indicate that production of canola remains high with about 68 million tonnes of canola were produced in 2016/2017. Canola is a preferred source of oil due to its high oil content which is extracted from its seed with some varieties yielding between 35 and 50% of oil (Daun, 2011; Zum Felde et al., 2007). The seed remains the principal source of oil accounting for close to 65 to 80% of the oil produced while the remaining 20-35% is processed into canola meal. The canola meal is an important source of livestock and fish feed due to its high protein content of 35 to 50% (Tan et al., 2011; Enami, 2011).

In Kenya, canola farming is characterized by small-scale farming and it was first introduced in Nyeri County in the past two decades and later spread to other counties especially within the Rift Valley part of Kenya. Kenya’s demand for oil crops such as sunflower, canola, soybean and linseed remains high with the country producing only 50% of its needs. Most of the edible oils produced in Kenya face a huge gap between production and consumption, a gap that is filled by imports from neighboring countries such as Uganda and Tanzania. For example, the demand for sunflower is about 10,000 metric tons while the country produces only 5,000 metric tons. Kenya has high potential to grow the oilseed crops since most of them grow well in poor soils, they are drought resistant and adapt well to diverse agro-ecological zones. The Government of Kenya’s (GOK) general agricultural policy calls for food self-sufficiency by 2030, but so far that has been difficult to achieve in the vegetable-oil sector.

Examining the oilseed sector, some studies exist in the literature that tackles oilseed production. For example, Mruthyunjaya et al. (2005) investigated the Indian edible oilseed production and processing efficiency. The study evaluated the four major edible oilseeds of India namely groundnut, rapeseed and mustard, soybean and sunflower. The study used both primary and secondary data for the years 2002-03/2003-04 for 690, 240, 270 and 510 samples for groundnut, rapeseed and mustard, soybean, and sunflower farmers respectively. The study used the stochastic production frontier model to estimate the technical and allocative efficiencies of oilseed production and processing. The results indicated that oilseed production experienced inefficiency ranging from ¼ to 1/3 on average with greater technical, allocative and scale inefficiency being observed at the farm/processing unit level. Külekçi (2010) evaluated the technical efficiency and the socio-economic determinants of efficiency of sunflower farms in Erzurum, Turkey. The study used a stochastic production frontier analysis and a sample of 117 randomly selected sunflower farms. The results exhibited a mean technical efficiency for the sunflower farms of 64%. The inefficiency parameter estimates showed that older farmers, farmers with a higher level of education, the number of years of experience, farm size and higher access to information reduced inefficiency, while a larger family size and more credit usage resulted in increased inefficiency. Otitoju and Arene (2010) investigated the factors that constrained and determined the technical efficiency of 64 medium-sized scale soybean producers in Benue State of Nigeria. The study used mean and standard deviation and translog stochastic frontier. The results indicated that lack of adequate processing facilities (X = 3.42) and mechanical services (X = 3.41) were the major constraints of soybean production. The mean technical efficiency of the soybean farmers was found to be 73% on average. The determinants of technical efficiency of soybean production was gender, age and farming experience. Similarly, Taphee and Jongur (2014) investigated the productivity and efficiency of groundnut cultivation in Northern Taraba State of Nigeria. The study interviewed 150 randomly selected farmers in the study area. Estimates from the frontier production function found that the gamma (γ) and sigma-squared (δ2) variance was statistically significant at 1% significance level. The average technical efficiency score was 0.97, with the minimum and maximum technical efficiency being 0.63 and 0.99 respectively. The determinants of efficiency were seed, fertilizer, farm size and family labour.

