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Technical efficiency of rice farmers in Anambra State value chain development programme

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The study is aimed at determining the technical efficiency of rice farmers in Anambra State value chain development programme. A well-structured questionnaire was administered to elicit information from 372 rice farmers from the five participating Local Government Areas (Ayamelum, Awka North, Anambra West, Anambra East, and Orumba North) after which only 337 respondents were fit for the study. Cobb Douglas stochastic frontier model was used to ascertain the frontier line of the farmer's production potentials. The determinant of technical inefficiency was sex and farming experience. The findings revealed that the gamma value (0.0315) captures the variation in technical efficiency by farmers, therefore, about 3.15% variation is observed and frontier output is due to rice farmer's technical inefficiency effect. The study equally showed that the mean technical efficiency as predicted in the study was 84.76% implying that the farmers are operating 15.24% below their optimum production capacity. These, therefore, justify the need for policymakers to constantly organize training and sensitization workshops for the rice farmers in Anambra State and Nigeria at large paying particular attention to women farmers and the general farmer's farming experience which will help to tailor down training to specific needs.

Key words: Stochastic frontier, technical efficiency and inefficiency, return to scale, influence, utilization, sensitization.

INTRODUCTION

Nigerian agricultural sector is undergoing series of reformation that will help to bring about food security and stabilization in the country. Confirmation to this was the recent border closure by the Nigeria government aimed at spurring farmers especially rice farmers to increase production and equally force the consumers to demand more domestic food products. Rice botanically known as *Oriza sativa* is a tropical crop cultivated in almost all parts of Nigeria including Anambra State. Many rice small growers are resource-poor and cultivate about 0.5 and 3 ha. Rice is the main cereal crop, which is seriously affected by climatic factors (Abu et al., 2017) even in Anambra State. It is one of the fastest-growing food commodities in Nigeria with a likelihood of continued growth; its increase in demand is associated with the rapid population growth, urbanization and consumer's

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preference for rice as convenience food (Akande, 2003; Obianefo et al., 2019; USDA, 2014).

Nigeria as a country is yet to attain self-sufficiency in rice production since demand is yet to equal supply (Nkwazema, 2016). Foyeku and Rice Millers, Importers and Distributors Association of Nigeria (2019) reported that Nigeria annual rice demand in 2018 was 7 million metric tonnes while only 56% of this demand was produced in Nigeria. Equally, the annual rice demand growth rate in Nigeria is 7.8% and the supply growth rate is 5.5% which leaves a deficit demand-supply gap of 2.3%.

Many researchers have reported that the problems hindering Nigeria from meeting local demand were low productivity, inefficiency in resource allocation, little or no access to improved varieties, and production in the hand of small scale out-growers who rely heavily on traditional technology (Oluwadamilola, 2018). Also, farmers are challenged by inadequate farm inputs like improved seeds, cost of agrochemicals, insufficient knowledge and information for best practices (Banful, 2011; Keelan et al., 2014). These farmers need to be abreast with the knowledge of efficiency in agricultural production especially in the area of resource allocation that will help to bring about increased agricultural productivity (Wategire and Ike, 2015). Corroboratively, researchers in Nigeria have argued that low productivity and high technical inefficiency are the major problems of rice production in Nigeria and Africa at large (Chaovanapoonphol et al., 2009). This suggests the need for farmers in Nigeria to be abreast with efficiency in resource allocation.

Though, input-output process in arable crop production is important in four major areas like; the distribution of farmer's income, allocation of farm input resources, the relation between stocks and flows, as well as the measurement of efficiency or productivity (Olayide and Heady, 1982; Nnamdi et al., 2016). Thus, an increasing rate of investment in agricultural production will correspond with increasing rate of returns with a high production efficiency (Assa et al., 2012). Hence, farmers input mix decisions on rice farming will affect their input-output processes and returns per hectare either positively or negatively depending on decision made.

This work was anchored on Aigner (1977)'s relative term technical efficiency which many researchers argued that technical efficiency is the ability of a farm to obtain maximum output from a given set of inputs under certain production technology. Identification of the technical efficiency level and the determinants of inefficiency effects will go a long way to assist the policymakers and other governmental and non-governmental agencies to tailor down training that will help the farmers optimize their production capacity to bring about self-sufficiency in rice supply in the country. Thus, the study specifically looked at the rice farmers' overall technical efficiency and inefficiency factors in Anambra State value chain development programme.

Concept of technical efficiency

Efficiency was described by Nnamdi et al*.* (2016) as the extent to which time, effort, or cost is well managed for an intended task or purpose; it also refers to the success of producing a large amount of output as possible given a set of input (Ajayi et al., 2018; Ohajianya et al., 2013b). Measuring efficiency is an important process because it is the first step in production that leads to substantial resource savings that have its implication for policy formulation and farm management (Amos, 2018). Aigner (1977) defined "efficiency" in three related terms: First, was technical efficiency" as the measure of a firm's success in producing maximum output from a given set of input; second, "price or allocative efficiency," which measures a firm's success in choosing an optimal set of input based on their relative prices. Khan et al*. (*2010) regarded it as the ability of a farm to use the inputs in optimal properties given their respective prices. The third is the "overall or economic efficiency," which is simply the product of both technical and price efficiencies.

Efficiency measurement is very important because it has a direct effect on productivity and economic growth; scholarly authors affirmed that efficiency study helps firms to determine the extent to which they can raise productivity, incomes, and profit by improving their efficiencies, with the existing resource base and the available technology (John et al., 2018). Insights into the distribution of technical efficiency and identification of important inefficiency factors on rice production cannot be overemphasized (Surendra, 2016). For farmers to maintain efficiency in rice production, their input allocation capacity, especially in seed, fertilizer, agrochemical, farm size and labour, must be built (Sani et al., 2010).

Researchers identified level of education, farm size, training, and extension contact as factors influencing the technical efficiency of Golda farmers in coastal areas of Bangladesh (Rahman et al., 2014), while other authors reported household size, age, farm size as the variables significantly impacting on technical efficiency (Piya et al., 2012); age, marital status, farming experience and level education were also reported by Ashagidigbi et al*.* (2011) as the inefficiency factors. Thus, the mean technical efficiency of rice farmers in Bangladesh was estimated at 0.80 and 0.75 in Thailand and 0.819 in Upper North Thailand (Abu et al., 2017; Mohammad et al., 2013; Chaovanapoonphol et al*.,* 2009). Thus, Coelli (1996) proposed a formula for measuring these technical efficiency and inefficiency factors using the stochastic production frontier defined by:

$$Yi = f(X_i; \beta) \exp (V_i - U_i), i = 1, 2 \ldots.n$$

Where;

Yi is output of the ith farm or farmers
Xi is the vector of input quantities used by the ith farm
β is a vector of unknown parameters to be estimated.

The term V_i is a symmetric error, which accounted for random variations in rice output due to factors beyond the control of the farmer such as weather, measurements errors, disease outbreaks, among others (Nnamdi et al., 2016). This random error V_i is assumed to be identically and independently distributed as $N(0, \sigma^2 V)$ independent of the Ui's which are assumed to be non-negative truncations of the $N(0,\sigma^2)$ distribution representing technical inefficiency in rice production relative to the stochastic frontier. The error terms εi = (Vi-Ui) is the composed error terms, consisting of Vi, which is the two-sided error term while Ui is the one-sided error term (Osawe et al., 2018).

METHODOLOGY

Anambra state is located in the south-eastern part of Nigeria, and comprises of 21 Local Government Areas which include Aguata, Awka North, Awka South, Anambra East, Anambra West, Anaocha, Ayamelum, Dunukofia, Ekwusigo, Idemili North, Idemili South, Ihiala, Njikoka, Nnewi North, Nnewi South, Ogbaru, Onitsha North, Onitsha South, Orumba North, Orumba South and Oyi. The state is sub-divided into four (Onitsha, Aguata, Awka and Anambra) agricultural zones to aid planning and rural development. Its name is an anglicized version of the original Oma Mbala, the Igbo name of the Anambra River. The state administrative head quarter is in Awka (Obianefo et al., 2019b).

The state is bounded with Delta State to the West, Imo State and Rivers State to the South, Enugu State to the East, and Kogi State to the North. The indigenous ethnic groups in Anambra state comprised of 98% Igbo and 2% Igala mainly living in the north-western part of the state. Anambra East, West and Ayamelum (Anambra zone), Orumba North (Aguata zone) and Awka North (Awka zone) play a host community to the value development programme due to their comparative advantage in the rice and cassava production (FMARD, 2016). Anambra State is situated between Latitudes 5°32ˈ and 6°45ˈ N and Longitude 6°43ˈ and 7°22ˈ E. The State has an estimated land area of 4,865sqkm^2 with a population of 4,177828 people as at the last census (NPC, 2006). The State equally have an annual temperature and rainfall of 25.9^{o}C and 138 mm respectively (Retrieved March 14, 2020 from Anambra Climate Summary).

It is very important to bring to the public notice that value chain development programme activities in the 5 LGAs of operation include; farmers organization strengthening on good governance and business development, 50% input support to farmers, 70% support to farmers on farm machineries, contiguous land development to support mechanized agriculture, construction of farm access road, among others (Figure 1 and Table 1).

A multi-stage sampling technique was employed by the researcher for the selection of the study representative. In the first stage, the sample frame (5396) was obtained from the list of registered/participating rice farmers from the programme database in Anambra State. Taro Yamane (1967) sample size determination in Otabor and Obahiagbon (2016) was further used to calculate the sample size for the study as defined by;

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

Where:
N=population of the study, n=sample Size, (e) =margin of error, 1= unit (a constant), (e)=0.05.

$$n = \frac{5396}{1+5396(0.05)^2} = \frac{5396}{1+5396\ (0.0025)}$$

$$= \frac{5396}{1+13.49)} = \frac{5396}{14.49}$$ =372.39 = approximately = 372 farmers.

In the second stage, the researcher adopted R. Kumaison formula to allocate sample stratum for the study; the R. Kumaison formula for stratum calculation is defined by:

$$i_{th} = \frac{n_i}{N} * n$$

Where;
n = total sample size, n_i = number of items in each stratum in the population, N = the population size in the strata, i_{th} = sample allocation.
Thus,

Ayamelum: $ith = \frac{2558}{5396} * 372 = 176$

Awka North; $ith = \frac{1066}{5396} * 372 = 73$

Anambra West; $ith = \frac{1027}{5396} * 372 = 71$

Anambra East; $ith = \frac{436}{5396} * 372 = 30$

Orumba North; $ith = \frac{309}{5396} * 372 = 21$

Finally, 7 villages make up a rice cluster in value chain programme and each village must have at least 3 rice farmers cooperative from which farmers were randomly selected based on the LGA stratum values as shown in Table 2 and a well-structured questionnaire was used to primarily collect data from a cross section of 372 out of which only 337 questionnaire was valid. Farmer's level of technical efficiency and determinants of inefficiency factors were analyzed using the stochastic production frontier defined by:

$Yi = f(X_i;\ \beta)\ exp\ (V_i - U_i),\ i = 1, 2 \ldots.n$

Where;
Yi is output of the ith farm or farmers, Xi is the vector of input quantities used by the ith farm, β is a vector of unknown parameters to be estimated.
The technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output given the available technology as the defined by:

$$TE = \frac{Yi}{Yi^*} \frac{f(Xi,\beta)exp\,(Vi-Ui)}{f(Xi,\beta)exp\,(Vi)} = exp(-Ui)$$

Where:
Yi is the observed output of rice and Yi* is the frontier output which the farmer is expected to attain given his/her input level. The parameters of the stochastic frontier production function are estimated using the maximum likelihood method. This stochastic production frontier function is empirically defined by:

$LnY = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_5 LnX_5 + \beta_6 LnX_6 + (V_i - U_i)$

Where Y is the output of rice in kg, X_1 = rice seed measured in kg, X_2 = Fertilizer used measured in kg, X_3 = Agro-chemical used measured in liter, X_4 = Farm size measured in hectare, X_5 = Labour measured in man-days, X_6 = Capital depreciation measured in Naira.

It is expected that all the included explanatory variables will have

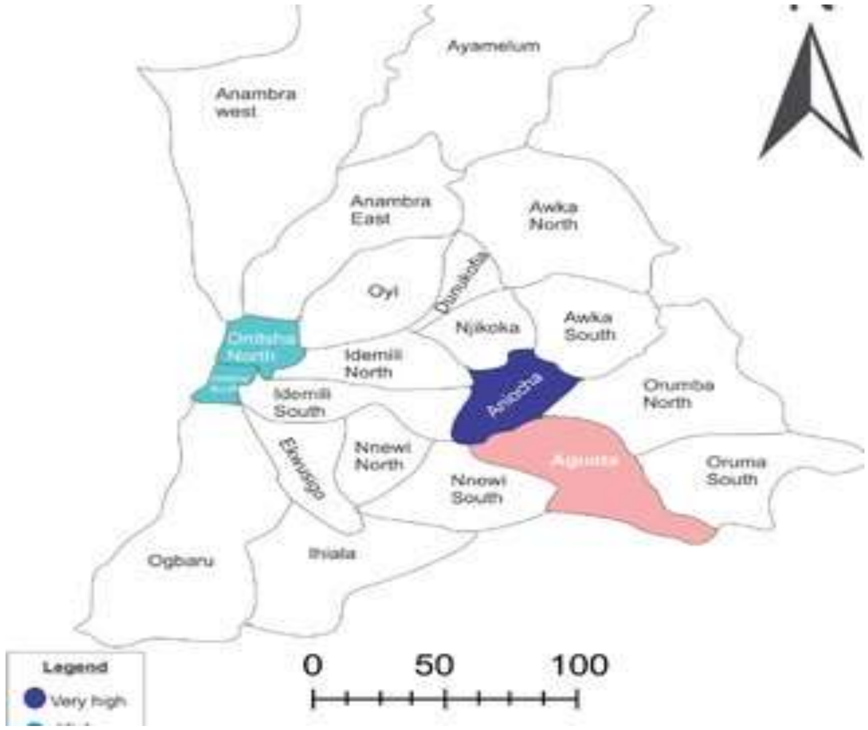

Figure 1. Map of Anambra State showing the areas of programme implementation.

Table 1. Coordinate of the participating local government area.

S/N	Local government	Coordinate
1	Awka North	6.2636° N 7.1252° E
2	Anambra East	6.3093° N 6.86375°E
3	Anambra West	6.4902°N 6.7922°E
4	Ayamelum	6.4878° N 6.9639°E
5	Orumba North	6.0543° N 7.2194°E

Table 2. Sample representation of rice farmers in the 5 local government areas.

S/N	Local government area	No of farmers	Sample size
1	Ayamelum	2558	176
2	Awka North	1066	73
3	Anambra East	436	30
4	Anambra West	1027	71
5	Orumba North	309	21
Total		5396	**372**

Source: Researcher's computation, December (2018).

a positive sign. Therefore, $\beta_0 > 0$; $\beta_1 > 0$; $\beta_2 > 0$; $\beta_3 > 0$; $\beta_4 > 0$; $\beta_5 > 0$ and $\beta_6 > 0$.

Vi and Ui remained as defined earlier. Furthermore, for the purpose of this study, Ui is assumed to follow a half normal distribution. Therefore, the farm specific efficiency is given as 1 – TE values (Assa et al., 2012). The determinants of technical inefficiency in rice production follow the model formulated and estimated jointly with the stochastic frontier model in a single stage maximum likelihood estimation procedure as described by (Coelli, 1996) and expressed as:

$$TIEi = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5$$

Where TIEi is the technical inefficiency of the i-th farm
Z_1 = Sex of farmers (dummy; "1" if male and "2" if female)
Z_2 = Age of the farmers measured in years
Z_3 = Level of education measured in years
Z_4 = Farming experience measured in years
Z_5 = Household size of farmers measured by number of persons in the household
It is expected that δ_1, δ_2, δ_3, δ_4 and δ_5 are negative

RESULTS AND DISCUSSION

Description the efficiency and inefficiency variables

Table 3 reflects the summary statistics of the sampled rice farmers, a typical rice farmer is 42 (42.26) years of age with 11 (11.13) years of formal education and household size of 9 (8.83) persons, 15 (15.41) years of farming experience, farm size of 2.41 ha, employed 126.46 man-days of labour and produced an output of 4.81 tons/ha.It is worthy to note that the average capital depreciation is ₦127,622.98 (USD 349.65 at ₦365 per USD 1), seed use is 119.42 kg, fertilizer is 727.45 kg, and agro-chemical is 4.72 L.

Factors of rice production in Anambra State value chain development programme.

Table 4 reflects the parameters and related statistical test results obtained from the stochastic frontier production function analysis using Maximum Likelihood Estimates (MLE). The functional parameters of maximum likelihood estimates has a sigma square (σ^2) value of 0.0669, significant at $p < 0.05$ critical level. The variance parameters (lamda), which showed the ratio of standard error {u (∂u)} to the standard error {v (∂v)} is 5.548479. Furthermore, the gamma ratio estimated from the sigma square value is 0.0315 and significant at $p < 0.05$ critical level. This gamma value is not up to 1.0 which is in agreement with Assa et al. (2012)'s postulation that a true gamma value should be less than 1.0 and significant. The value captures the variation in technical efficiency by farmers and about 3.15% variation is observed and frontier output are due to rice farmers technical inefficiencies. Gamma ratio according to Ogundari and Ojo (2006) in Nnamdi et al. (2016) is the relative magnitude of variance associated with inefficiency effect. Therefore, the goodness of fit and correctness of the specified assumptions of dominance of U on V can be ascertained provided the value is significantly different from zero (Ume and Ochiaka, 2016).

Apart from seed, other variables; fertilizer, agro-chemical, farm size, labour and capital depreciation were significant at either alpha level of 5 and 1%. Also, apart from seed and agro-chemical, other variables are in agreement with the *a priori* expectation. The coefficient of seed was negative and not significant at either 5% or 1% level of probability. Thus, increasing the quantity of seed does not guarantee an increase or decrease in rice yield. This finding is in agreement with Sani et al. (2010) in Resource-Use Efficiency in Rice Production under Small Scale Irrigation in Bunkure Local Government Area of Kano State.

The coefficient of fertilizer (0.0587001) was positive and significant at 5% level of probability; this implies that a unit increase in the quantity of fertilizer used by the farmers will equally increase rice output by 0.0587001 unit in the study area. This was expected by a priori expectation as fertilizer help to improve soil fertility and plant vegetation especially in grains production which rice belong. This is also in line with Md. Abu et al. (2017) on Rice farmers' technical efficiency under abiotic stresses in Bangladesh.

The coefficient of agro-chemical (0.1300962) was negative and significant at 1% level of probability. This implies that a unit increase in the number of farmers that wrongly apply agro-chemical will reduce the farmer's output by 0.1300962 units in the study area. This agrochemical is in the form of selective and non-selective. Therefore, wrong choice and application of these chemicals will adversely affect rice yield, this finding is in akin with Mohammad et al. (2013) in the assessment of technical efficiency of rice farmers in a selected Empoldered area of Bangladesh. The coefficient of farm size (1.050276) was positive and significant at 1% level of probability. This implies that a unit increase in the total number of hectares cultivated by the farmers will increase output or yield by 1.050276 units in the study area. This is justifiable as mechanization is easy to practice on contiguous land. This finding is equally in agreement with Sani et al. (2010) whose farmland was also significant at 1% level of probability in their study on Resource-Use Efficiency in Rice Production under Small Scale Irrigation in Bunkure Local Government Area of Kano State.

The coefficient of labour (0.1428544) was positive and significant at 1% level of probabilityl the implication is that a unit increase in the number of labour force supplied to the farm or an increase in the number of hours the labour force put into farming operation will increase rice output by 0.1428544 unit in the study area. This result is equally in agreement with Chaovanapoonphol et al. (2009) on the impact of agricultural loans on the technical efficiency of rice farmers in the Upper North of Thailand. The coefficient of depreciated capital (0.0199831) utilized by the farmers was positive and significant at 1% level of probability; this implies that an increase in the amount of capital equipment the farmers employ in rice farming operation will increase their rice output scope by 0.0199831 unit in the area. The model also show s an

Table 3. Description of input used by the rice farmers.

Variable	Description	Mean	Std. Dev.
	Socioeconomic		
Z_1	Age (years)	42.26	11.38
Z_2	Farming experience (years)	15.41	5.89
Z_3	Household size (No)	8.83	3.27
Z_4	Level of education (years)	11.13	4.40
	Input use		
Y	Output (ton)	4.81	0.51
X_1	Capital depreciation (₦)	127,622.98	2.33
X_2	Farm size (hectare)	2.41	0.55
X_3	Seed (kg)	119.42	0.55
X_4	Fertilizer (kg)	727.45	0.54
X_5	Agro chemical (liters)	4.72	0.56
X_6	Labour in man-days	126.46	0.46

Source: Field Survey Data (2019).

Table 4. Maximum likelihood estimates for the stochastic frontier production function of rice production.

Production variables	Model parameter	Estimates	SE	t-value
Constant	β_0	8.002606	0.3125609	25.60
Seed (kg)	β_1	-0.1112745	0.0762407	-1.46
Fertilizer (kg)	β_2	0.0587001**	0.0223661	2.62
Agro-chemical (lt)	β_3	-0.1300962***	0.0392855	-3.31
Farm size (ha)	β_4	1.050276***	0.0850059	12.36
Labour (man-day)	β_5	0.1428544***	0.0270535	5.28
Capital depreciation (₦)	β_6	0.0199831***	0.0045343	4.41
Return to scale		1.0304		
Diagnostic statistics				
Log likelihood function		173.454		
Sigma squared	δ^2	0.0669***	0.00036	
Gamma	ϒ	0.0315***	0.8376	
Lamda		5.548479***	0.0173795	319.26

*,Significant at 10%, **, Significant at 5% and ***, Significant at 1%.
Source: Field Survey Data (2019).

increasing return to scale of 1.0304 in rice production in the area. This implies that an increase in the use of aggregate farm inputs in rice production by 1 unit can give more than 1 unit of rice output in the area.

Technical efficiency of rice production in Anambra State value chain development programme

Table 5 reflect the mean technical efficiency of rice farmers, the predicted technical efficiency is 0.8476, implying that, on average, the technical efficiency of the farmers in the area is about 84.76%. This suggests that rice farmers can still optimize or increase their output by 15.24%. This finding is in akin with the study of Abu et al. (2017) on rice farmers' technical efficiency under abiotic stresses in Bangladesh. This value ranges from a minimum efficiency level of 23.76% to a maximum efficiency level of 97.70% in the area. The researcher could deduce from this result that there is a wide disparity in farmers' technical efficiencies suggesting the need to bridge their technical efficiencies.

Cumulatively, many (31.2%) farmers are found below the overall mean technical efficiency. For 68.8% are above the overall mean technically efficiency in the area. This shows that with efforts made by the programme implementing unit and the farmers toward efficient technology use in rice production, high technical efficiency will be maintained in a long run to enhance output.

Table 5. Distribution of farmers according to their technical efficiency level.

Technical efficiency limit	Frequency		Percentage (%)
Technical efficiency $\leq$ 25	2		0.6
25 – 54	6		1.8
55 – 84	97		28.8
Technical efficiency > 84	232		68.8
Total	337		100.0
Mean technical efficiency		84.7	
Minimum efficiency		23.7	
Maximum efficiency		97.6	

Source: Field Survey Data (2019).

Table 6. Determinants of Technical Inefficiency in rice Production in Anambra State value chain development programme.

Inefficiency effect	Parameter	Estimates	SE	t-value
Constant	δ_1	0.2129465	0.0415732	5.12
Sex	δ_0	-0.0399863***	0.0122338	-3.27
Age	δ_2	-0.0001788	0.000687	-0.26
Education	δ_3	-0.0002355	0.0014965	-0.16
Experience	δ_4	-0.0021556**	0.0011845	-1.82
Household size	δ_5	-0.0021433	0.0019869	-1.08

*,Significant at 10%, **, Significant at 5% and ***, Significant at 1%.
Source: Field Survey Data (2019).

Determinant of technical inefficiency of rice production in Anambra State value chain development programme

Table 6 reflect the technical inefficiency model, this variables show the influence exerted upon farmer's ability to optimally utilize production input which is termed technical inefficiency. The variable with a negative sign is the one contributing to the technical efficiency of input use while those with a positive sign are the major contributors to technical inefficiency of input utilization. Thus, the coefficient of sex, age, experience, level of education and household size are the variable contributing to the technical efficiency of rice production in the study area. The coefficient of age, level of education and household size were not statistically significant at 10, 5 or 1% alpha level of probability.The predictive value of sex was negative and significant at 1% level of probability; this implies that an increase in the number of female rice farmers participating in the programme will reduce technical inefficiency by 0.0399863 unit (4%). This indicates that female rice farmers are technically efficient than their male counterpart. Rice production is time consuming especially during the bird-scaring stage of the production, at this stage, only women can exercise such needed patient to scare bird for 21 days. This finding is also in line with the *a priori* expectation. The coefficient of farming experience was negative and significant at 5% level of probability, suggesting that a unit increase in the number of farmers that are experienced in rice farming practice will reduce technical inefficiency of rice output by 0.0021556 unit in the area. This is in akin with MAbu et al. (2017) on rice farmers' technical efficiency under abiotic stresses in Bangladesh, and consistent with the a priori expectation.

Conclusion

The study on technical efficiency of rice farmers in Anambra State value Chain Development Programme is very important at this time Nigeria as a nation is struggling to attain self-sufficiency in rice supply; over many years now, demand has always grown above supply trend. Though, this demand deficit has been linked to explosive population growth on an annual base. Self-sufficiency in rice production and supply is likely to remain a mirage if farmers' input utilization pattern is not constantly under check to enable the policymaker's easy identification of the area that needs to be worked upon. Thus, the need for this study at this very time Nigeria as a country is struggling to attain self-sufficiency in rising supply cannot be overemphasized. The study through the predicted mean technical efficiency of 84.67% revealed that a good number of the farmers are producing 15.25% below their optimum capacity and/ or potentials. Also, the study has been able to establish that sex and farming experience of the farmers are the major determinant of technical inefficiency in the study area. Therefore, value chain development programme should put in more effort to encourage women's participation especially the experienced ones, since the programme will help to change farmer's conventional ideology on rice production. Importantly, agricultural programs should target more youths for sustainability sake.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Performance analysis of Nigerian agricultural credit guarantee scheme: Bounds test approach to cointegration

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This study examined the performance of the Agricultural Credit Guarantee Scheme (ACGS) which is the major credit policy of the Federal Government of Nigeria. It was established in 1977 but started operation in 1978. Time series data from 1978-2014, extracted from the 2014 bulletin of the National Bureau Statistics were used for the study. Total volume and number of loans given were used to proxy the strength of the scheme, while the contribution of agriculture to GDP was used to proxy agricultural productivity. ARDL (Bounds) test approach to cointegration was employed to investigate both long and short run dynamics of ACGS and agricultural growth. The estimated results revealed that there is a long relationship among the total volume of loans, total number of loans and agricultural productivity. The long run elasticity showed that total volume of loan will not significantly influence productivity in the long run while the total numbers of loans have a significant long run relationship with the productivity. In the short run elasticity, total volume of loans was not significant with productivity in the current year while it was significant in the past four years. The total number of loan beneficiaries had a negative but significant relationship with productivity in the past 2 and 3 years while the relationship in the past year was also negative but insignificant. However, there was a positive and significant relationship between total number of loans issued and productivity in the current year. The speed of adjustment, ECT(-1) value of -0.1991 shows that the model will return to long run equilibrium at the speed of 19.91% from short run disequilibrium.

Key words: Agricultural credit, Agricultural Credit Guarantee Scheme (ACGS), ARDL, loan volume.

INTRODUCTION

Credit has been a main focus of many research works in agricultural finance. To some, credit is “all in all” for a farmer to produce (productive input) while others hold different opinions. Whichever way it is looked at, credit is an important instrument in the development of agriculture. In fact, as emphasized by many researchers, the smallholder farmers caught in the quagmire of the vicious cycle of poverty require not only labour or land but

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an injection of adequate capital to extricate it from that cobweb. Funds for agricultural finance are met through macro and micro finance sources. The macro finance source pertains to financing agriculture through government capital allocation to agriculture and mobilizing resources for agricultural development using institutional credit agencies (Olowa and Olowa, 2011). Loans are usually acquired for productive reasons: particularly to enhance business operating capacity and generate more revenue for the business survival. The role of financial capital as a factor of production to facilitate economic growth and development, as well as the need to appropriately channel credit to rural households for economic development of the poor rural farmers cannot be over emphasized. Credit (capital) is viewed as more than just another resource such as labour, land, equipment and raw materials (Rhaji, 2008). Shepherd (2002) opined that credit determines access to all of the resources on which farmers depend. Consequently, provision of appropriate macroeconomic policies and enabling institutional finance framework for agricultural development are critical to facilitating agricultural development with a view to enhance the contribution of the sector in the generation of employment, income and foreign exchange (Olomola, 1997).

According to Alfred (2005), acquisition and utilization of credit for agricultural purposes promote productivity and consequently improve food security status of a community. Good access to credit would enable farmers venture into new areas as well as acquire improved technology for enhanced productivity. Credit is an important support service for increased agricultural productivity. Nwaru et al. (2006) observed that credit facilitates adoption of innovations, leading to increased farm productivity and income, encourages capital formation and improves marketing efficiency. In addition, it enables farmers to purchase required inputs, hire adequate labour and procure equipment and improved seed varieties for increased agricultural production. According to Nwankwo (2013), there has been serious argument in favour of on agricultural financing to reverse the persistent decline in the sector's contribution to growth and development in many developing countries. Despite the steady decline of the financing of agriculture, it is still a leading economic sector, providing major employment, income and means of livelihood, especially for the poor and vulnerable rural households.

Over the years, the inability of the agricultural sector to expand vis-à-vis its inherent potentials and as well contribute significantly to economic growth of Nigerian was due to inadequate financing to facilitate farmers' access to modern technologies/inputs and engaged adequate labour. Also, the problem of rapid agricultural development in Nigeria indicates that efforts directed at achieving expanded economic base of the rural farmers were frustrated by the scarcity of and restrictive access to loanable fund (CBN, 2010). In light of the above, the government of Nigeria has over the years developed policies and programs aimed at making financing available to the agricultural sector of the nation's economy. These policies and programs among others include:

1. Agricultural Development Programme (ADP), 1975
2. Operation Feed the Nation (OFN) 1976
3. Rural Banking Programme (1977)
4. Green Revolution, 1980
5. Nigerian Agricultural Insurance Corporation (NAIC), 1987
6. National Poverty Eradication Programme (NAPEP), 1999
7. Agricultural Credit Guarantee Scheme (ACGS), 1977
8. Bank of Agriculture, (BoA) 2010.

There are two major sources of agricultural credit, that is, formal and informal sources. In the formal credit window, institutions provide intermediation between depositors and lenders, and charge farmers for relatively lower rates of loans interest that usually are government subsidized. In informal credit medium, loanable funds are lent by private individuals (John and Osondu, 2015). Among all of these programs and policies, aside NAIC which makes money available to farmers in form of indemnification in the event of an insured loss, only ACGS and BoA are still existing in extending credit facilities to farmers for production. While BoA is a product of a re-engineering of a former agricultural policy named Nigerian Agricultural Bank (NAB) which was incorporated in 1972 and was re-christened in 1978 to Nigerian Agricultural and Co-operative Bank Limited, (NACB) to reflect the inclusion of co-operative financing into its broader mandate and was later merged with People's Bank of Nigeria (PBN) and the risk assets of the Family Economic Advancement Programme (FEAP) in 2001 for overlapping functions, in 2010, following the rebranding of the Bank to reflect its institutional transformation programme, the Bank adopted the new name "Bank of Agriculture".

According to World Bank (2009), the Agricultural Credit Guarantee Scheme is one major credit policy of the Federal Government of Nigeria and for this reason, it is crucially important to study how this agricultural policy has influenced productivity in the agricultural sector of Nigeria. The Agricultural Credit Guarantee Scheme was set up in 1977 but started operation in 1978. The Federal Government holds 60% and Central Bank of Nigeria 40% of the shares of the shares. It was designed primarily to induce banks to increase and sustain lending to agriculture. To show how serious the government is, this policy is protected within the legislative framework (Decree No 20 of 977), that is, it is protected by law against being scrapped by any government due to any reason without going through the process of amendment which will put such government on the spot to explain why such development policy is to be scrapped. It is resident at the apex bank of Nigeria, Central Bank of Nigeria, CBN. Bank loans to farmers under this scheme are guaranteed 75% against default by the CBN.

Critical among the factors contributing to poor attainment of the development objectives of the agricultural sector are inadequate and/or non-availability of loanable fund with which agro-entrepreneurs can explore opportunities along the agricultural value chain (Awe, 2013; Zakaree, 2014).

In an attempt to break barrier of paucity of fund for agricultural production and processing, the Federal Government through the Central Bank of Nigeria established Commercial Agricultural Credit Scheme (CACS) in 2009 in collaboration with the Federal Ministry of Agriculture and Water Resources to facilitate adequate and timely funding of agricultural projects by commercial banks. A whooping sum of ₦200 billion seven-year bond was raised through the Debt Management Office and channeled through designated commercial banks for onward lending to actors in the agricultural sector (Olomola and Yaro, 2015)

Furthermore, Nigerian Incentive-Based Risk Sharing for Agricultural Lending (NIRSAL) came on board in 2011 to mitigate the challenges of underfunding in agro-business development, especially value chain enhancement in six major crops popularly grown across six agro-ecological belt of Nigeria. These crops are cassava, tomato, soya beans, cotton, maize and rice. NIRSAL's mandate supports provision of adequate credit line to participants along value chain of the aforementioned crops in different scales/sizes of production.

These composite programmes, schemes, projects, policies and incentives, cum enormity of financial resources deployed towards scaling up agricultural production notwithstanding, the sector continues to record abysmal performance, as it cannot meet national food requirement, supply basic inputs (raw materials) for industrial production and produce cash across agro-climatic regions with comparative and competitive advantages to generate robust foreign exchange reserve (Awe, 2013; Olomola and Yaro, 2015; Anector et al., 2016). The bane of development in the sector as highlighted by these researchers has been underfunding, as target beneficiaries of various programmes/schemes/projects could not mobilize adequate and timely financial resources to operate at optimal production level.

The dearth of literature on the performance of this government credit policy is a source of concern. There have been studies on the effects or influence of agricultural credit on farmers' productivity using primary data collected from the farmers based on their cost of production and revenue from their production process. However, primary data studies are location-specific and cannot explain the influence of credit on agricultural performance at a national level. This gap is the reason this study was executed so as to position the ACGS policy for better performance. After almost 40 years of operation of this credit scheme, about ₦84bn has been disbursed to about 931,863 farmers in the 36 states of the federation (ACGS, 2016). Sequel to the foregoing, it is imperative to assess the performance of the ACGS scheme in line with its programme development objectives.

Review of literature

Literature is replete with studies on the relationship between agricultural production and credit supply. However, point(s) of congruency on degree of association between credit supply and agricultural output have not been firmly established. In the study of Ammani (2012) where the relationship between agricultural production and formal credit supply in Nigeria was investigated, simple regression model was used. He established that formal credit positively and significantly influenced agricultural productivity. The study revealed the effects of formal credit on key agricultural sub-sectors- crops, livestock and fishery. But key set back of the study was the use of cross-sectional data which made the result location specific.

Ayegba and Ikani (2013) assessed how agricultural credit has improved rural farmers' production/productivity in Nigeria, using cross-sectional data and found that agricultural credit supply had not significantly boosted production and productivity of farming households in the rural area. Similarly, Awe (2013) investigated the mobilization of domestic financial resources for agricultural productivity in Nigeria, using credit supply through Nigerian Bank for Commerce and Industries (NBCI) and commercial banks. His finding showed that there was a positive relationship between credit supply and agricultural productivity in Nigeria. Tasie and Offor (2013) analyzed the impacts of International Fund for Agricultural Development (IFAD) credit supply on rural farmers' production and income in River State, Nigeria through the administration of questionnaires. They found that the IFAD credit programme contributed significantly to farm output and income.

Furthermore, Zakaree (2014) examined the impact of ACGSF on domestic food supply in Nigeria, using the ordinarily least square approach and asserted that the credit scheme had a positive and significant impact on domestic food supply. Recent study of Chisasa and Makina (2015) on bank credit and agricultural output in South Africa using cointegration and error correction model (ECM) revealed that credit supply has a positive and significant impact on agricultural output in the long run, while the ECM result showed that bank credit had negative impact on agricultural out in the short run. In the study of Anector et al. (2016) on Credit Supply and Agricultural Production in Nigeria: A Vector

Table 1. Description of variables.

Variable	Description
Dependent variable	
In AGCGDP	Natural logarithm of contribution of Agriculture to Gross Domestic Product, GDP.
Independent Variable	
In TVLN	Natural logarithm of total volume of loan given within the period under study.
In TNL	Natural logarithm of total number of loan given within the period under study.