Few studies exist in the literature focus on canola production. Dolatabadi and Ghahremanzadeh (2016) investigated the technical efficiency of canola farmers in Tabriz County, Iran and its determinants. The study used a sample of 157 canola farmers and a stochastic production frontier approach for analysis. The results of the study indicated an average technical efficiency of 0.8(80%) with a low of 0.25 (25%) and the highest of 0.95

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(95%). The differences in input production elasticities were found to emanate from water consumption and education level. The socio-economic determinants of efficiency of this study were found to be education level, training course number, and the cultivated area which were found to be positively associated with technical efficiency while the age of the farmer negatively affected technical efficiency. Unakitan and Lorcu (2011) evaluated the technical efficiency of canola production in Turkey. The study used a sample of 100 canola producers and the input-oriented data envelopment analysis technique for analysis. The mean technical efficiency of the canola farmers was 0.754 with the technical and scale efficiency being 0.812 and 0.927 respectively. The study found that on average, canola farmers obtained a yield of 310 kg/da with the 14 farmers operating on the frontier attaining an average yield of 382 kg/da. Similarly, Mousavi-Ayyal et al. (2011) used the data envelopment technique to evaluate the energy use pattern for canola production in Golestan province of Iran. The data used a sample of 130 canola farms that were randomly selected. The production inputs considered were human labour, diesel, machinery, fertilizers, agrochemicals, irrigation water, seeds and electrical energy with canola yield value being modelled as the output variable. The results indicated that the mean technical efficiency was 0.74 and 0.88 under constant and variable returns to scale respectively. The study found that majority of the canola farmers (85%) were inefficient with only 15% of farmers being fully technically efficient. The study found that on average 17,786 MJ ha^{-1} of energy was used in the canola production process. The results suggested that, on average, a potential of 9.5% (1696 MJ ha^{-1}) reduction in total energy input was likely if the canola farmers were to achieve full technical efficiency.

So far none of the studies that exist in the literature tackle canola production in Africa and more so in Kenya. To fill the above gap, the goal of this study was to investigate the technical efficiency of canola farming and its determinants in Kenya using Kieni West constituency as the case study. The specific objectives were three-fold. First, the study measured the technical efficiency of canola farming in the region. Second, the study investigated the determinants of canola production in the study area. Last, the study investigated the profitability of canola production in the study region. The findings of the study provide useful insights on canola production to farmers and policy-makers and spells out measures that will help boost canola production.

METHODOLOGY

Study area

This study was carried out in Kieni West Constituency which is one of the six constituencies of Nyeri County, Kenya. The constituency consists of Mwiyogo, Mugunda, Gatarakwa, Endashara and Mweiga locations with a population of about 68,861 residents. The main economic activity is agriculture. The area is home to several cottage industries including canola processing.

Sample size and procedure

Cross-sectional data obtained from a field survey of canola farmers was used in this study. Simple random sampling technique was used to get a sample of the canola farmers from the list provided by the County Ministry of Agriculture containing canola farmers in the county. A sample size of 50 canola farmers was randomly selected as an ideal representative of the entire population of canola farmers in Kieni West Constituency who are few in this area.

Data collection technique

Using a well-structured questionnaires and interview schedule, data was collected from the sample. The data collected was on canola output, inputs and socio-economic characteristics of the farmers. Data collection was done in January 2019. The data were coded, entered and edited in Microsoft Excel with four (4) respondents being dropped for being outliers. Frontier 4.1 version was used in data analysis.

Theoretical framework and analysis model

The technical efficiency of an individual firm/farm is defined simply as the ratio of the observed output of the corresponding frontier output given the level of inputs used by the firm/farm. Technical inefficiency is therefore defined as the ratio of the amount by which the level of production for the firm/farm is less to the frontier output. The popular approach to measure the technical efficiency component is the use of parametric methods such as stochastic frontier production function or non-parametric methods such as data envelopment analysis. The use of parametric methods has an advantage since it captures the stochastic measures. The Cobb Douglas production Frontier is one of the parametric ways of measuring efficiency. The Cobb Douglas function was used in this study to specify the stochastic production frontier, hence forming the basis for deriving the technical efficiency and its related efficiency measures. The stochastic Cobb Douglas production function was chosen because this functional form has been widely used in farm efficiency analyses for both developing and developed countries. The stochastic production frontier approach that was first independently proposed by Aigner et al. (1977) and Meeusen and Van den Broecl (1977) which is defined as follows was considered:

$$Y_i = f(x_i;\ \beta) + e_i \quad (1)$$

$$e_i = v_i - \mu_i$$

where i is the ith farm= 1, 2,……N. Y_i represents the amount of canola output, X_i is the vector of inputs used in canola production while β_i is the vector of parameters of production function to be estimated. The error-term $e_i = v_i - \mu_i$consists of two components; u_i which represents the component beyond the control of the canola producers while μ_i represented the inefficiency components. u_i is asymmetrical random-term which is assumed to be normally distributed [N(0, σ2, v)]. u_i is a firm-specific (non-negative) inefficiency effect assumed to follow a truncated (at zero) normal

distribution, N (μ, σ^2 υ). υ_i and u_i are distributed independently of each other and of the inputs (X_i) used. Here, a canola farmer faces own stochastic production frontier f (X_i, β_i) exp (υ_i); a deterministic part f (X_i, β_i) common to all canola farmers and canola farmer specific part exp (υ_i) which contributes to the ith farm not reaching the frontier or maximum efficiency of production; its value ranges between zero and one and is thus associated with technical efficiency. The stochastic frontier production function used to analyze resource use efficiency in canola production is given by Equation:

$$y_i = \propto_0 + \sum_{k=1}^{4} \propto_k + lnx_{ki} + v_i - \mu_i \quad (2)$$

where, ln denotes natural logarithms, output y of canola production, x variables are the actual inputs used and $v_i - \mu_i$ is the error term. α's are parameters to be estimated from the production function.

The inefficiency model is estimated from the equation given below.

$$\mu_i = \delta_0 + \sum_{m=1}^{7} \delta_{m_i} z_i \quad (3)$$

where δ_0 and δ_m are parameters in the inefficiency model to be estimated together with the variance parameters which are expressed in terms of

$$\sigma^2 = \sigma_\mu^2 + \sigma_v^2$$

known as sigma squared and $\gamma = \sigma_\mu^2/\sigma^2$ known as gamma which captures the total variation of observed output from its frontier output.

Equation 4 below shows a joint estimate equation of a stochastic frontier production function in Frontier 4.1 software:

$$\ln Y_i = \beta_0 + \beta_1 Land + \beta_2 Seed + \beta_3 Labour + \beta_4 Fertilizer + \delta_0 + \delta_1 Gender + \delta_2 Age + \delta_3 Years\ of\ schooling + \delta_4 Household\ members + \delta_5 Market\ distance + \delta_6 Farming\ experience + \delta_7 Training + v_i - u_i \quad (4)$$

where:

Y_i = Canola production in Kgs;

Land size= number of acres of land under canola
Seed = Quantity of canola seeds in Kgs;
Labor = labor quantity in number
Fertilizer = Quantity of fertilizer in Kgs
Gender = dummy for Male=1 Female = 0;
Age = Number of years of canola farmer
Household members = Number of household members
Market distance = Distance to canola market in Kilometres
Canola experience = Years of experience as canola farmer
Trainings = Number of trainings attended on canola farming
$v_i - u_i$= error terms

This study employed the single stage maximum likelihood estimation method to estimate the technical efficiency levels and the inefficiency determinants simultaneously using the frontier version 4.1 software.

RESULTS

Summary statistics of canola farmers

The summary statistics of the canola production variables and socio-economic determinants of the farmers are provided in Table 1. Examining the output and inputs, the output was measured by the amount of canola harvested. The average output of canola was 1930.65 kg with the minimum being 430 kg and the maximum was 4900 kg. On-farm inputs, majority of the canola farmers farmed on 1.69 acres of land with the minimum being 0.5 acres and the maximum being 4 acres which strongly suggests that canola farmers were mostly small scale producers. On labour, the number of people used in canola farming is on average three (3) people with a minimum of one (1) person and a maximum of 7 people providing labour for canola farming. The amount of fertilizer used for canola farming was on average 40.2 kg with a minimum of 10 kg and a maximum of 90 kg being applied.