Table 2. Unit root test result.

Variable	ADF Statistics		Critical values			Order of Integration
	Levels	1st Difference	1%	5%	10%	
InAGCGDP	-1.62(1)	-4.57(0)**	-3.63	-2.95	-2.61	I(1)
InTVLN	-0.54(0)	-6.60(0)**	-3.63	-2.95	-2.61	I(1)
InTNL	-1.39(1)	-5.41(0)**	-3.63	-2.95	-2.61	I(1)

**Stationary at 5%. The value in parenthesis is the optimal lag for the ADF. Authors' Computation via Eviews 9.

Autoregressive (VAR) Approach, they found that ACGSF had performed poorly in explaining agricultural sector performance while commercial loans to agricultural sector had a significant impact on agricultural production. The key area of departure of the present work from the previous studies is in the matching of volume of credit facilities of ACGF with number of beneficiaries and isolating its impacts on agricultural productivity at national level.

MATERIALS AND METHODS

This study was carried out in Nigeria. Nigeria is a West African country blessed with green land in vast quantity and available labour to maximize the opportunities nature has afforded her. Time series data of 1978-2014 from the 2014 bulletin of the National Bureau of Statistics, NBS, were used for the purpose of this research. Agricultural productivity was proxy with the contribution of agriculture to Gross Domestic Product, while the total volume of loans given in naira (₦) and total number of loans issued were proxy as performance of the credit policy within the period under review. The definition of variables is stated in Table 1.

To ascertain the order of integration of the variables, the Augmented Dickey Fuller (Dickey and Fuller, 1979) unit root test was carried out using:

$$\Delta Y_t = \propto + \rho Y_{t-1} + \sum_{i-1}^{j} Y\Delta Y_{t-j} + U_t \quad (1)$$

where, Y_t refers to the variables (InAGCGDP, InTVLN and InTNL) to be tested. The sufficient lag lengths, *i*, are chosen using Schwarz Information Criterion (SIC). The sufficient lag lengths *j* of ΔY_t whitens the errors. The U_t is the error term. These tests were employed under the null hypothesis that there is unit root in the variable. If the t-statistics is higher than the critical value, the null hypothesis cannot be rejected; otherwise, the null hypothesis cannot be accepted. The estimate of the ADF unit root test is stated in Table 2.

From the above, the three variables are integrated of order I(1), that is, they are all stationary after first difference. The ARDL model which was developed by Pesaran and Shin (1999) and Pesaran et al. (2001) was employed to estimate the long and short run dynamics of ACGS credit policy and agricultural productivity. The ability of this model to estimate both long and short run relationship of variables in a single model informed its adoption for this study. The ARDL functional relationship is stated as:

$$\text{InAGCGDP} = \beta_0 + \beta_1 \text{InTVLN} + \beta_2 \text{InTNL} + \varepsilon_i \quad (2)$$

Where:
$\beta_0, and\ \beta_1, \beta_2 = constant\ term\ and\ parameter\ to\ be\ estimated$;
ε_i = white noise

To test for the long and short run dynamics in Equation 2 according to Pesaran et al (2001), Equation 2 was developed into the unrestricted error correction model. The general ARDL model is given as:

$$\Delta\text{InAGCGDP} = \gamma_0 + \sum_{i=1}^{n} \alpha_1 \Delta InAgric_{t-i} + \sum_{i=0}^{n} \alpha_2 \Delta InTVLN_{t-i} + \sum_{i=0}^{n} \alpha_3 \Delta InTNL_{t-i} + \delta_1 InAgric_{t-1} + \delta_2 InTVLN_{t-1} + \delta_3 InTNL_{t-1} + \epsilon_i \quad (3)$$

Where, γ_0 is the intercept, $\alpha_1, \alpha_2, \alpha_3$ are the short-run coefficient, $\delta_1, \delta_2, \delta_3$ are the long-run coefficients and ϵ_i is the white noise.

In order to ascertain the presence of cointegration among the variables, Bounds test was carried out. The Bounds testing which is based on F-statistics was used to test the hypothesis of no presence of cointegration against the alternative of presence of cointegration which is stated as:

H_0: $\beta_1 = \beta_2 = \beta_3 = 0$, that is, there is no conitegration among the variables;
H_a: $\beta_1 \neq \beta_2 \neq \beta_3 \neq 0$, that is, there is cointegration among the variables.

Since a long run relationship was established among the variables under study, then, the parameters (elasticities) of the long-run relationship were estimated in the following equation:

$$\text{InAGCGDP} = \beta_0 + \beta_1 InAgric_{t-1} + \beta_2 InTVLN_{t-1} + \beta_3 InTNL_{t-1} + \epsilon_i \quad (4)$$

To estimate the short run influence of total volume and number of loans given over the period under study, the following short run function was estimated:

$$\Delta\text{InAGCGDP} = \gamma_0 + \sum_{i=1}^{n} \gamma_1 \Delta InAgric_{t-i} + \sum_{i=0}^{n} \gamma_2 \Delta InTVLN_{t-i} + \sum_{i=0}^{n} \gamma_3 \Delta InTNL_{t-i} + \beta_3 ECM_{t-1} + \epsilon_i \quad (5)$$

RESULTS AND DISCUSSION

Due to the small sample size of this study, the Narayan (2005) critical values table was used to compare the F-statistics for the validation or otherwise of the hypothesis. Where, the F-statistic is below the lower bound I(0), the null hypothesis of no cointegration is accepted and if it is above the upper bound I(1), the null hypothesis of no cointegration cannot be accepted; therefore, the alternative is accepted. However, if the F-statistic falls in-between the lower and upper bound values, the result is deemed inconclusive. The number of lags used for his study based on the Akaike Information Criterion is 5. The calculated F-statistics from the bound test is presented in Table 3.

From the estimates above, the F-statistics is higher than the upper bound critical value. Thus, there is presence of a long run relationship among the variables, indicating a long run economic relationship among agricultural productivity, numbers and volumes of loans given to the farmers under the ACGS credit policy.

Estimate of long-run parameters

The result of the estimate of the influence of total volume of loan in the long run on agricultural productivity is presented in Table 4. As indicated in the table, the total volume of loan in the long run does not significantly influence agricultural productivity. This may be due to the fact that the volume of loan given yearly has been static with imperceptible marginal increase. For instance, the two notable periods where there were increases in the volume of loans given out were between 2010/2011 and 2013/2014. The volume of loan given in 2011 increased to about ₦10.19bn from about ₦7.7bn in 2010 and the highest increase was from about ₦9.42bn in 2013 to about ₦13bn in 2014. Whereas, the total number of beneficiaries increased from 50,849 in 2010 to 56,328 in 2011 and from 56,277 in 2013 to 72,322 in 2014. Though total number of loans given was highly significant and positive, the volume of loans made available for this increase in beneficiaries could not justifiably influence agricultural productivity. The positive and significant relationship between total number of loans and agricultural productivity may be associated with the fact that the farmers look elsewhere for alternative sources of credit to fund their farming activities. Be that as it may, *ceteris paribus*, the result further revealed that everyone involved in agriculture added to productivity irrespective of the magnitude. This may also account for the positive relationship of total number of loans with productivity because the higher the number of loans, the higher the number of beneficiaries. If the amount available to each beneficiary will now be adequate for production is another question which as well had being answered by the negative relationship of volume of loan with productivity. The negative coefficient of constant affirms the general saying that credit is the lubricant to the wheel of production without which other factors of production may not be employed. Thus, should there be no loan given to anyone, this negative relationship portends that productivity would be negative. Though agriculture could sometimes thrive even with no deliberate efforts from man, as some crops and fruits may just produce in their own time on their own, the kind of productivity being considered in this study is commercial agriculture. This thus confirmed the general understanding of credit as a lubricant without which rational and national agricultural productivity may not be achieved.

Short-run parameter estimate of dynamics of ACGS and agricultural productivity

Results of the elasticities of the short run dynamics of ACGS credit policy and agricultural productivity are shown in Table 5. From the table, total volume of loan disbursed to farmers was significant in the past 2 and 3 years at 1% and 4 years at 10%. While it positively and significantly influenced productivity within these periods, ACGS credit policy has a positive but insignificant relationship with productivity in the penultimate year and a negative, insignificant relationship in the current year. Apart from the current year where total number of loan is positive and significant with productivity, there is a negative relationship between total number of loan and productivity in the past 3 years. However, there is no significant relationship in ΔInTNL (-1). This negative relationship can be attributed to inadequacy of the volume of loan given to farmers under this scheme. The ECT (-1) is both negative and significant at 1%, suggesting backward movement of the model from a short run disequilibrium to a long run steady state at the speed of adjustment of 19.91%. This also confirms the presence of long run relationship among the variables.

Residual diagnostic tests

The results of the diagnostic tests are presented in Table 6. Information contained in Table 6 indicates that the model is free from serial correlation, normally distributed and free from heteroskedasticity with p-values greater than 5% in all residual tests.

Table 3. Bounds test result for long-run relationship.

Critical values (restricted intercept and no trend)	Lower bound	Upper bound
1%	5.155	6.265
5%	3.538	4.428
10%	2.915	3.695

Calculated F-statistics = 27.3534 at k=2; Authors' computation via Eviews 9.

Table 4. Long-run estimated parameters.

Variable	Coefficient	Standard Error	T-statistics	P-value
InTVLN	0.1378	0.1536	0.8971	0.03809
InTNL	1.4173	0.2977	4.7617	0.0001***
Constant	-6.1317	2.8845	-2.1258	0.0469**

R^2 = 0.958 Adj R^2 = 0.945ARDL (1,5,4) selected based on Schwarz Bayesian Criterion. Authors' Computation via Eviews9.
{*} significant at 5%{1%}.

Table 5. Short-run estimated parameters.

Variable	Coefficient	Standard error	T-statistics	P-value
∆InTVLN	-0.5399	0.0569	-0.9493	0.3544
∆InTVLN(-1)	0.0531	0.0506	1.0493	0.3072
∆InTVLN(-2)	0.2071	0.0452	4.5809	0.0002***
∆InTVLN(-3)	0.2454	0.0529	4.6407	0.0002***
∆InTVLN(-4)	0.0833	0.0432	1.9273	0.0690*
∆InTNL	0.4169	0.0834	4.9958	0.0001***
∆InTNL(-1)	-0.0773	0.0942	-0.8198	0.4225
∆InTNL(-2)	-0.5658	0.0927	-6.1062	0.0000***
∆InTNL(-3)	-0.4501	0.1048	-4.2956	0.0000***
ECT_{t-1}	-0.1991	0.0177	-11.2556	0.0000***

Authors' Computation via Eviews9; ***(*) significant at 1%(10%).

Table 6. Residual diagnostic test.

Test for normality			
Jarque-Bera	1.1847	Prob(Jarque-Bera)	0.5530
Breusch-Godfrey serial correlation LM test			
F-statistic	0.6518	Prob.F-stat:(2, 17)	0.5337
Obs*R-squared	2.2789	Prob.Chi-square(2)	0.3200
Breusch-Pagan-Godfrey Heteroskedasticity test			
F-statistic	0.3581	Prob.F-stat:(12, 19)	0.9635
Obs*R-squared	5.9028	Prob.Chi-square(12)	0.9209

Author's Computation via Eviews9.

Stability tests

As proposed by Brown et al. (1975), the CUSUM and CUSUMSQ tests were used to examine the stability of the model. If the plot of the cumulative sum goes outside the area of 5% critical lines, the parameter estimates are

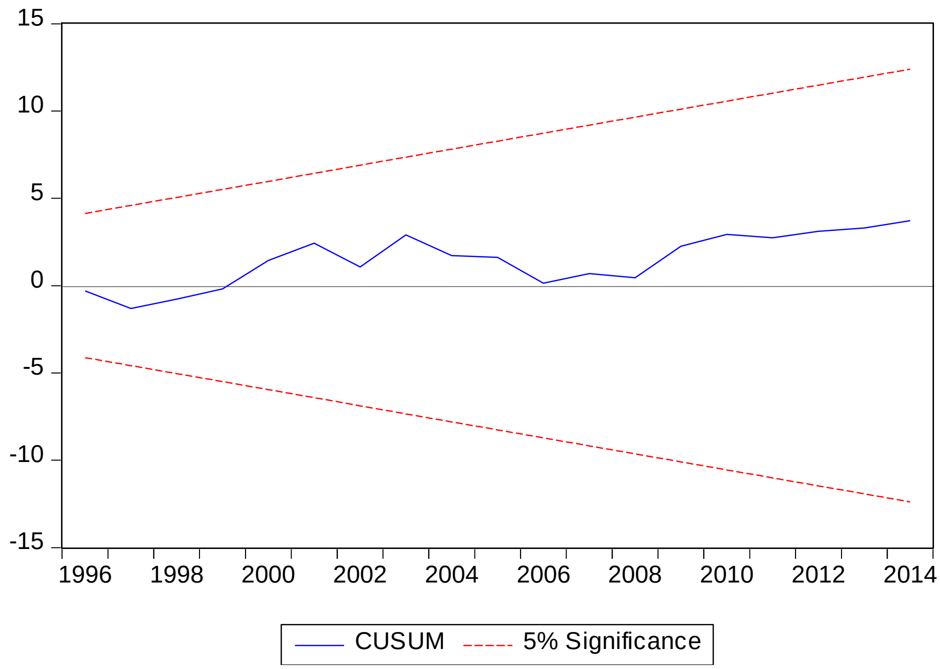

Figure 1. Plot of CUSUM test.

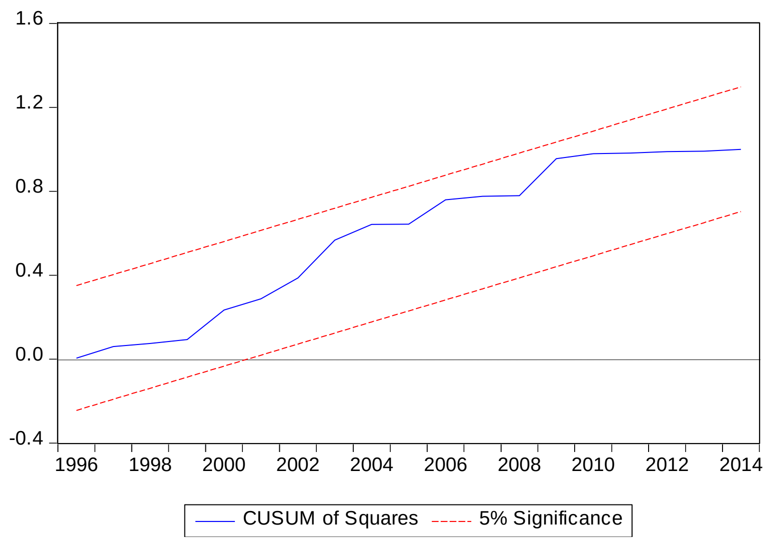

Figure 2. Plot of CUSUMSQ.

found not to be stable. The test results are graphically presented in Figures 1 and 2. As shown in the figures, both CUSUM and CUSUMSQ are stable with the mean and variance lying in-between the two critical boundaries at 5% significance level. This implies that the residuals of model used in this study is stable, hence policy implications and recommendations emanating from this study are adoptable and adaptable to improve agricultural productivity in Nigeria through the ACGS credit scheme.

Summary of findings

This study examined the performance of the major credit policy of the Federal Government of Nigeria, that is, the Agricultural Credit Guarantee Scheme which was created in 1977, but started operation in 1978. The data used for this study spanned from 1978 to 2014. The focus is on how well this major credit policy of the government has been able to influence agricultural productivity. Credit is so crucial to agricultural production such that without it, it might be impossible for optimum production to take place. If production takes place without credit, it will be subsistent production. Hence, such a credit policy which began over 30 years should be examined so as to position it rightly to maximize its potentials.

Autoregressive Distributed Lag model was used to estimate the long and short run dynamics of the performance of the credit policy and agricultural productivity after the variables have been confirmed not to contain an I(2) variable, that is, variable stationary after second difference. From the ADF unit root test, the variables are all I(1). That is, all the variables became stationary after first difference. The ARDL (Bound) testing approach to conitegration was used to establish the presence of a long run relationship among the variables. From the F-statistic, there is a presence of long run relationship among the variables. The long run estimates show that the total volume of loans was not significantly related to productivity. This may be, because the total amount of loans made available for the beneficiaries was not adequate for commercial agriculture which is the kind of production system that can take Nigeria away from its present economic comatose, as well as make agriculture work again like it was before the oil boom. However, the total number of loan given is significant. This is because even though the amount given to each beneficiary may not have been enough for production, each beneficiary adds to the total productivity in agricultural sector, no matter how little the output could be. The short run estimates however differ on the total number of loans given within the period. Although, there is a significant relationship between the number of loans given under the credit policy and productivity in the current year, and past 2 and 3 years, it was not significant in the past 1 year. Except for the current level where total number of loan had a positive relationship with productivity, in the past three years, it shows a negative relationship. There is a negative and insignificant relationship between productivity and volume of loan in the current year while the relationship in the past year is though positive but insignificant. However, there is a significant and positive relationship in the past 2-3 years. This may be due to adequate monitoring of the loans which were given to beneficiaries in the past 2-3 years and favourable weather conditions, which enhanced higher production.

Conclusion

In sum, it cannot be emphatically said that ACGS credit policy has really achieved much in terms of using the instrument of credit to stimulate commercial agriculture and greater productivity, as well as ensure that farmers earn commensurate returns on their investment and adequate food availability for the citizens in good quantity, quality and prices. This reason for this is not far-fetched. With insignificant volume of loan, the numbers of farmers benefiting from the credit scheme have been increasing disproportionately to credit amount, such that the available facility cannot adequately go round among the beneficiaries for commercial production.

Policy implication

It is therefore important that government should focus on how to make use of the scheme to engineer commercial agriculture. Loan volume disbursed to farmers in year 2014 with a total volume of about N13bn for instance, would have achieved better result, if it was disbursed to 30,000 intended beneficiaries (farmers). Agriculture is a business and should be treated so. Disbursement of credit to farmers should be done without political inclination, such that only the target beneficiaries access the designed facility. Hence, every political tendency which lead to propaganda of creating thousands of jobs in agricultural sector devoid of quality production should be put aside and commercial focus and market driven agricultural production be built into the credit policy.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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Abbreviations

ADP, Agricultural Development Programme; **OFN,** Operation Feed the Nation; **RBP,** Rural Banking Programme; **GR,** Green Revolution; **NAIC,** Nigerian Agricultural Insurance Corporation; **CACS,** Commercial Agricultural Credit Scheme; **NIRSAL,** Nigerian Incentive-Based Risk Sharing for Agricultural Lending; **NAPEP,** National Poverty Eradication programme; **ACGS,** Agricultural Credit Guarantee Scheme; **BoA,** Bank of Agriculture; **TVL,** total volume of loans; **TNL,** total number of loans.

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Full Length Research Paper

Integration of post-harvest management in agricultural policy and strategies to minimise post harvest losses in Lesotho

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Despite global efforts to increase food availability and curb high incidence of malnutrition in Africa, there are concerns with regard to high post-harvest losses in Africa. Lesotho like most countries in sub-Saharan Africa faces documented challenges with food insecurity and nutrition. Food availability could be increased by reduction of post-harvest losses without further exploitation of resources. Mitigation of post-harvest losses is seen as a possible antidote for increasing food availability and nutritional status in countries experiencing high food losses. This study investigated the extent of integration of post-harvest management in agricultural policy in Lesotho and strategies to minimise post-harvest losses. Purposive sampling was utilised in order to select a sample of twenty-five respondents on which interviews were conducted. Thematic analysis was used to identify a set of overarching themes that can be used to describe the policy environment and strategies to reduce post-harvest losses. The analysis suggests that there is absence of a direct policy to guide post-harvest management activities in Lesotho, it is only referred to indirectly in other policies with the exception of dairy products sector which has a direct post harvest management policy. Strategies to curb post-harvest losses were also identified. The study concludes that there is need for a direct policy to address post-harvest management in Lesotho.

Key words: Lesotho, post harvest management, natural resources, food policy, agricultural development.

INTRODUCTION

Lesotho is largely a rural economy although it is rapidly urbanising with over 70% rural population dependent mainly on agriculture related activities for their livelihoods (Government of Lesotho, 2018). Lesotho for years has experienced successive frequent climate shocks such as dry spells, floods and recurrent droughts with dire consequences on the food security of the population (Government of Lesotho, 2018). Therefore, in all practical terms Lesotho is generally regarded a food deficit country and it is highly dependent on its neighbour, South Africa for supplementation of its food requirements. Furthermore, expansion of Lesotho agricultural sector is prone to severe challenges such as land degradation, limited land and water resources, increased weather

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variability and difficulty in adapting to climate change (Aulakh and Regmi, 2013; Wikle, 2015). It is imperative that post-harvest management principles be inculcated into local farmers so that post-harvest losses from the produce realised are minimised. Global food loss and waste is estimated at 32% (FAO, 2011a). In sub Saharan Africa (SSA), the estimated food loss and waste is roughly 37% (Sheahan and Barrett, 2017; Kaminski and Christiaensen, 2014). Food loss mitigation strategies present opportunities that suggest an urgent need for greater attention to post-harvest loss (PHL) in addressing the world's food challenge (World Bank, 2011a; World Bank et al, 2011b). FARA (2006) asserts that sub-Saharan African agriculture productivity and per capita value of agriculture output is the lowest in the word. World Bank et al. (2011b) opines that despite the low total agricultural productivity, post-harvest losses of the food being produced are significant. The enormous magnitude of food losses has prompted experts to agree that investing in post-harvest losses reduction is a quick impact intervention for enhancing food security (GIZ, 2013).

Post-harvest management has been around for decades; however, there has been renewed interest in investment in agriculture since 2008 which has also put post-harvest management practices at the forefront of agricultural sector development debate (Kiaya, 2014). In addition to the renewed interest in investment in agriculture, in September 2015, the United Nations (UN) ambitiously announced a goal of halving worldwide food waste and substantially reducing the global food loss by 2030 as part of Sustainable Development Goals (SDGs) agenda (Sheahan and Barrert, 2017). This has been largely in line with the global goal of ensuring food security for the growing world population and at the same time ensuring that production of food for consumption is sustainable. Despite major investments in improved and increasing climate smart crop and livestock production practices, one of the most significant and unaddressed sources of food insecurity is post-harvest losses due to ineffective post-harvest management. Obviously, one of the major ways of strengthening food security is by reducing these losses (Affognon et al., 2015).

A food self-insufficient and food insecure country like Lesotho needs to take a pragmatic approach in terms of addressing challenges emanating from post-harvest losses. Efforts to improve farmers' welfare through increasing yields for major crops in Lesotho will be futile if a substantial proportion of the crops produced is lost during and/or after harvesting due to inappropriate crop handling, processing, marketing activities and storage technologies (Abass et al., 2014). Postharvest Loss (PHL) is defined to include any loss in quality or quantity that occurs between the time of harvesting and the time it reaches the consumer (Grolleaud, 2002). The postharvest sector includes all points in the value chain from production in the field to the food being placed on a plate for consumption. In this regard, postharvest activities include harvesting, handling, storage, processing, packaging, transportation and marketing of agricultural products.

Postharvest management determines food quality and safety, competitiveness in the market, and the profits earned by producers. In most developing countries, postharvest management of produce is far from satisfactory (Tadesse et al., 2018). The major constraints include inefficient handling and transportation; poor technologies for storage, processing, and packaging; involvement of too many diverse actors; and poor infrastructure. Apparently, farmers and farm produce handlers, especially women, lack adequate information on proper crop harvesting and handling methods, leading to significant damage by insect pests during storage and marketing (Rugumamu, 2009; Kereth et al., 2013). The high postharvest losses have a negative impact on the income, livelihoods and motivation to expand production among farmers. Inadequate storage which is among the important causes of postharvest losses, constitutes a public health threat when people consume spoiled food, causes supply fluctuations and exacerbates the problem of high food prices.

In order to mitigate food losses multi-stakeholder cooperation is required since the food losses can have a high impact on the nutritional and income status of the producers, market operators and the consumers. Lesotho has a great challenge with malnutrition and stunting which was last reported to be 33.2% (Government of Lesotho, 2018). Quality and quantity of crops produced in Lesotho have to be preserved in order to address these two twin challenges. There is an increasing interest in effective intervention for post-harvest losses reduction in sub-Saharan Africa and other developing countries. Chegere (2018) asserts that food losses in developed countries are as high as in developing countries. Nonetheless, in developing countries the largest proportion of food is lost during post-harvest handling processes and storage; while in developed countries the food losses occur mostly at retail and consumer levels (FAO, 2011b). Abass et al. (2014) concur with Chegere (2018) asserting that post-harvest losses in the developed countries are lower than in the developing countries because of more efficient farming systems, better farm management and effective storage and processing facilities that ensure a larger proportion of the harvested foods is delivered to the market in the most desired quality and safety.

Post-harvest management is believed to have an enormous potential in assuring the quality and safety of crops, addressing on the-farm and post-farm losses (Kader and Rolle, 2004). In order to ensure sustainable use of economic resources wastage and losses should be minimised and at best eliminated. Loss of quality and quantity also has implications nutritionally and in terms of food security. Kiaya (2014) states that food losses are mainly due to poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors and lack of markets (these factors are largely common amongst poor small-scale farmers). Hence, most food losses are experienced by poor farmers who become greatly disadvantaged due to the losses as this has financial implications (Tadesse et al., 2018). Therefore, it is of paramount importance to interrogate the extent to which national policies in Lesotho integrate post-harvest management practices. Abass et al. (2014) argue that it is a priority of most African countries to identify best practices and innovative arrangements for increasing agricultural productivity to improve income and nutrition of farm households. Policies offer direction and certainty for concerned stakeholders, and if there are no clear-cut policies, the operation and business climate become less appealing. Lesotho has limited arable land (Forum for Food Security in Southern Africa, 2002; FAO, 2005), therefore a strong post-harvest management policy is important to ensure that losses are minimised so that food and nutritional security is achieved self-sufficiently. Reduction of food losses offers an important pathway of availing food, alleviating poverty, and improving nutrition (Affognon et al., 2015).

Reduction of both post-harvest losses and quality deterioration are essential in increasing food availability from the existing production. Food availability can be increased without further exploitation of natural resources if food losses are curbed. Tadesse et al. (2018) assert that increasing the food availability is therefore not only increasing the productivity in agriculture, but also lowering losses. Minimizing this loss has a great significance for food security, economic growth and welfare of the society (Kasso and Bekele, 2018). In Lesotho, post harvest management is practiced informally, however, there has not been a study on integration of post-harvest management in the national strategic plans and strategies to the best of author's knowledge. This particular study seeks to understand the extent of integration of post-harvest management in policies in Lesotho. It would also be important to understand the challenges faced by various key actors in post-harvest management in Lesotho and strategies to overcome those challenges.

MATERIALS AND METHODS

A descriptive qualitative research design is used to explain post-harvest management strategies and policy environment in Lesotho. The actors were asked to describe the policy environment whether it is conducive for post-harvest management activities. Furthermore, the study solicitated strategies to overcome post-harvest losses from the respondents. The study purposively used the experience and views of actors who are involved in the post-harvest activities rather than review national policies. The study collected primary data from key actors in the Lesotho agricultural sector that are involved in the postharvest activities. The actors included officials from the Ministry of Agriculture and Food Security which has a number of departments (Table 1), Non-Governmental Organisations (NGOs), Farmer Association Representatives, Smallholder Agriculture Development Lesotho (SADP), and Members of Academia (Agriculture Colleges and Universities). Table 1 summarises and profiles the participants of the study in terms of organisation (affiliation), years of experience and job title. The study used purposive sampling approach where the respondents were selected after careful consideration of their experience, knowledge and role in post-harvest management. The respondents were included in the study after careful consideration of the role that they play in post-harvest management activities in Lesotho. The study had a sample of 25 respondents who were interviewed using an interview schedule which was composed of open ended questions.

The data was analysed using thematic analysis, a qualitative data analysis approach. Nowell et al. (2017) postulated that thematic analysis is an apt qualitative method that can be used in analysing qualitative dataset. The study used thematic analysis because a rigorous thematic analysis can produce trustworthy and insightful findings (Braun and Clarke, 2006). Thematic analysis was used to analyse the data collected from the respondents to the study and thereafter a report of the findings of the study was produced. Braun and Clarke (2006) argue that thematic analysis is a method for identifying, analysing, describing and reporting themes found in a dataset. The data analysis for this study was done following the six steps first given by Braun and Clarke (2006) illustrated in Figure 1.

RESULTS AND DISCUSSION

Word Bank (2011) asserts that despite a number of endeavours to counter PHLs, there are few success stories implying that the strategies and approaches for mitigating PHLs have not yielded compelling impacts in SSA. A good understanding of the agro-ecological and socioeconomic drivers of post-harvest losses is important in order to inform policies targeted at its reduction (Kaminski and Christiaensen, 2014). In Lesotho, through this study, the following factors have been highlighted by the respondents to the study (Figure 2). The respondents represented a broad base of stakeholders directly and indirectly involved in post-harvest management activities. Each of the main factors identified are as shown in Figure 2 which shows the main factors identified by the respondents as the major drivers of PHL in Lesotho. Each of these factors was based on the themes which were extracted from the responses given by study participants and these themes would be discussed in the following.

Absence of direct PHM policy and regulations

Questions that were linked to the extent towards which post-harvest management was integrated in policy were largely directed to the government officials, United Nations agencies and other non-government organisations. The officials revealed that there was a dearth of policy at the national level crafted by government to address issues to deal with post- harvest management. The policies that are currently available deal with post-harvest management indirectly and sometimes in

Table 1. Profile of the study respondents.

Participant	Organisation	Position	Years of experience in the field
1	Rural Self Help Development Association	Agronomist	4 months
2	World Vision Lesotho	Technical Program Manager	6 years
3	Catholic Relief Services	Technical Officer Agriculture	12 years
4	LENAFU	Crop Scientist and Agronomy Consultant	5 years
5	SADP	Senior Technical Officer	8 years
6	UNDP	Programme Assistant	21 years
7	Basotho Poultry Farm Association	Head of Institution	10 years
8	Exclusive Piggery Network of Lesotho	Committee Member	1 years
9	Lesotho National Dairy Board	Supervisor	12 years
10	Maseru Piggery Association	Head of Institution	1 years
11	Department of Marketing	Senior Marketing Officer	12 years
12	Department of Livestock	Principal Livestock Officer(Cattle)	10 years
13	Department of Crops (Horticulture)	Technical Officer	5 years
14	Department of Research	Senior Research Officer	10 years
15	Department of Planning and Policy Analysis	Asssistant Economic Planner	4 years
16	Department of Research	Senior Research Officer	8 years
17	Department of Field Service	Director	28 years
18	Department of Crops (Agronomy)	Crop Production Officer	10 years
19	Department of Research	Research Officer	10 years
20	Lesotho Agricultural College	Lecturer	10 years
21	Lesotho Agricultural College	Lecturer	12 years
22	National University of Lesotho	Lecturer-Crop Science	12 years
23	National University of Lesotho	Lecturer-Animal Science	2 years
24	National University of Lesotho	Lecturer-Nutrition	9 years
25	Lesotho College of Education	Lecturer	2 years

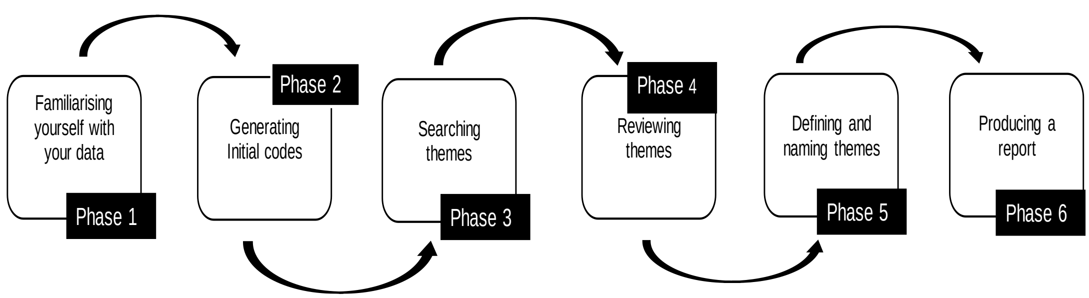

Figure 1. The six-phase thematic analysis.
Source: Adapted from Nowell et al. (2017) and Braun and Clarke (2006).

a shallow manner. The dearth of policies that directly address PHM results in challenges with regards to implementation of post-harvest management activities since lack of clear policy direction impede such efforts. Parmar et al. (2017) argue that effective government policy at institutional and regulatory levels should complement efforts and interventions aimed at reducing post-harvest losses.

Government officials, non-governmental organisations and some members of the private sector who were target respondents for questions related to regulation of post-harvest handling practices. The respondents highlighted the lack of regulations for post-harvest handling as well as lack of technical standards. The market rejects the farmer's products sometimes as a result of poor quality due to lack of technical standards leading to increased postharvest losses. This is confirmed by Affognon et al. (2015) asserting that in many SSA countries quality standards are not enforced or do not exist. The absence of technical standards compromises quality and the

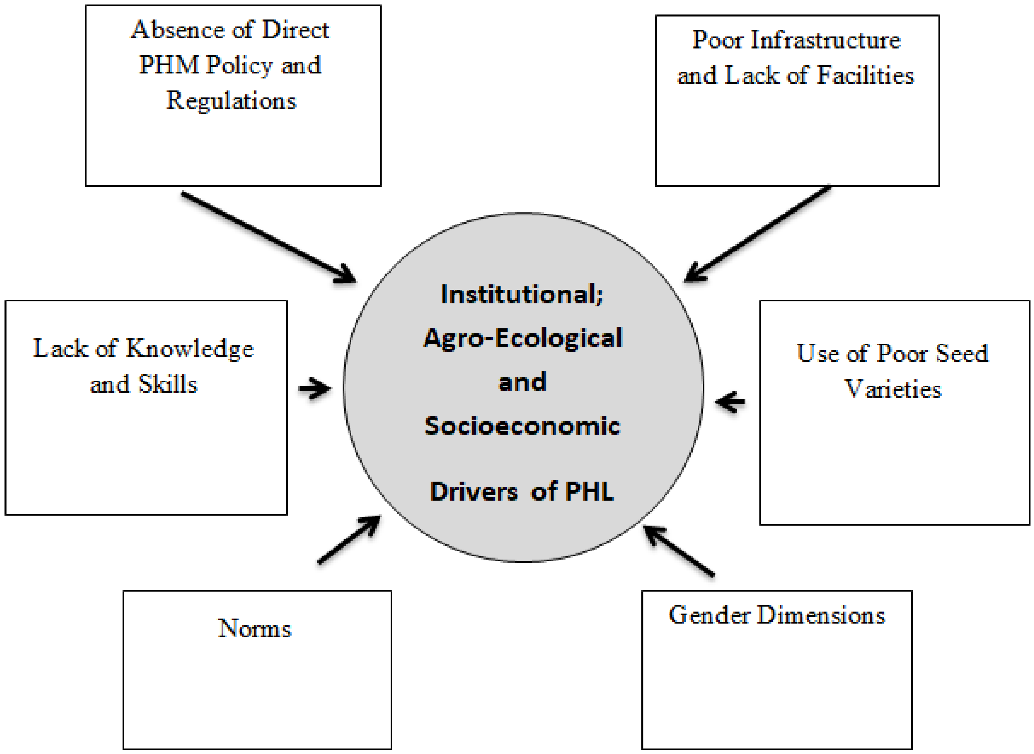

Figure 2. Institutional, Agro-ecological and Socioeconomic drivers of PHL in Lesotho.
Source: Author Survey and Compilation (2019).

safety of the foodstuffs when they reach the final consumer. Technical and quality standards are important in order to ensure food safety for consumers as well as to ensure good farmers are rewarded. Swinnen et al. (2015) assert higher product standards signalled as a result of investment in food safety may lead to increased opportunities for exports and access into international markets for SSA producers and processors. The respondents encouraged government to develop international and national standards for Lesotho farmers' produce.

Dairy production was the only agricultural produce sector of Lesotho which was identified to have in place a direct policy, regulations and standards. It is regulated by the Distribution of Dairy Products Act of 1991 and also the Milk Hygiene regulation. These national policies regulate the marketing, standardisation and milking of cows. GPLP Project (2014) argues that having a policy alone, though necessary is not sufficient to address the problem of high postharvest losses. This is mainly due to the fact that having a well-designed policy in terms of contents and implementation strategies is one thing and having the policy implemented successfully is a different matter. Lack of successful implementation of the policies was identified as a challenge in the dairy produce industry. The policies are also old and need to be reviewed.