Examining the socio-economic characteristics of the canola farmers, the results indicate that male canola farmers were 54.3% while the female was 45.7%. The age of the canola farmer ranged between 35 to 68 years with the mean age of the canola farmers being 43 years. The average number of years of schooling of canola farmers was 11 years with the minimum and maximum being 7 and 15 years respectively. The number of household members ranged from five to nine with the average number of household members is three (3). Most of the farmers in this region had a maximum of 6 years in canola farming with 65.2% of the farmers having an experience of 3 years in farming canola. Canola farming in Kenya and specifically in Kieni West Constituency was a recent venture in agriculture. The average number of trainings attended on canola production was found to be 2 which were mostly carried out by the canola output buyer.

Stochastic production frontier results

The maximum likelihood estimate results of the stochastic production frontier function with the inefficiency model is as shown in Table 2. The mean technical efficiency of the canola farmers was 97.9%. This implies that given the same level of inputs and technology, there is potential to increase canola output by a further 2.1% keeping all the other factors constant. The highest efficient score was 1.00 (100%), the lowest being 0.821 (82.1%) with half (50%) of the farms being fully efficient. Thus, it is observed that canola production in this region is highly efficient.

Examining the input variables of canola production, all the inputs mainly land, labour, seed and fertilizer were found to positively affect technical efficiency. Land size coefficient had a positive elasticity and was statistically significant at 1% significance level. This implies one unit

Table 1. Summary statistics of canola farmers.

Parameter	Variable	Mean	Min	Max	Std Dev
Y_i	Canola output (Kg)	1930.65	430	4900	1001.24
X_1	Land size (Ha)	1.685	0.5	4	0.796
X_2	Seeds (Kg)	7.207	3	17	3.509
X_3	Labour (No)	2.870	1	7	1.191
X_4	Fertilizer (Kg)	40.217	10	90	19.42
Socio-economic variables					
δ_1	Gender (Dummy: 1=Male; 0=Female)	0.543	0	1	0.498
δ_2	Age (Years)	43.609	35	68	6.489
δ_3	Years of schooling (Years)	11.435	7	15	1.814
δ_4	H/Members (No)	5.000	3	9	1.251
δ_5	Market distance (Km)	3.848	1	6	1.122
δ_6	Canola experience (Years)	3.000	1	6	1.216
δ_7	Trainings Attended (No)	2.109	0	6	1.323

Table 2. Maximum likelihood estimate for the parameters of the stochastic frontier production function and technical inefficiency effect model for canola production.

Parameter	Variable	Coefficient	Standard-error	t-ratio
β_0	Constant	5.719	0.203	28.172***
β_1	Land size (Ha)	0.411	0.123	3.338***
β_2	Seeds (Kg)	0.245	0.083	2.949**
β_3	Labor (No)	0.216	0.122	1.777*
β_4	Fertilizer (Kg)	0.247	0.057	4.330***
Inefficiency model				
δ_0	Constant	0.013	0.164	0.081
δ_1	Gender (1=Male; 0=Female)	0.038	0.019	2.055**
δ_2	Age (Years)	0.007	0.002	2.933**
δ_3	Years of schooling (Years)	-0.015	0.006	-2.613**
δ_4	Household Members (No)	-0.026	0.009	-2.875**
δ_5	Market distance (Km)	0.003	0.020	0.170
δ_6	Canola experience (Years)	-0.006	0.010	-0.599
δ_7	Trainings Attended (No)	-0.008	0.006	-1.333
Sigma-squared	$\sigma^2 = \sigma_\mu^2 + \sigma_v^2$	0.005	0.001	7.449**
Gamma	$\gamma = \sigma_\mu^2/\sigma^2$	0.000	0.000	0.017
	Log likelihood function			58.33***
Technical efficiency scores				
	Mean efficiency	0.979		
	Maximum efficiency	1.000		
	Minimum efficiency	0.821		

*, **, *** Significant at 10, 5 and 1%, respectively.

increase in the amount of land under canola production will lead to canola output increasing by 0.411 units keeping all the other factors constant. This finding is consistent with a number of studies that find land to be positively influencing production (Abate et al., 2018; Bhatt and Bhat, 2014; Danquah et al., 2019; Dessale, 2019;

Table 3. Canola yield gap due to technical inefficiency.