Poor infrastructure and lack of facilities

Majority of policy makers and implementers who responded to the study indicated that access to markets, poor infrastructure and in some instances absence of infrastructure hinders postharvest management activities. Some of the missing critical facilities for post-harvest management in Lesotho include market centers, silos, abattoirs and slaughter houses. Kasso and Bekele (2018) reported that in Dire Dawa town in Ethiopia farmers did not have suitable storage facilities and marketing sites. World Bank et al. (2011b) confirms that in low-income countries processing, storage infrastructure and market facilities are either not available or are inadequate. All categories of stakeholders specifically mentioned poor storage, lack of storage facilities, poor road network and lack of market information as key challenges that lead to high postharvest losses.

Inadequate storage facilities is a common challenge as suggested by Tedesse et al. (2018) who found that farmers raised concern over the lack of storage facilities. Education stakeholders stated that they do not have adequate facilities and hence they are unable to perform certain postharvest management practicals during the course of student instruction. The respondents representing stakeholders from the poultry and piggery associations raised concern over lack of abattoirs and slaughter houses. Electricity shutdowns were also singularly raised as a major concern by meat producers as power cuts lead to compromise on the quality of meat. The frequency of load shedding and power cuts should be reduced so that quality of meat is preserved when it is in storage. Governments in low income countries have to consider investing in good storage facilities so that the quality of produce is preserved before it is taken to the market.

Kaminski and Christiaensen (2014) stated that the use of improved storage technologies reduce post-harvest losses, with the use of modern storage technologies reducing post-harvest losses more than the use of traditional storage technologies. Traditional facilities used for storage attract pests and diseases which destroys the produce. These challenges are very common in Lesotho. Lesotho is a low-income country and farmers have difficulty in accessing modern technology, the farmers use poor storage facilities such as plastic bags, in house or ceiling storage, unprotected piles, open drums and sacks. The poor storage and processing techniques are associated with increase in post-harvest losses (World Bank et al., 2011b; Kasso and Bekele, 2018; Gardas et al., 2017). World Bank et al. (2011b) state that losses are aggravated by poor post-harvest handling, infrastructure, harvesting methods, distribution, sales and marketing policies. Abass et al. (2014) claim that post-harvest losses in developed countries are limited by more efficient farming systems; better transport infrastructure, effective storage and processing facilities.

Lack of knowledge and skills

Farmers' associations revealed that lack of postharvest management knowledge and skills increase post-harvest losses. This is similar to findings by Tedesse et al. (2018) that farmers in Southwest Ethiopia lack skills of pre and post-harvest management. Tedesse et al. (2018) argued that training in pre and post-harvest management is one of the important factors in reducing post-harvest losses. Lesotho farmers would therefore need to be equipped with skills and knowledge of post-harvest management. Rugumamu (2009) and Kereth et al. (2013) highlighted the challenge of lack of adequate information on proper crop harvesting and handling amongst most farmers and crop handlers in Africa. Educational status of household members is of importance as it may affect PHL directly since more educated households may have a better understanding of how to avoid PHL (Kaminski and Christiansen, 2014). Household heads who had acquired post primary education experienced lower rates of PHL (Kaminski and Christiaensen, 2014). Farmers acquire knowledge and skills from institutions of learning as well as from extension workers. Transmission of knowledge and skills to farmers through training and other extension services would ensure that farmers know the right varieties to plant so that they avoid plant varieties with high pre-harvest and post-harvest losses. There are maize varieties which are highly susceptible to pest attack on the field and during storage while others are resilient. Such information if provided to farmers will curb post-harvest losses. This is besides the fact that households have indigenous knowledge which is passed down from generation to generation, which is also vital.

Abass et al. (2014) assert that dissemination of improved agro-processing technologies and training of the smallholder farmers is necessary to achieve food security and improved nutrition. Through training, farmers acquire knowledge and skills which are necessary for effective conduct of post-harvest management activities. Maize farmers in semi-arid Central and Northern Tanzania had limited knowledge in relation to the proper harvest management methods especially pest control and storage (Abass et al., 2014). This is similar to the findings of this study which also found there was limited knowledge of proper harvest management techniques and technologies, in other cases lack of awareness of post-harvest losses. Training is necessary to bridge this gap in knowledge and skills; extension officers who are meant to advise and interact with farmers are trained in vocational training centers, colleges and universities. In Lesotho, the agricultural vocational training colleges revealed that their curriculum directly supports post-harvest management. However, the depth of post-harvest management is weak in non-agriculture vocational training colleges since it is offered under sub-topics. It was suggested that there has to be a curriculum review so that these colleges can offer independent post-harvest management courses. The current curriculum in the agricultural vocational training colleges is deep, offering both theory and practicals as part of training, with independent post-harvest management courses. Furthermore, the courses cover most components of post-harvest management such as harvesting, on-farm handling, post-harvest handling, preservation, storing, processing, packaging, transporting and marketing. The students are trained on how to handle fruits, vegetables and cereals.

Lack of proper facilities is an issue however, therefore the colleges are not able to do post-harvest management of meat. In the university, postharvest management courses are not all independent as postharvest management is taught as course topics in some departments with certain crops and animals. In contrast to the vocational college curriculum at the university level, the curriculum covers theory with limited practicals, however, the curriculum covers most aspects of post-harvest management. The academic staff have an overwhelming desire to offer more practicals if equipment and facilities are made available in the university. There is also an intention to revise the curriculum so that post-harvest management is offered as an independent course. Kitinoja et al. (2011) stated that postharvest management should be integrated in the curriculum to increase the postharvest loss reduction efficiency. This should be done to ensure future young farmers and extension officers know all components of postharvest management, the importance and benefits of postharvest management so that they can be able to practice it.

Use of poor seed varieties

Good quality seeds, favorable climate and good soil quality have a prominent role to play in increasing agricultural production (Gardas et al., 2017; Afadhali, 2015; Mwendwa, 2015). Sheahan and Barret (2017) concur stating that one of most important means of mitigating losses in the field is the cultivar selection and development. The officials from the Department of Research and Department of Crops expressed concern over the use of uncertified seed. Farmers often use the maize seed from harvest of the previous season as seed in the upcoming season. The challenge with uncertified seeds is the lack of capacity to resist pest attacks. PHL interventions that aim to reduce PHL while crops are still in the field are arguably more effective than deploying strategies that only start after harvest (Ippolito and Nigro, 2000). These interventions have grown in popularity because of the compounding effects of pests and deterioration accumulated before harvest. Lesotho needs to invest in accessibility of improved seed varieties for pre and post-harvest loss reduction. Such interventions have potential to increase agricultural production while minimizing post-harvest losses.

Norms

Farmers should desist from common practices such as mono-cropping which was identified to be a common practice with Basotho farmers. Monocropping results in hardening and multiplication of certain pests and weeds in a field. Pest control becomes a challenge over time which would increase pre and post-harvest losses. Lesotho is ranked first in Africa and sixteenth in the world on bridging the gap between the sexes and has passed as well as adopted several gender sensitive laws since 2011 (Millennium Development Goals Status Report, 2013). Despite this however, there is really not much that has changed on the ground it is believed that policy and practice are not consistent. Millennium Development Goals Status Report (2013) asserts that achieving gender equality in Lesotho is a complex matter due to the highly patriarchal nature of Lesotho's society and culture. Government officials and non-government organizations reported norms and beliefs of Basotho which include, mono-cropping, wife is the property of her husband and women are not allowed to walk into or near the cattle kraal as this is regarded a male designated role to hinder the implementation of postharvest management while other stakeholders reported that norms and beliefs do not hinder famers in urban area to practice postharvest management. This would only be prominent in male headed households; however, there is a significant percentage of female headed farming households in Lesotho. The results of the study are logical since they confirm that norms and beliefs compromise efficiency of postharvest management as postulated by Honfoga et al. (2014).

Gender dimensions

Affognon et al. (2015) contend that gender issues in post-harvest management have not been well researched. The few studies that are found in literature focus on appraisal of participation levels across gender in post-harvest management (Rugumamu, 2009) and challenges encountered by women in adoption of technologies (Morris et al., 2002; Okorley et al., 2001). In most least developed countries post-harvest systems perform below expectations due to lack of the resources and opportunities they need to access technologies and services to help transform agricultural production. Majority of the respondents in this study said post-harvest management practices are not gender biased, although men and women at times have certain designated roles which are largely based on tradition. For example, livestock postharvest management related issues are done by men, and poultry and piggery postharvest management issues are done by women. These findings are inconsistent with the literature as it has shown that gender is a problem in the chain of activities in postharvest management.

It has been argued elsewhere that women face more severe constraints than men in accessing productive resources and markets (Affognon et al., 2015). FAO (2011a) asserts that based on evidence from large scale comparative studies, gender inequalities are costly and inefficient. Lesotho has a big challenge of unemployment, with the largest employer being the Chinese owned textile industry where women are the major employees (Lesotho Country Analysis, 2017; Central Bank of Lesotho, 2016). Therefore, the greater proportion of the male adult population often migrates to South Africa in search of opportunities, especially working in mines. The bulk of the unemployed women have to look for opportunities elsewhere and agriculture is one of such avenues (Lesotho Country Analysis, 2017; Kingdom of Lesotho, 2018). As a result of this, Lesotho has significant proportion of female headed farming households (Kingdom of Lesotho, 2018).

Since Lesotho has significant proportion of female headed farming households women conduct post-harvest management activities freely, this is a possible explanation for the inconsistency of the findings of this

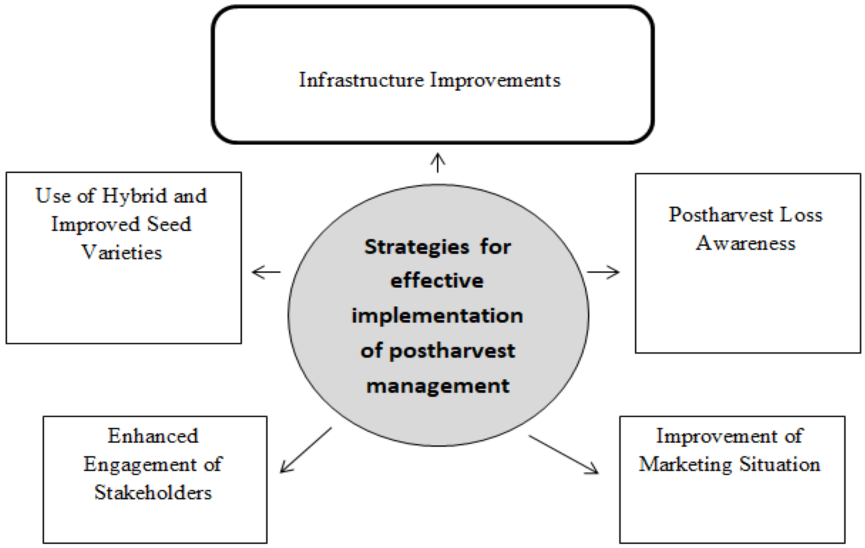

Figure 3. Strategies for effective implementation of postharvest management.
Source: Author Survey and Compilation (2019).

study to literature. Okorley et al. (2001) argue that in many SSA countries, postharvest systems under perform because women lack the resources and opportunities they need to access technologies and services to help transform agricultural produce. Since awareness of post-harvest losses management is still in its infancy stages in Lesotho, acquisition of technologies to curb such losses may not be a priority. Therefore, the argument that women lack resources and opportunities is of little consequence with regard to post-harvest management in Lesotho. However, it is still acknowledged that few activities are designated to a particular gender due to culture and norms of the Basotho.

Strategies for effective implementation of postharvest management

The twenty-five (25) respondents to the study were also asked to identify and suggest strategies that could be used to effectively implement postharvest management in Lesotho. The responses that were provided by the respondents to the study were coded analysed and were organised into themes which are discussed in detail subsequently. Figure 3 shows a summary of the various themes identified in a diagram.

Infrastructure Improvements

Infrastructure upgrades are necessary in least developed countries since poor infrastructure is a recurrent challenge highlighted in literature. The majority of policy makers, implementers and agriculture stakeholders who responded to this study expressed concern over the poor infrastructure and advised that government should be deliberate and decisive in upgrading infrastructure. Post-harvest losses could be significantly reduced if farmers have access to proper storage, processing, packaging, loading and unloading facilities at the farm and market place (Gardas et al., 2017). The farmers in Lesotho need good roads for easy access to markets, access to electricity and access to facilities such as abattoirs, silos, slaughter houses and access modern post-harvest management technologies. Policy makers and implementers should encourage government, development partners, donors and farmers to invest in improved in storage technologies. The respondents felt that government should do more to assist in the provision of good storage facilities. Kaminski and Christiaensen (2014) argue that the use of improved storage technologies reduce PHL, with the use of modern storage technologies reducing PHL more than the use of traditional storage technologies. Since concerns were raised over the lack of storage facilities like silos which result in increase in post-harvest losses public and private investment should address this challenge. Access to appropriate storage technology is a critical need for the smallholder producers, and officials who are responsible in government and also private sector players can intervene.

Use of hybrid and improved seed varieties

Abass et al. (2014) assert that farmers considered changes in weather, pest damage in the field and storage pests as the major factors that exacerbate post-harvest losses. These factors are to some extent within the control of the farmer. There are hybrid seeds available which are resistant to certain climatic conditions, resistant to pest attack on the field and also have a high tolerance to storage pests. Efforts should be made to ensure awareness, accessibility and availability to farmers, they should also be made aware of benefits of using the improved seed varieties.

Postharvest loss awareness

Ministry of Agriculture departments and other ministries representative insisted that farmers should be made aware of postharvest losses that usually occur on the farm and off the farm. The reality in Lesotho is that awareness of post-harvest losses and how they can be avoided is an area which requires attention. Some farmers are aware of the post-harvest losses but have no knowledge of how they can be controlled (Abass et al., 2014). Some of losses that the farmers suffer they bring upon themselves with misplaced norms and cultural beliefs which are detrimental to their farm enterprise. The results were found consistent with FAO (2011a) which suggested that making farmers aware of the losses they incur after harvest can actually help reduce them.

Enhanced engagement of stakeholders

Enhanced engagement of farmers in the plans and strategies was raised by government officials and United Nations representatives. Farmers most of the time are excluded in the planning and formulation of strategies of programmes and interventions which are directed towards them. Although the assumption is that the experts, consultants and specialists know so much, farmers have indigenous knowledge which must not be undermined. In addition, the input of farmers is invaluable as the interventions are meant for their use and benefit. Government officials and United Nations officials highlighted the need for more research to be undertaken to address the emerging issues, and inclusion of research and extension services in post-harvest management activities. These results are consistent with Cerna (2013) findings which showed that involving other stakeholders, specifically farmers can result in effective implementing. Stakeholders also stated that there should be advocacy to influence opinions and decisions of people and organizations through media as was said by GPLP Project (2014). This can assist in assuring stakeholders that they are on top of issues and in some cases stakeholders can be used to solve problems (Jeffery, 2009).

Improvement of marketing situation

Kasso and Bekele (2018) argued that market situation is a major cause of post-harvest loss and quality deterioration. Kaminski and Christiaensen (2014) contend that post-harvest losses decline with better market access. In Lesotho the challenge is made worse due to low prices, lack of proper means of transportation and a poor road network infrastructure. Affognon et al. (2015) highlight that at times markets are unrewarding, unavailable and inaccessible; when produce is not graded and is of poor-quality, farmers would reject it leading to losses. Lesotho has no regulations on technical and grading standards for most agricultural produce. This has the potential of increasing post-harvest losses. Accessibility to markets also involves transportation in other instances which increases when there is poor road network connectivity. Cunguara and Darnhofer (2011) reported infrastructural impediments to market access in Mozambique. Distance to markets has the potential of increasing post-harvest losses as such produce require special storage facilities in order to retain quality and freshness. In such cases when markets are far there are high chances of increased post-harvest losses. Furthermore, in Lesotho there is a challenge of lack of proper and organised formal market centres for produce. Establishment of such market centres will assist in linking farmers to consumers which would reduce post-harvest loss and curb quality deterioration. There is also no formal market information system in Lesotho and privileged farmers depend on the South African market information system. More efficient markets and value chain would reduce post-harvest losses in Lesotho.

CONCLUSION AND RECOMMENDATIONS

The government of Lesotho needs to ensure that it drafts a deliberate post-harvest management policy. Policy and implementation strategy are crucial as a starting point in mitigating post-harvest losses. The unique circumstances Lesotho finds itself calls for a concerted effort in curbing post-harvest losses so that the country would ensure it has both food and nutritional security. The policy should address standards and regulations in handling Lesotho agricultural produce after harvest. Poor infrastructure and lack of adequate post-harvest management facilities requires the government to forge private and public investment partnerships to upgrade infrastructure and post-harvest management facilities. Lack of proper storage facilities was listed among major impediments of post-harvest management activities in Lesotho. From the policy perspectives, national agricultural development strategies need to guarantee the availability of effective community-based storage infrastructure. Community-based storage infrastructure would have a positive effect on the food security situation and food prices. Market centers should be established and also a proper and functioning market information system to assist with up to date market information. The private partnerships in market infrastructure investment can reduce losses and improve economic efficiencies of the value chain.

The Lesotho government need to put in place a stand-alone post-harvest management policy with sound implementation measures and follow up on the implementation strategy. Policy alone would not be effective if there is no implementation strategy and supervision of the implementation process. The Policy should ensure that food safety, nutritional value and economic value of produce is not compromised since there would be regulations on safety and standardisation of produce. A good post-harvest management will foster agribusiness in Lesotho since farmers' income would improve, and hence provide employment and other opportunities such as export of produce. The poor state of available post-harvest handling infrastructure and farmers' inadequate knowledge on proper postharvest handling methods in Lesotho seems to further aggravate the already fragile food insecurity. In addition, losses during manual processing and during storage deprive the farmers the opportunity to gain from increased market prices of processed products, thereby worsening poverty. Processing offers farmers an advantage to diversify their incomes and food by processing their agriculture commodities into different products. Tertiary institutions in Lesotho should refocus the curriculum so that it equips future farmers with the skills and knowledge to fulfill the multiple roles in post-harvest management, so that postharvest losses can be effectively reduced. Private sector, government and donors should assist tertiary institutions with acquisition of technologies and facilities needed for practicals since other institutions have inadequate facilities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Analysis of economic efficiency among smallholder sorghum producers in Kenya

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This study used Cobb-Douglas Stochastic Profit Frontier to analyze economic efficiency of sorghum farmers in Tharaka Nithi County, Kenya. Using a multi-stage stratified sample of 259 farmers, results depicted a wide range of profit efficiency between the best (0.96) and the worst (0.12) farmer with a mean of 0.17. The actual and potential profit was USD 164.88 ha^{-1} and USD 969.87 ha^{-1} respectively. This indicates that, sampled farmers incurred profit-loss of approximately USD 804.99 ha^{-1}. Family labour and fixed capital base were the major contributing factors to sorghum profitability. Drivers of profit efficiency pointed out that, farmers who had more experience in sorghum farming, accessed agricultural credit, attended trainings, lived closer to the market and agro-dealers were likely to be more efficient. To increase profit efficiency, this study therefore advocates for policy strategies targeting these factors. Further, policy move targeting increase in uptake and correct application of fertilizer and other inputs should be reinforced.

Key words: Improved sorghum varieties, economic efficiency, Cobb-Douglas stochastic profit frontier, Kenya.

INTRODUCTION

In the past decade, Kenya’s population has increased by over 25% and stands at 47.56 million by year 2019 (GoK, 2019a). The population growth trend is expected to exert more pressure on food production and worsen the current situation where demand outstrips supply. This underpins the need to address agricultural production in the country which is a net importer of many agricultural products. From year 2006 to 2016, food imports in the country increased at a rate of 10% annually (GoK, 2019b). Population increase and existing land practices including massive fragmentation into uneconomic units adversely affect food production in the country (GoK, 2019b).

This means that, for Kenya to produce enough for her population, several strategies should be employed including increasing agricultural productivity by efficiently utilizing available limited resources.

Sorghum, which ranked fourth important cereal after maize, wheat and rice (CBS, 2016) is a good option for farmers especially in arid and semi-arid areas. This is because of its adaptability and resilience to low moisture stress and excessive heat (Orr et al., 2016). By the year 2018, about 43 improved sorghum varieties (ISVs) had been released (GoK, 2018). However, it is disappointing that nationally, average yields remain below 1 ton ha^{-1}

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compared to potential of 2-5 tons ha^{-1} (GoK, 2015).

In Kenya, eastern region is the country's sorghum basket that has continued to benefit from Government's heavy investment in the sector. Several big sorghum projects have been launched in the area in partnerships with donors latest being Kenya Cereal Enhancement Programme-Climate Resilient Agriculture Livelihood (KCEP-CRAL). However, despite these investments in the sorghum sector, yields are still low (GoK, 2015).

Although low yields can be attributed to several factors some of which are beyond farmers' control such as climate change, high level of inefficiencies is a major contributing factor (Wollie et al., 2018; Chepng'etich et al., 2014; Chimai, 2011). Sorghum farmers in eastern Kenya have been reported to be technically inefficient with a low mean level of 41% (Chepng'etich et al., 2014) despite huge investment in the value chain. This underscores the need for continued research efforts on efficiency which perhaps should expand the scope to other efficiency aspects beyond technical. This study is not aware of any research that has attempted to assess profit efficiency levels of sorghum farmers in eastern Kenya.

Therefore, this study aimed to bridge the identified knowledge gap by analyzing profit efficient levels among sorghum farmers in Tharaka Nithi County using Cobb-Douglas Stochastic Frontier. This method allows a researcher to investigate both the profit efficiency levels of individual farms and their underlying determinants (Battese and Coelli, 1995). Understanding the causal effect of these determinants on profit efficiency is crucial in generating valuable information to inform policy.

METHODOLOGY

Data

The data used in this study are based on a farm survey of 259 sampled households from Tharaka Nithi County collected in year 2018. Multi-stage stratified sampling technique was utilized with the first stage involving purposive sampling of Tharaka Nithi County, which is one of the leading sorghum producing regions in upper eastern Kenya (KBL, 2018). The second and third stages involved purposive selection of Tharaka Sub-County and Mukothima ward due to their high sorghum production levels respectively (Figure 1). The fourth and fifth stage entailed selection of 36 sample villages and construction of a sample frame comprising of all households in the sampled villages from where respondents were selected randomly. The sampling of households was random based on proportionate to size of the population in each village. The sampled households from these villages ranged from 6 to 25.

Theoretical framework

In 1957, Farrell first defined frontier production functions including maximality aspect and provided a three-dimensional way of distinguishing efficiency, viz; technical, price or allocative and economic (which combines technical and allocative aspects). The study defined productive efficiency as the ability of a firm to produce a given level of output at lowest cost. The three efficiency components have been measured by the use of frontier production function which can be deterministic or stochastic. Deterministic frontier production function explains that all deviations from the frontier are attributed to inefficiency whereas in stochastic frontier production function, it is possible to discriminate between random errors and differences in efficiency.

Theory evolved and afterwards, Aigner et al. (1977) and Meeusen and Van den Broeck (1977) proposed a stochastic frontier model. Several authors later argued that, it was important while dealing with farm level efficiency in developing countries to include several important aspects especially on selection of functional forms and relevant parametric estimation approaches as opposed to non-parametric (Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Coelli, 1995). In profit function context, Ali and Flinn (1989) defined profit efficiency as the ability of a farm to achieve the highest possible profit, given the farm's prices and levels of fixed factors. Consolidating on this, Ali et al. (1994) stated that, profit function approach combines the concepts of technical and allocative efficiency and any error in the production decision is assumed to translate into lower profits or revenue for the farmer.

In literature, several function forms for estimating profit function exist that includes Cobb-Douglas, normalized Quadratic, normalized Translog and generalized Leontif. The results significantly differ across different function forms and thus the choice is critical. Battese and Coelli (1995) contributed to improvement of the stochastic profit frontier model by suggesting that the inefficiency effects can be expressed as a linear function of explanatory variables, reflecting farm-specific characteristics.

Sorghum profitability analysis

This study used profitability analysis on data collected during 2017/2018 cropping year to evaluate performances of sorghum farmers in Tharaka Nithi County. The basis of this analysis for profitability was on per unit of land measured in hectares (ha). Dependent variable net profit was derived by subtracting the total cost from total revenue.

The total variable cost include costs of inputs (seed, fertilizer, labour and insecticides) which was used as opposed to their respective prices due to their similarity, thus no difference would be evident. Since farmers would buy different quantities of inputs, then cost would vary. Labour costs were captured and quantified as per activities executed during sorghum production such as land preparation, planting, fertilizer application, weeding, spraying, birds scaring, harvesting, transport to homestead, threshing, transport to collection centre and loading to buyer's vehicle. Labour was categorized as hired or from family members. Family labour segment captured the ages and gender of the member and subsequently male equivalent opportunity cost was calculated using wage rate for the study area as the base using [1]formula suggested by FAO (2005).

The total cost included value of fixed capital assets such as farming implements, buildings, machinery and land. Farmers in the study area were customary owners of land and hence not paying taxes. Sometimes, the farmers would leave land fallow for a certain period and as such during fallow period, land had no economically valuable output. Several studies have argued that, fixed cost has a negligible contribution to the farming enterprise especially in smallholder subsistence farming (Ohen and Ajah, 2015; Abdullahi, 2012). With this in mind, and due to the unreliability of data, cost of land was not included in the analysis. However, this study included depreciation cost for fixed capital. Given that the implements were used until completely worn out, their residual value was equated to zero.

[1]I man-equivalent day (8 hours) = 1.25 woman days = 2 child days

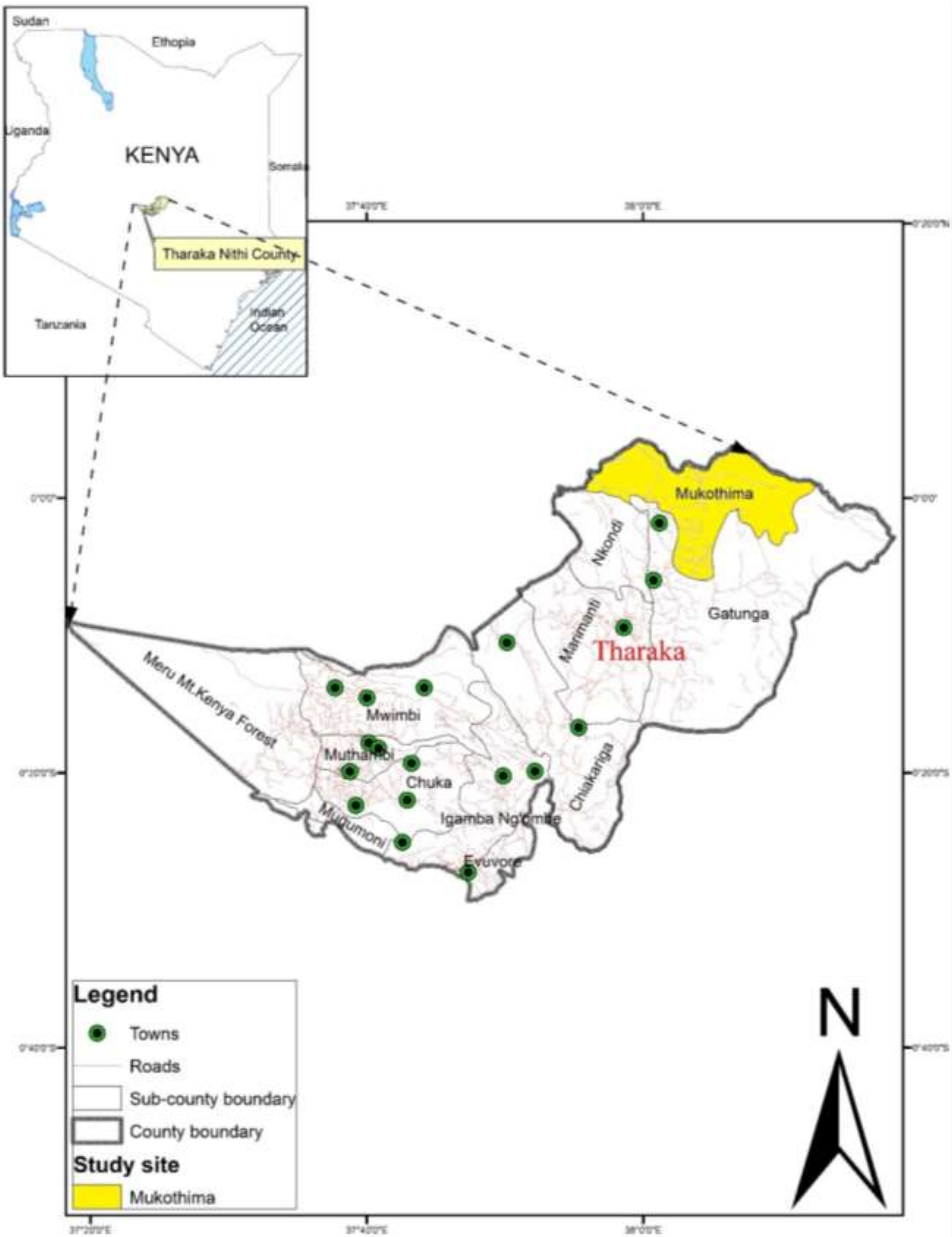

Figure 1. Map of the study area.
Source: Generated from ArcGIS using georeferenced survey data (2019).

Table 1. Likelihood ratio tests for underlying hypotheses.

Null hypothesis	χ^2/LR	df	Prob>χ^2	Decision
$H_0: \beta_{ij} = 0$	23	21	0.34	Fail to reject *H₀* Cobb-Douglas function is appropriate
$H_0: U_i = iidN^+(0, \delta_u^2)$	0.06	1	0.26	Fail to reject H_0 Profit efficiency levels are assumed to be half normal distributed
$H_0: \gamma = 0$	7.81	1	0.002	Reject H_0 Inefficiency effects are present in the model

Depreciation for farm implements used for production of ISVs was carried out using straight line method as follows.

$$d = \frac{Iv - Rv}{n}\left(\frac{LdISV}{TotLD}\right) \quad (1)$$

where:
d = annual depreciation
IV = initial value of the tool
RV = residual implement value
n = economic life span of the implement in years
LdISV = area of land under ISV
TotLD = total area of land under crops.

Empirical model specification

Several profit efficiency models exist in literature including Data Envelopment Analysis (DEA). However, this study used Stochastic Profit Frontier due to its ability to give way for the sensitivity of data to random shocks and includes a conventional random disturbance term in the estimation of the profit frontier. This enables the research to attribute only deviations influenced by controllable decisions to inefficiency (Joforullah and Premachandra, 2003).

Hypotheses tests for model specification

The choice of functional form is important due to the fact that, results significantly differ according to the function form applied. In profit function literature, many functional forms are available and have been used extensively. However, the two most popular functional forms are Translog and Cobb-Douglas (Battese and Coelli, 1995). Therefore, the first test was to choose the functional form which best fitted the data using likelihood ratio test conducted following the formula by Greene (2012).

$$LR_\lambda = -2\left\{ln\frac{L(H_0)}{L(H_1)}\right\} = -2\{[ln(L(H_0)] - \ln[L(H_1)]\} \quad (2)$$

where: $L(H_0)$ and $L(H_1)$ represent the values of the log likelihood under null and alternative hypothesis, respectively. LR_λ has approximately a Chi-square distribution with the number of degrees of freedom equal to the number of restrictions, assumed to be zero in the null hypothesis. Null hypothesis fails to be rejected when LR_λ is lower than the correspondent critical value for a given significance level (Abu and Kirsten, 2009).

The null hypothesis stated that, coefficients of the second-order variables in the Translog model are zero; implying that the Cobb-Douglas function is best fit for the model (Table 1). Mathematically, this can be presented as follows:

$$H_0: \beta_{ij} = 0$$

The results failed to reject the first null hypothesis, meaning that, Translog model actually reduced to the Cobb-Douglas profit function. Therefore, results from Cobb-Douglas model were considered more accurate and was the functional form which best fits the data. Further, AIC and BIC values support the results in that, Cobb-Douglas model reported smaller values (943.48 and 968.38) compared to those of Translog function form (962.48 and 1,062.07) respectively.

The second test was on distribution assumption for the error term. Null hypothesis was half normal distribution while the alternate was the general truncated normal distribution. The results failed to reject the null hypothesis implying that, half normal distribution assumption was the most appropriate.

The third test was to find out whether inefficiency effects were present in the model. The null hypothesis specified that, inefficiency effects were absent in the model. Results in Table 2 rejected the null hypothesis. The findings were supported by the estimated Gamma value (0.95) highly significant at 1% significance level.

The Cobb-Douglas functional form was specified as follows:

$$ln\pi_i = \beta_0 + \beta_1 lnP_{1i} + \beta_2 lnP_{2i} + \beta_3 lnP_{3i} + \beta_4 lnP_{4i} + \beta_5 lnP_{5i} + \beta_6 lnP_{6i} + (V_i - U_i) \quad (3)$$

where:
subscript "*i*" represents the i_{th} farmer in the sample
π_i = Normalized profit per ha in USD computed as profit divided by output price.
P_{1i} = Normalized cost of seed per ha (standard prices for different seed varieties per 2 kg packet were as follows; *Gadam* = USD 4; *SC Sila* = USD 4.5; *Kari Mtama 1* = USD 3.2 and *Advanta 23012* = USD 12)
P_{2i} = Normalized cost of insecticides per ha
P_{3i} = Normalized cost of family labour per ha
P_{4i} = Normalized cost of hired labour per ha
P_{5i} = Normalized cost of fixed capital base per household
P_{6i} = Area of under under ISVs in ha.
β_k= Parameters to be estimated
V_i = Random error assumed to be independently and identically distributed.
U_i = Non-negative profit inefficiency effects which are assumed to be half normal and independently distributed.

It is worth noting that, all variables labeled as normalized means that, each of their totals was divided by the output price respectively.

Equation 3 was estimated using Frontier version 4.1 where several parameters were estimated and reported such as profit efficiency levels, value of gamma and determinants of inefficiency in the sorghum production.

To estimate inefficiency model, the following empirical expression was used:

Table 2. Description of variables used in the inefficiency model.

Variable	Description	Unit of measure	Hypothesized sign
Age	Age of household head	Years	- or +
School	Years spent in school by a household head	Years	-
Experience	Experience in sorghum farming	Years	-
Adult	Household's adult equivalent	Number	
Extension frequency	Average times a household sought extension advice	Number	-
Group membership	Whether a household head was a member of any farming group	1=yes; 0=no	-
Agricultural credit	Agricultural credit access	1=yes; 0=no	-
Agrodealer distance	Distance to the nearest agro-dealer	Kilometre (km)	+
Training	Whether household head attended any training on sorghum farming	1=yes; 0=no	-

$$U_i = \delta_0 + \delta_1 W_1 + \delta_2 W_2 + \delta_3 W_3 + \delta_4 W_4 + \delta_5 W_5 + \delta_6 W_6 + \delta_7 W_7 + \delta_8 W_8 + \delta_9 W_9 \quad (4)$$

where:

W_1, W_2, W_3, W_4, W_5, W_6, W_7, W_8 and W_9 represents *extension frequency, experience in sorghum farming, group membership, school, adult , agricultural credit, age, training and distance to the nearest agro-dealer* respectively.

$\delta_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \delta_9$ represented parameters to be estimated.

Data diagnostic tests were carried out before running models. Variance Inflation Factor (VIF) and Breusch Pagan test were used to test for multicollinearity and heteroscedasticity respectively VIF mean value was less than 10 (1.06) indicating that there was no multicolinearity in the data, while the Chi-square value for Breusch Pagan test was insignificant.

RESULTS AND DISCUSSION

Summary descriptive statistics

On average, the household heads' were aged 45.4 years and had completed 7.7 years in school (Table 3). The mean adult was reported at 2.3. On average, distance from the location of sampled households to the nearest administration Centre where extension agents and agro-dealers are domiciled was 3.1 km with farmers traveling up to a maximum of 15 km to seek advice. Terrain is very rough and main mode of transport available is use of a motor cycle commonly referred to as *'bodaboda'*. The transport cost goes as high as USD 7.86 back and forth for a distance of 15 km.

Approximately, 4% of the sampled households used fertilizer for planting majorly Diammonium Phosphate (DAP). On average, farmers used 10% of the required planting fertilizer application rate per ha. About 33% of the sampled households used several insecticides namely; *Tihan, Thunder, Profile, Duduthrin, Oshothion, Voltage* and *Alphakil*. On average, majority of farmers used 20 to 50% of the recommended application rate per ha for the various insecticides especially *Oshothion*, *Duduthrin* and *Voltage*.

Maximum likelihood parameter estimates of the profit efficiency model

Table 4 presents maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic profit frontier model. The results show statistically significant coefficients for sigma squared (σ^2) and gamma (γ) parameters.

The estimated gamma or variance ration parameter coefficient (0.95) means that, approximately 95% of profit variation could be attributed to inefficiencies with one sided error. This confirms that, there exists a high level of inefficiency between sorghum farmers and is stochastic. The estimated sigma squared (5.91) is significant at 1% level of significance meaning the model was a good fit (Rahman, 2003). The elasticity findings show that, when the cost of family labour and fixed capital increases by 1%, profit increases by 0.14 and 0.20% respectively.