Parameter	Min	Max	Mean	Std. Dev
Actual canola yield kg/ha	430	4900	1930.65	1001.24
Technical efficiency estimates	0.821	1	0.979	0.035
Potential/Frontier yield kg/ha	523.610	4900	1965.92	1012.17
Yield gap/loss kg/ha	93.610	0	35.27	10.93

Laha, 2013). The elasticity of the coefficient of the amount of canola seeds used for planting was positive and statistically significant at 5% level of significance. This implies that one unit increase in the amount of canola seed used increased canola output by a further 0.245 units keeping all the other factors constant. Canola seeds being small in size implies it is possible that canola are applying seeds at below optimum levels, hence increasing canola seed would increase canola output. The coefficient of labour was positive and statistically significant at 10% significance level meaning that labour responded positively with canola output. This implies that one unit increase in labor increased canola output by 0.216 units keeping all the other factors constant. This finding is consistent with that of Dessale (2019), who found wheat output to be positively associated with labor in Jamma district of Ethiopia. Labor for canola is critical especially during harvesting and packaging since ploughing is normally done by machinery. The elasticity of the coefficient of amount of fertilizer was positive and significant at 1% significance level implying that one unit increase in fertilizer will result to a change increase in canola output by 0.247 units keeping all other factors constant. This relation is very strong which suggests that increasing the fertilizer used, will have a huge impact on the yield of canola (Dessale, 2019; Wudineh and Enderias, 2016).

Examining the inefficiency model, the socio-economic determinants of canola production were found to be gender of the canola farmer, age of the canola farmer, years of schooling of the canola farmer and number of household members of the canola farmer. The coefficient of gender was positive and statistically significant at 5% significance level which implies that the male canola farmers were less efficient than the female canola farmers. This finding coincides with the findings of Yami et al., 2013 who found male wheat farmers to be less efficient than their female counterparts in selected waterlogged areas of Ethiopia. The finding however contradicts with some studies that exist in the literature which conclude that male farmers are more efficient than the female canola farmers (Ironkwe et al., 2014; Oladeebo, 2012). However, it may be assumed that given women play a critical role in canola farming by providing close to half of the total labour used in canola arming, then this finding holds. The age of the canola farmer was positive and statistically significant at 5% significance level which implies that the older farmers were less efficient than the younger farmers. The finding coincides with those of Mugera and Featherstone (2008) who found that age increased inefficiency among a sample of 126 Philippines hog keepers. The coefficient of years of schooling was negative and statistically significant at 5% significance level which implies that schooling reduced inefficiency. This can be interpreted that years in school helped the canola farmers to gain knowledge on efficient and accurate use of farm resources such as land, seed, labour and fertilizer. The number of household members was negative and statistically significant at 5% level of significance which implies that as the number of household members increased, the efficiency of canola farming increased holding all other factors constant. An increase in household members helps to reduce inefficiency by availing required labor at a low cost. This is because the family members are able to take care of farming activities without necessarily incurring additional costs. The coefficients of years of experience in canola farming and number of trainings had a negative coefficient although the variables were not significant. The coefficient of the distance to the market for canola inputs and outputs was positively associated with inefficiency although the variable was insignificant.

Canola yield gap due to technical inefficiency

Table 3 provides the canola yield gap due to technical inefficiency. The results indicate that the mean technical efficiency was 0.978 with the actual canola output being 1930.65 kg/ha while the potential output was 1965.92 kg/ha. This indicates that there was a yield gap or loss of 35.26 kg/ha of canola which was caused by technical inefficiency.

Profitability of canola farming

Canola profitability was found to differ from one farmer to another. Canola is a plant that requires less attention from the time of planting to harvesting which has enabled

Table 4. Profitability of canola farming.

Variable (Kshs)	Average	Min	Max	Std Dev
Total seed costs	2882.61	1200.00	6800.00	1403.46
Total fertilizer costs	2010.87	500.00	4500.00	970.99
Labour costs	13282.61	5000.00	32000.00	6422.32
Other costs	1943.48	300.00	5800.00	1139.73
Total costs	20119.57	7900.00	45200.00	8603.55
Income	96532.61	21500.00	245000.00	50062.15
Profit	76413.04	11400.00	211000.00	45264.64

its farming to have a lower cost-revenue ratio. The average cost of canola production was 20119.57 (201.2 US$) while the total income was Kshs 96532.61 (965.32 US$). The profit from canola production was on average Kshs 76413.04 (764.13 US$). The cost/revenue ratio was found to be 0.208 which implies that canola production was a profitable venture in Kenya. The bulk of the cost emanates from labour which is required mainly during land preparation and harvesting. Canola production is profitable due to three main reasons. First, the canola produce is sold at stable prices, currently at 50 Kshs (0.5 US$) per kg regardless of the quality of seeds as compared to other crops such as maize or beans whose prices frequently fluctuate. Second, canola requires low investment costs and maintenance as confirmed by 89% (41) of the respondents who stated that was their main reason for farming canola (Table 4). Canola farming is a highly mechanized venture, and less labour is required. It's planted by drill method using planters since it has very tiny seeds which would take so long for human labour to plant one acre. Harvesting is also done by the use of combined harvesters which minimizes on wastage during harvesting. In canola land preparation, tractors are used for planting and harrowers for levelling and ensuring that the soil is fine enough. All these machines charge a fixed amount of fee usually based on the size of land and the area a farmer comes from. Third, canola farming also requires less labour and less monitoring between planting to harvesting time as confirmed by 34 of the respondents (74%) who said that their main work was to prepare the land and plant then wait for harvesting and then sell their produce.

Challenges faced by canola farmers

Despite canola farming being profitable, canola farmers face serious challenges. The first is bird infestation which reduces the level of yields hence lowering the income of the farmers'. Second, whiteflies being the only insect that attack this plant, it is common especially before rains falls. The farming system (broadcast) poses a challenge of spraying with the respective insecticide. This is represented by 93% of the respondents. It is a challenge to acquire loans to facilitate canola farming from various financial institutions. Some farmers were unable to acquire loans to invest in canola which was 29 (63%) of the total respondents. There is no government intervention, for example, supply of subsidized fertilizers, regulation of buyers and standards of output such as quality, and specific bodies to look into canola farming like in other farming activities such as coffee and tea. This was raised by 13 of the respondents (28%) who felt there was a need for government intervention.

CONCLUSION AND RECOMMENDATIONS

The study found that canola farming in the study area was efficient although the number of farmers growing the crop still remain low. Canola farming was also found to be a profitable venture since the investment costs of farming canola were quite low with less work required to be done after planting till the harvesting season. Furthermore, canola can do well in poor soils, is more resistant to a large number of weeds and field pests which further lowers the cost of investment in terms of labour and agrochemicals. Thus, the study recommends that there is need for policy makers to promote the crop as an alternative to other crops grown commonly in the area such as maize and coffee which have less return than canola. Measures should specifically be put in place to popularize the crop especially among the younger canola farmers who were found to be more efficient than the older farmers. Seed is also not readily available in Kenya, hence measures that would help farmers' access high quality canola seeds should be put in place.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abate TM, Dessie AB, Mekie TM (2018). Technical efficiency of