Distribution of profit efficiency scores

Table 5 shows the distribution of profit efficiency levels among sampled sorghum farmers. The scores indicate a wide range of profit efficiency from 0.12 to 0.96 for the worst and best sorghum farmer respectively with a mean of 0.17. This implies that, on average, a farmer in the study area could increase profits by 83%.

Further, results reveal huge profit efficiency variation with over 70% of sampled farmers recording an efficiency score of less than 0.25. The least profit efficient and average farmers need a cost saving (efficiency gain) of 87.50%[2] and 82.3%[3] respectively, to attain the profit efficiency level of the best farmer in the study area. On the other hand, the best farmer needs a cost saving of 4%[4] to be on the frontier.

Further, with mean profit efficiency estimated at 0.17 and actual profit at USD 164.88 ha^{-1}, sampled sorghum

[2] [1-(0.12/0.96)]*100
[3] [1-(0.17/0.96)]*100
[4] [1(0.96/1)]*100

Table 3. Summary statistics of the characteristics of sorghum farmers (N=259).

Variable	Unit of measurement	Mean/Percent	Standard deviation
Age	Years	45.4	13.6
School	Years	7.7	4.2
Adult	Number	2.3	0.6
Experience	Years	20.3	12.8
Agrodealer distance	km	3.1	1.6
Group membership	1=Yes	65	
Agricultural credit	1=Yes	6	
Training	1=Yes	61	
Profit	USD ha^{-1}	164.88[#]	155.64
Sorghum yield	tons ha^{-1}	1.39	0.75
Land area under sorghum	ha	1.05	0.86
Fixed capital base cost	USD/HH	6.07	2.06
Seed cost	USD ha^{-1}	18.26	7.68
Hired labour cost	USD ha^{-1}	49.11	11.37
Family labour cost	USD ha^{-1}	150.85	93.04
Fertilizer cost	USD ha^{-1}	0.28	1.48
Insecticide cost	USD ha^{-1}	4.15	6.26

[#]1 USD was equivalent to 101.81 Kenya Shillings at the time of study, that is, end year 2018.

Table 4. Maximum likelihood estimates for parameters of the Cobb-Douglas stochastic profit frontier model.

Variable Name	Parameter	Coefficient	t-ratio
Constant	β_0	1.49 (0.66)**	2.26
$lnP_{seed\ cost}$	β_1	-0.02 (0.27)	-0.08
$lnP_{insecticide\ cost}$	β_2	0.08 (0.10)	0.80
$lnP_{familylabourcost}$	β_3	0.14 (0.07)**	2.11
$lnP_{hiredlabour\ cost}$	β_4	-0.12 (0.13)	-0.92
$lnP_{fixed\ capital\ cost}$	β_5	0.20 (0.09)**	2.12
$lnP_{land\ under\ ISV}$	β_6	0.21 (0.25)	0.85
Diagnostic statistics			
Sigma-squared	σ^2	5.91 (0.73)***	8.05
Gamma	γ	0.95 (0.02)***	39.62
Log likelihood function value	LLF	-461.81	
Sample size	259		

Figures in parentheses represent standard errors associated with the coefficients. ***P<0.01, **P<0.05 and *P<0.10 mean significant at 1, 5 and 10% probability levels, respectively.
Source: Survey data.

farmers incurred profit-loss[5] of approximately USD 804.99 ha^{-1}. Therefore, this implies that, sorghum farmers could, on average, attain potential profit[6] of about USD 969.87 ha^{-1} through improvement of technical, allocative, and scale efficiencies. This is quite a significant amount of income for sorghum farmers in Tharaka Nithi County and calls for appropriate policies formulated and implemented with intent of enhancing profit efficiency of sorghum farming.

Sources of profit inefficiencies among sorghum farmers

Table 6 presents results of the inefficiency model. Since

[5] Profit-loss = Actual profit * (1-Profit efficiency)/Profit efficiency
[6]Potential average profit = actual profit + profit-loss.

Table 5. Deciles frequency distribution of profit efficiencies of sorghum farmers.

Efficiency level	Frequency	Relative percentage
< 0.25	185	71.43
0.26 - 0.50	52	20.08
0.51 - 0.60	7	2.70
0.61 - 0.70	9	3.47
0.71 - 0.80	2	0.77
0.81 - 0.90	0	0.00
0.91 - 1.00	4	1.54
Total	259	100
Minimum		0.12
Maximum		0.96
Mean		0.17
Std. Dev.		0.21

Table 6. Determinants of profit inefficiency.

Variable name	Parameter	Coefficient	t-ratio
Constant	δ_0	0.894 (0.054) ***	16.52
W_1=*Extension frequency*	δ_1	-0.001 (0.001)	-0.34
W_2 = *Experience*	δ_2	-0.006 (0.002)***	-2.77
W_3 = *Group membership*	δ_3	-0.001 (0.018)	-0.06
W_4 = *School*	δ_4	0.003 (0.002)	1.22
W_5 = *Adult*	δ_5	-0.013 (0.013)	-1.04
W_6 = *Agricultural credit*	δ_6	-0.116 (0.026) ***	-4.38
W_7 = *Age*	δ_7	0.001 (0.001)	1.33
W_8 = *Training*	δ_8	-0.046 (0.021)**	2.21
W_9 = *Agro-dealer distance*	δ_9	0.010 (0.003) ***	2.76

Figures in parentheses represent standard errors associated with the coefficients. ***P<0.01, **P<0.05 and *P<0.10 mean significant at 1, 5 and 10% probability levels, respectively.
Source: Survey data.

the dependent variable is the inefficiency component of the total error term estimated in combination with the profit frontier, the coefficients are interpreted in reference to inefficiency instead of efficiency. It is worth noting that, the coefficient sign is very important in result interpretation. A negative sign implies that, the variable has a reducing effect on profit inefficiency and vice versa (Abu and Kirsten, 2009; Galawat and Yabe, 2012). Assa et al. (2012) suggests that, one can interpret the coefficients in reference to profit efficiency instead of inefficiency by taking the opposite sign of the reported results.

The coefficient associated with experience in sorghum farming is negative (-0.006) and significant at 1% level. This implies that, experienced farmers are more likely to be profit efficient. They are expected to operate at a higher level of profit efficiency compared to their less experienced counterparts. The results corroborate those of Konja et al. (2019), Saysay et al. (2016), Trong and Napasintuwong (2015), Munir et al. (2015), and Sadiq and Singh (2015) but contradict Tanko and Alidu (2017).

Access to agricultural credit and profit efficiency depicted a significant positive relationship denoted by negative coefficient (-0.116). Sampled farmers were reported to be cash constrained and access to credit could push the financial constraint outward enabling farmers to acquire required inputs in sorghum farming particularly fixed capital base with labour reported as the major contributing cost elements depressing profits. Further, access to credit hands farmers more purchasing power and catalyzes adoption and usage of improved seed and fertilizer. These determinants are reported to be crucial in improved productivity and profitability yet used by few sampled farmers. This result is in agreement with Wongnaa et al. (2018), Saysay et al. (2016) and Biam et al. (2015).

As expected, trained farmers were operating on a higher profit efficient level compared to their untrained counterparts. This is evident from the negative significant coefficient (-0.046). Trainings are crucial in disseminating extension information to farmers particularly on good agronomic practices, post-harvest handling and market information among other topical subjects. This finding is in agreement with Bocher and Simtowe (2017), Dang (2017), and Trong and Napasintuwong (2015).

Distance to the nearest agro-dealer depicted a negative relationship with profit efficiency (0.10). This relates to the high transaction and transformation cost associated with an increase in distance which discourages farmers from accessing inputs and information. Terrain in the study area is rough and motorcycles are the most predominant means of transport from households to the nearest market where agro-dealers are domiciled. Due to shortage of means of transport options, motorcycles charge exorbitant prices, therefore discouraging farmers from visiting the market to purchase input and acquire necessary information. This result concurs with those of Bocher and Simtowe (2017).

Recommendations

Low average yield among the sampled farmers could be attributed to several factors among them like low usage of fertilizer and technical knowhow on sorghum production. The fact that, few farmers used fertilizer with an underdose application rate, which is a key ingredient to increased productivity, leads this study to recommend that, stakeholders formulate and adopt sustainable awareness and demand creation activities' models e.g. demonstration plots. The demonstration plots managed jointly by lead farmers, agro-dealers and fertilizer companies give farmers an opportunity to witness and associate themselves with the results. The demonstration plots could be used as training sites for more practical oriented approach.

Demand creation activities aim to increase the number of farmers who purchase and use correct dosage of the right fertilizer. However, availability and affordability might be limiting factors. Affordability is usually influenced by multiplicity of factors with product pricing and associated transformation and transactions costs being central. Therefore, deliberate concerted efforts should be channeled towards making sure that, fertilizer and other inputs in general are available closer to the farming households. This could be through incentivizing agro-dealer start-ups via waiving certification requirements e.g. licences, permits etc. Further, existing agro-dealers should be encouraged to expand their network through availability of favorable credit.

Credit providers should offer affordable facilities and consider relaxing loan application and processing requirements. They should also consider embracing digital lending and adopt sustainable and cost effective delivery models such as use of business champions in the interior parts of the study area, opening up of agency banking among others.

To incentivize and increase lending appetite of credit institutions to smallholder farmers and agro-dealers often considered as credit risky, Government should put in place de-risking mechanisms e.g. guarantee schemes, insurance subsidies etc. This policy move would increase the number of farmers and agro-dealers accessing credit for sorghum production. Government should also consider improving rural access roads which would significantly reduce the costs of inputs and credit. This policy move would contribute significantly towards increasing profitability of sorghum farming in the study area.

Conclusions

The purpose of this study was to evaluate the profit efficiency levels of smallholder sorghum farmers. From the Cobb-Douglas stochastic frontier model that was employed, the wide disparity of profit efficiency levels show that, sorghum farmers have opportunities to increase profit by 83%. This implies that the formulated hypothesis which states that smallholder sorghum farmers in Tharaka Nithi County are not profit efficient is not rejected.

Further, this study concludes that, family labour and fixed capital base are the major contributing factors to sorghum profitability. In the study area, sorghum productivity was less than half of the expected level of up to 5 tons ha^{-1}. Also, few farmers (4%) used planting fertilizer and on average, their rate of application was about 10% to the recommended rate.

Several factors positively influenced profit efficiency namely experience level, access to agricultural credit and trainings. However, a negative significant influence between distance to the nearest agro-dealer shop and profit efficiency was reported. This means that, farmers who lived in close proximity to agro-dealer shops were reported to be more profit efficient.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Adoption of artificial insemination service for cattle crossbreeding by smallholder farmers in Laelay-Maichew district, Tigray, Ethiopia

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Adoption of artificial insemination (AI) in Ethiopia is low and there is paucity of information in documentation. Therefore, the aim of this study is to identify the determinants of smallholder farmers' adoption of AI technology in Laelay-Maichew district. Multi-stage random sampling technique was employed to select 155 sample respondents for the study. The primary data were collected through individual interviews using semi-structured interview and check list. Descriptive, inferential statistics and binary logistic model were employed to describe the study results and identify the determinants of farmers to adopt improved breeding method of AI. The farmers' adoption of AI was influenced by access to credit facilities and mobile phone, social participation, formal training, frequency of extension contact, knowledge about AI practice and perception of AI profit positively and participating in off-farm activities negatively. In conclusion, ownership of information and communication technology (ICT), access to extension services (training and extension visit), knowledge of AI practices and perception of profit determined farmers' AI adoption. There is a need to improve the effectiveness of extension service through strengthening the training, frequent home visit, making credit service accessible, and educating farmers regarding the knowledge and importance of AI technology for its effective dissemination.

Key words: Adoption, artificial insemination (AI), crossbreeding cattle, binary logit econometric model.

INTRODUCTION

The demand for livestock products and by-products is increasing in Ethiopia. This is due to the population growth, improving income and urbanization (Smith, 2013). Dairy farming mostly considered as promising option to improve household income and nutrition in developing countries including Ethiopia (Francesconi et al., 2010; Headey et al., 2014). The large cattle population, the favorable climate for improved, high yielding cattle breeds, and the relatively animal disease free environment make Ethiopia to hold a substantial potential for dairy development (Zelalem, 2012).

Ethiopia has a huge potential for dairy development with the number of milking cows estimated to be 9.9 million dairy cows. The larger proportion of the milk is

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produced from cattle about 83% nationally and followed by goat and camels. The country milk production estimates 3.3 billion liters (CSA, 2015). However, this milk production could not fill the demand of the country and imported an additional $10.6 million of dairy products (Reddy and Kana, 2016). Because of the milk yield depends on the indigenous cattle with low yielding and the country is found to be net importer of dairy products (FAOSTAT, 2014).

To meet the ever increasing of milk, milk products in Ethiopia and their enhancing income, ensure households food security and alleviate poverty of households and at national level, adoption of appropriate breeding method is crucial to improve the dairy productivity. Genetic improvement of the indigenous cattle through AI program was proposed as one of the options in Ethiopia.

Governmental and non-governmental organizations have been making efforts to improve the cattle genetic resources through conventional artificial insemination (AI) service, distributing improved bulls, introducing pure exotic and crossbred (F1) dairy cows. Those organizations have been providing AI service in operation for over 50 years. In 1967, an independent service was started in the Arsi Region, Chilalo Awraja (district) under the Swedish International Development Agency (SIDA) with establishment of Chilalo Agricultural Development Unit (CADU) that the technology of AI for cattle has been introduced at the farm level in the country as a tool for genetic improvement (Zewdie et al., 2006).

However, the effectiveness of the program is less successful. As a result, the cattle populations of hybrid and exotic breeds are less than 2% (CSA, 2015).

There are many literatures on adoption of agricultural technology. Views show that adoption technologies are subjected by a combination of personal (demographic), social, economic, physical and psychological factors (Boahene et al., 1999; Edwards-Jones, 2006; Pannell et al., 2006; Ergano, 2015).

Personal or demographic factors affected the adoption decision of agricultural technology positively and negatively. For instance, a research shows that age and sex were found to be influenced positively and negatively whereas education shows positive relationship with adoption of AI, dairy and breeding technologies (Howley et al., 20l2; Gillespie et al., 2014; Emil, 2011; Dennis, 2010).

The other factors that influence the adoption on AI, dairy and dairy marketing technologies and other agricultural technologies, socio economic and physical factors are the other important point. Research findings like land holding size, livestock holding, off-farm activities and farm income variables show positively and negatively influenced the aforementioned technologies (Howley et al., 2012; Yohannes, 2014; Kaaya et al., 2005; Tefera and Gebre, 2015; Dehinenet et al., 2014; Sime et al., 2014; Singha and Baruah, 2011). Similarly, physical factors of owning mobile phone and distance of AI service influenced positively and negatively on adoption of dairy technologies, respectively (Gashaw et al., 2014; Yohannes, 2014; Dehinenet et al., 2014; Ergano, 2015).

Institutional factors specifically, advisory service (extension visit), training participation, credit access and social participation variables were found as positive relationship and influence adoption of AI breeding method and husbandry technologies (Howley et al., 2012; Sime et al., 2014; Umeta and Temesgen, 2013; Asmelash, 2014; Singh and Singh, 2013). In other words, psychological factors of knowledge about improved livestock husbandry practices and perception to profit of AI service indicated positive relationship with adoption of these technologies (Fita et al., 2012; Tefera and Gebre, 2015; Yohannes, 2014).

Therefore, the objective of the study aimed to identify the determinants of farmers' adoption of AI for crossbreeding service in Laelay-Maichew district.

METHODOLOGY

The study was conducted at Laelay-Maichew district which is located in the Central Zone Tigray regional state of northern part of Ethiopia. It is 1080 km far away from capital city of Addis Ababa. Geographical location of the district is found at 14°07'00" to 14°09'20"N latitude and 38°38'00" to 38°49'09"E longitude in semi-arid tropical belt of Ethiopia with mid-highland agro climatic zone (Behailu et al., 2004). The district has area coverage of approximately 53,833.39 ha. According to the Laelay-Maichew district Planning and Finance Office (2015), the total population of the district is 65,296 (32165 males and 33,131 females). The map of the study area is as shown in Figure 1.

Household heads who own dairy cows were used as sample frame for the study. Hence, the sample size for the study was determined by Taro (1967) formula. Multistage sampling technique was used to select sample respondents. First stage, Laelay-Maichew district was selected purposively for its potential of dairy cattle and AI used for crossbreeding dairy cattle. Second stages, five Kebelles were selected from 15 rural Kebelles using random sampling method. Third stage, household's stratified into adopters and non-adopters. Finally, 155 sample households were selected systematically and randomly taken proportional to sample size from each stratum (adopters and non-adopters) of the rural household heads who owns dairy cows. Semi-structured questionnaire employed as data tool and collected data interviewing of households and from key informant group discussion of quantitative and qualitative data in 2016/2017. Stata software version-12 was used to analyze the collected data. A descriptive statistical analysis was employed to discuss the collected survey data using frequency, mean, standard error and percentage. Inferential statistical method of t-test and χ2-test was also used to test for significant differences in socio-economic and significant association in socio-economic characteristics of adopters and non-adopters, respectively. Binary logit econometric model was used to see the influence of hypothesized variables on the decision to adopt/or not to adopt AI (Table 1).