smallholder farmers in red pepper production in North Gondar zone Amhara regional state, Ethiopia. Journal of Economic Structures 8(1):1-18.
Aigner DK, Lovell CK, Schmidt P (1977). Formulation and Estimation of Stochastic: Frontier Production Function Models. Journal of Econometrics 6:21-37.
Bhatt MS, Bhat SA (2014). Technical efficiency and farm size productivity-micro level evidence from Jammu and Kashmir. International Journal of Food and Agricultural Economics 2(4):27-49
Dessale M (2019). Analysis of technical efficiency of small holder wheat-growing farmers of Jamma district, Ethiopia. Agriculture and Food Security 8(1):1-8.
Daun J (2011). Origin, distribution and production. In "Canola: Chemistry, production, processing and utilization" (Daun J, Eskin MN, Hickling D, eds.). AOCS Press, Urbana, Illinois, pp. 1-27.
Dolatabadi SR, Ghahremanzadeh M (2016). Measuring the technical efficiency of canola farmers and determining the effective factors in Tabriz County, Iran. International Journal of Agricultural Management and Development 6(40):505-513.
Danquah FO, Twumasi MA, Asiamah BK (2019). Impact of land fragmentation on technical efficiency: The case of maize farmers in the transitional zone of Ghana. International Journal of Environmental and Agriculture Research 5(2):15-26.
Enami HR (2011). A review of using canola/rapeseed meal in aquaculture feeding. Journal of Fisheries and Aquatic Science 6(1):22-36.
Ironkwe A, Ewuziem J, Ekwe K (2014). Gender factors influencing technical efficiency of cassava farmers in Akwa Ibom State, Nigeria. Journal of Agriculture and Food Sciences 11(2):26-36.
Külekçi M (2010). Technical efficiency analysis for oilseed sunflower farms: a case study in Erzurum, Turkey. Journal of Science Food and Agriculture 90(9):1508-1512.
Laha A (2013). Technical efficiency in agricultural production and access to credit in west Bengal, India: a stochastic frontier approach. International Journal of Food and Agricultural Economics 1(2):53-64.
Tan KT, Lee KT, Mohammed AR (2011). Potential of waste palm cooking oil for catalyst free biodiesel production. Energy 36:2085-2088.
Meeusen W, Vaden Broeck J (1977). Efficiency estimation from Cobb Douglas production function with composed error. International Economics Review 18(2):435-444.
Mousavi-Avval SH, Rafiee S, Jafari A, Mohammadi A (2011). Improving energy use efficiency of canola production using data envelopment analysis (DEA) approach. Energy 36(5):2765-2772.
Mruthyunjaya SK, Rajashekharappa MT, Pandey LM, Ramanarao SV, Narayan P (2005). Efficiency in Indian edible oilseed sector: Analysis and implications. Agricultural Economics Research Review 18:153-166.
Oladeebo JO (2012). Technical efficiency and rural poverty among farmers in Nigeria: A gender perspective. Global Journal of Science Frontier Research 12(8):1-8.
Otitoju MA, Arene CJ (2010). Constraints and determinants of technical efficiency in medium-scale soybean production in Benue State, Nigeria. African Journal of Agricultural Research 5(17):2276-2280.
Taphee GB, Jongur AAU (2014). Productivity and efficiency of groundnut farming in Northern Taraba State, Nigeria. Journal of Agriculture and Sustainability 5(1):45-56.
Wudineh G, Enderias G (2016). Technical efficiency of smallholder wheat farmers: The case of Welmera district, Central Oromia, Ethiopia. Journal of Development and Agricultural Economics 8(2):39-51.
Unakıtan G, Lorcu F (2011). Technical efficiency of canola production in Turkey. African Journal of Business Management 5(10):3981-3985.
USDA (2017). United States Department of Agriculture, Washington DC. Available from www.fas.usda.gov
USDA (2012). United States Department of Agriculture, Washington DC. Available from www.fas.usda.gov
Wrigley CW, Corke H, Seetharaman K, Faubion J (2016). Encyclopedia of food grains, 2nd edn. Academic Press, Oxford. ISBN 978-1785397622
Yami M, Solomon T, Begna B, Fufa F, Alemu T, Alemu D (2013). Sources of technical inefficiency of smallholder wheat farmers in selected water-logged areas of Ethiopia: A translog production function approach. African Journal of Agricultural Research 8(29):3930-3940.
Zum Felde T, Baumert A, Strack D, Becker HC, Möllers C (2007). Genetic variation for sinapate ester content in winter rapeseed (*Brassica napus* L.) and development of NIRS calibration equation. Plant Breeding 126(3):291-296.

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