Definition of variables and working hypothesis

Definition of dependent variable

It is treated as dummy variable which takes the value 1 if the farmer

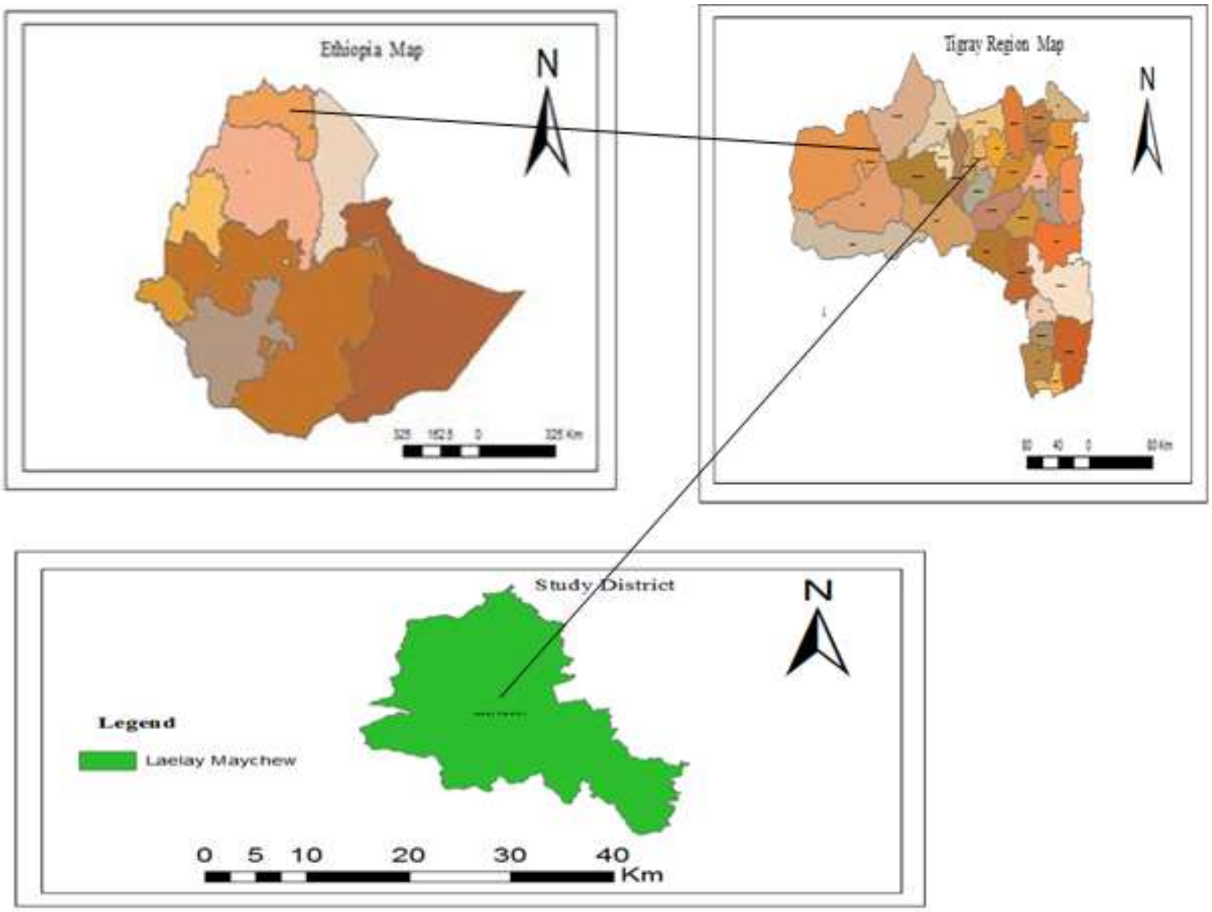

Figure 1. Map of the study area.

Table 1. Working hypothesis of dependent and independent variables.

No.	Variable	Types	Measurement	Hypothesis
	Dependent			
	Farmers' adoption AI	Dummy	1 if a farmer has adopted AI, 0 otherwise	
	Independent			
1	AGEHH	Continuous	Age of household heads in year	+/-
2	SEXHH	Dummy	Sex of household head 1= if male headed 0=otherwise	+/-
3	EDULEVEL	Dummy	1= if household head literate 0=otherwise	+
4	LHHH	Continuous	Total cultivable land of household heads in hectare	+/-
5	LIVHOLD	Continuous	Total livestock holding measured in TLU unit	+/-
6	OFFINM	Dummy	1=if participate on off-farm activity 0=Otherwise	-/+
7	ANFICM	Continuous	Total annual farm income of the household	+
8	ACMPN	Dummy	1=If household head own mobile 0=Otherwise	+
9	FREXTNCNT	Categorical	Frequency of HHs contact with extension agent	+
10	CREDACCS	Dummy	1=if the household heads get credit 0= Otherwise	+
11	DISAICR	Continuous	One way walking trip in km from home to AI service delivery center	-
12	SOCLPAN	Dummy	1=If the household head participate in social organizations 0= Otherwise	+
13	PAITRG	Dummy	1= if the household head attended in formal training 0= Otherwise	+
14	KNGEAI	Dummy	The household head knowledge towards AI	+
15	PPAIS	Categorical	The household head perception on profit of AI	+

Table 2. Descriptive analysis of continuous explanatory variables (mean±SE).

No.	Variable	Adopter	Non-adopter	t-value	p-value
		Mean ± SE	Mean ± SE		
1	AGEHH	50.932 ±1.376	52.564 ± 2.238	0.878	0.381[NS]
2	LHHH	1.087 ± 0.096	0.824 ± 0.071	2.292	0.004*
3	LIVHOLD	5.202 ± 0.280	4.536 ± 0.173	2.114	0.036**
4	ANFICM	6681.043 ± 831.923	3466.024 ± 377.575	2.372	0.019**
5	DISAICR	6.235 ± 0.501	7.665 ± 0.423	3.830	0.000*

Exchange 1$ = 22.4103 Eth birr (End of 2016). * and** represent significant at 1 and 5%, respectively. NS=Non-significant, SD=standard deviation.
Source: Computed from Own Survey (2017).

adopts AI breeding service (used AI for crossbreeding purpose of their indigenous dairy cows) and 0, otherwise.

Definition of independent variables and hypothesized relations

The relation of dependent variables are summarized in Table 1.

RESULTS AND DISCUSSION

Descriptive analysis of continuous variables

The result of the analysis shows that the average age of household heads of adopters were 50.90 years whereas the non-adopters were 52.60 years. The t-test shows no significance between the ages of adoption category. On other hand, landholding and livestock holding (in TLU) of the households of adopters were 1.087 ha 5.20 TLU and 0.82 ha 4.53 TLU of non-adopters, respectively. In other words, the average annual farm income of adopters, an Ethiopian birr of 6681.04 as well as non-adopters was 3466.02, which shows adopters earn an additional income Ethiopian birr of 3215.019 compared to the non-adopters from sale of agricultural products excluding off-farm income. The distance of the household's heads home of adopters to the extension service center was found to be 6.24 km whereas the non-adopters is 7.67 km (Table 2).

Descriptive analysis of dummy and category variables

The descriptive analysis of the dummy and categorical variables is shown in Table 3. The sex of adopter household heads was found 91% male and 9% female whereas the non-adopters are 85 and 15%. About 58% adopters and 31% non-adopters of household heads have access to off-farm activities as source of income. Household heads about 75 and 72% adopters and 33 and 26% non-adopters participated in social institutions and training accessibilities, respectively. In other hands, households 73 and 54.5% adopters and non-adopters, respectively have got credit accessibility from credit institution. 91 and 60% of the household heads own mobile phone adopters and non-adopters, respectively. The frequency contact of extension workers with the households shows about 15, 17 and 68.6% as well as 9, 10 and 80.7% of household heads adopters and non-adopters, respectively got an extension service from the district experts and development agents. In other words, the household heads were found to have a knowledge of 88 and 45.5% about the AI breeding practice adopters and non-adopters, respectively. About 95.5% adopters and 86.37% non-adopters respondents agreed on the profitability that they perceived AI is important on up-grade of indigenous dairy cows. In other words, 2.98 dis-agreed on the importance of AI service.

Determinants of adoption of AI

The result of the econometric model shows that out of the fifteen explanatory variables, eight variables significantly determine the probability of smallholder farmers adopting improved breeding method of AI at various level of statistical significance. These potential explanatory significant variables were participation on off-farm activities, social participation, attending formal training, access to credit and access to mobile phone, frequency of extension contact, knowledge about the AI breeding and perception to the profit breeding (Table 4).

Off-farm activity participation (OFFINM)

The result analysis is consistent with the expected hypothesis. Off-farm income activity participation had significant and negative relationship with adoption of improved breeding method of AI at 10% significance level. The result shows that access to off-farm activities decreased the probability of adopting the improved breeding method by 21.6%.

The reason could be that farmers obtained attractive income from the off-farm activities compared to the dairy production not likely to adopt AI breeding method. Raring crossbred dairy cows need intensive management to

Table 3. Descriptive analysis of dummy and categorical variables.

Variable	Description	Adopter		Non-adopter		Total		$\chi 2$	p-value
		N	%	N	%	N	%		
SEXHH	Male	61	91	71	81	132	85	3.2	0.070***
	Female	6	9	17	19	23	15		
OFFINM	Yes	39	58	27	31	66	43	11.78	0.001*
	No	28	42	61	69	89	57		
SOCLPAN	Yes	50	75	29	33	79	51	26.43	0.000*
	No	17	25	59	67	76	49		
PAITRG	Yes	48	72	23	26	71	46	31.73	0.000*
	No	19	28	65	74	84	54		
CREDACCS	Yes	49	73	48	54.5	97	62.5	5.61	0.018**
	No	18	27	40	45.5	58	37.5		
ACMPN	Yes	61 6	91	53	60	114	73.5	18.6	0.000*
	No		9	35	40	41	26.5		
EDULEVEL	Illiterate	15	22.4	36	41	51	33	4.05	0.257NS
	Literate	52	77.6	52	59	104	67		
FREXTNCNT	Weekly	10	15	8	9	18	11.6	5.91	0.015**
	Monthly	11	17	9	10	20	12.9		
	Some times	46	68.6	71	80.7	117	75.5		
KNGEAI	Yes	59	88	40	45.5	96	63.8	20.3	0.000*
	No	8	12	48	54.5	59	36.2		
PPAIS	St. agree	17	25.4	8	9.1	25	16.1	15.82	0.001*
	Agree	47	70.1	68	77.3	115	74.2		
	No opinion	1	1.49	12	13.8	13	8.38		
	Dis-agree	2	2.98	0	0	2	1.29		
	St. disagree	0	0	0	0	0	0		

*, ** and*** represent significant at 1, 5 and 10%, respectively. NS= Non-significant.
Source: Computed from Own Survey (2017).

make farmers ignore the technology; they obtain less profit compare to the off-farm income. Because they focused on off-farm activities income as their main business deciding not to adopt the AI breeding method; instead they used natural breeding method (local bull). The result of this research agrees with the findings of Howley et al. (2012) and Dehinenet et al. (2014) where off-farm activities participation was found to negatively affect adoption of AI breeding method and husbandry adoption. They reported that a household who participated in off-farm activities had time constraint and used AI as labor intensive than using a bull to breed cows that needs to observe detection coming to heat and find AI technicians. Conflicting result was reported by Sime et al. (2014) that off-farm income was found to positively affect household head adopting AI that off-farm income helps AI breeding method for more dairy cows crossbreeding which is used to keep more crossbred calves which they need to obtain additional source of income.

Social participation (SOCLPAN)

As the analysis result implies, participating in local and public institutions and organizations had significant and

Table 4. Binary logit model output of adoption of AI in Laelay-Maichew district.

No.	Variable	Coefficient	Standard error	Marginal effect	Z	P-value
1	SEXHH	0.785	0.722	0.151	1.09	0.277
2	AGEHH	0.001	0.023	0.002	0.04	0.967
3	LHHH	0.103	0.373	0.041	0.28	0.783
4	LIVHH	0.106	0.128	0.031	0.82	0.410
5	OFFINM	0.949	-0.495	-0.216	1.92	0.055***
6	ANFICM	0.001	0.0006	0.002	1.53	0.164
7	SOCLPAN	1.358	0.479	0.243	2.84	0.005*
8	PAITRG	0.958	0.452	0.178	2.12	0.034**
9	CREDACCS	1.417	0.467	0.277	3.04	0.002*
10	DISAICR	0.021	0.060	0.005	0.34	0.733
11	ACMPN	1.429	0.505	0.277	2.83	0.005*
12	EDULEVEL	0.249	0.592	0.059	-0.42	0.674
13	KNGEAI	0.751	0.302	0.059	2.49	0.013**
14	FREXTNCNT					
	Once a week	0.056	1.615	0.015	-0.03	0.972
	Once a month	0.747	0.373	0.146	1.99	0.015**
15	PPAIS-					
	Strongly agree	0.017	1.144	0.015	0.01	0.988
	Agree	3.230	1.477	0.262	2.19	0.029**
	No opinion	1.052	0.654	0.134	1.61	0.142
16	Con	-4.888	2.011		2.243	0.015
Hosmer and Lemeshow goodness of fit test ($\chi 2$=124.24, P=0.63)						
	Observation				155	
	-2Log-likelihood				72.20	
	Pseudo R^2				0.48	

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

positive relationship with the adoption of improved reproductive method of AI. This was found significant at 1% significance level and positively affected the likelihood of adopting the AI technology. Household heads involved in Iquib/edir and public organizations of cooperatives, farmers' development group/army show that the probability of adopting AI had increased by 24.3%. Households' heads participated in public organization of cooperatives, farmers' development group and farmers association help to get new information and other best experiences influence the use of improved breeding method. This result is similar with research findings of Asmelash (2014) that participation in extension organizations was found to be positively affect households to have credit access, access to extension and market.

Participating in training (PAITRG)

Participation in formal (technical) training session about livestock technologies helps to acquire new knowledge about improved livestock production techniques aware of the improved breeding method and required agricultural production. As the logit model indicates prior to expectation, attending formal training was found to be significant and positive relationship with adoption of improved breeding method of AI at 5% significance level. Household heads' attending formal training had the probability of adopting AI increased by 17.8%. Therefore, understanding from the model result analysis, households who participated in formal training have the probability to adopt the improved breeding method of AI technology would increase. The reason that obtained formal training helped respondents to know the pre-and post-adoption of AI crossbreeding practices and packages. The finding of this research is confirms with findings of Saka and Lawal (2009) in Nepal, Hagos (2015) and Gebiso (2015) in Ethiopia, who noted that participated households on organic vegetable, improved rice, teff and modern beehive related training were found to be positively affected by adoption of these improved technologies.

These findings justified those households' heads who had participated in the training and are helped to acquire skill and knowledge about the practical application of the production package.

Farmers' access to credit (CREDACS)

As it was expected, accessibility to credit facility was found to be significant and positively related to the adoption of improved reproductive breeding technique of AI at 1% significance level. The logit model indicated that attained credit facility makes the households' increased the likelihood to adopt the AI technology by 27.7%. Credit accessibilities help to provide enough resource and nutritional feed equally required as the AI service for conception and to reduce AI service repetition. The reason that credit facility service fills the farmers' gap, the financial provision expense for purchase Begait local dairy cows (for crossbreeding purpose) which are provided by the district in kind and cash and for other improved inputs of recommended feed and wise management. Therefore, credit access helps farmers to relax financial constraints to invest in dairy technology since the ongoing of adopting AI technology need high capital. The result of this survey agrees with the research findings of Umeta and Temesgen (2013) and Tsibuk (2015) who reported that credit accessibility helped farmers to purchase agricultural input for fattening cattle and improved seed and fertilizer for teff production, respectively.

Access to mobile phone (ACMPN)

Access to mobile phone is other important determinant factor and helps to get AI beneficiaries quick service from the AI to take their cows when coming to heat. As it was expected, ownership of mobile phone was found significant and positively related to the adoption of improved breeding method of AI at 1% significance level. Household heads' access to mobile phone had explained the likelihood of adopting the AI technology increase by 27.7%. In the study area, farmers used the mobile phone call for the AI technicians when they want a service for their cattle comes to heat. This contributes to the farmers to get quick responses from the AI technicians' availability of service to take their dairy cow to AI service delivery center. Therefore, having the accessibility to mobile phone would increase in favor to adopt the improved technology and improve their production efficiency. This agrees with the findings of Tadesse et al. (2014), Ergano (2015) and Yohannes (2014) that households who participated in cooperative and dairy production get timely information and better communication about their cooperative activities and dairy technologies.

Knowledge about AI (KNGEAI)

Knowledge is a key determinant of the farmers' to adopt and use continuously the improved method of AI to improve income of household. The result of logit model reveals that the knowledge of the households towards the reproductive method of AI had significant and positive relationship with adoption of AI at 5% significance level. As the analysis result show, the likelihood of adopting AI by household heads with knowledge about the technology increased by 5.9% significance level. This might be due to reason that knowledge about the specific practices of crossbreeding which needs the ability to select good performance cow fitted for crossbreeding, knowledge of heat detection and the accepted time for insemination, the proper feed supply, comparative advantage and disadvantage of the improved breeding method as compared to the natural breeding method (local bull) contributes to the adoption of AI technology by households. This confirms the research findings of Fita et al. (2012), where knowledge was found to positively related to the adoption of dairy husbandry practices and contributed knowledge acquired from the training of household heads had the probability of adopting dairy husbandry.

Frequency of extension contact (FREXTNCNT)

Frequency of contacts with extension agents is important and helps for making farmers technically skillful and confidential on managing integrated dairy production in a sustainable manner. Therefore, the frequency of contacts with extension agents had positively influenced the adoption of crossbreeding method at 5% significance level. The likelihood of adopting AI by households heads who get extension advice monthly in relation to households obtain advice sometimes within a year increased by 14.6%. The reason is that farmers gained technical advice about the preconditions needed for improved breeding method practice helped to adopt AI technology. Awareness of farmers about the input needed for crossbreeding dairy cows and the benefit given is important to the knowledge of households to the given advice by DAs to adopt the technology might be the most important attained by the households. This finding agrees with findings of Sime et al. (2014), frequency extension contact was found to positively affect adoption of AI. He justified that farmers obtained information about production activities and procedures of cattle breeding using AI.

Perception towards to profit AI service (PPAIS)

As expected from the prior hypothesis, the variable perception towards profit of AI technology was found to be statistically and positively related with the adoption of improved breeding method of AI at less than 5% significance level. The econometric model result showed the possibility of adopting improved reproductive practice by those household heads who agree that the breeding method is profitable compared to those who dis-agreed about the profit of AI that other things being constant adopting the AI technology increased by 26.2%. Farmers in the study area perceived that crossbred dairy cattle gives good performance to crossbred heifers and high milk yielding compared to the local dairy cows with less productive contribution of households to adopt the breeding method. Households keep productive dairy cattle than the local dairy cattle that consume more but give low milk yield important points to select AI breeding method for upgrade of the indigenous dairy cattle breeds. This result is in line with the research findings of Yohannes (2014) that household respondent's perception towards the importance of AI was found to be positively affected by the use of AI for their dairy cows.

CONCLUSION AND RECOMMENDATION

Respondents (adopters) who obtained credit facility and owning mobile phone, participated in social institutions and public organizations and obtained formal training had the probability of adopting the improved breeding method of AI to improve their indigenous dairy cattle. Households who got the extension advice by development agents having knowledge about the crossbreeding practices (AI) and respondents who perceived that AI is profitable contributed to being involved in crossbreeding program of indigenous dairy cattle through AI service. On the other hand, participation of respondents out of agriculture in off-farm activities as option of income source constrained adopting AI by smallholder farmers in the study area. Improving the effectiveness of extension service by strengthening the training, frequent home visit and making accessible the credit service plays great role in adoption of the technology. Educated and aware farmers regarding the knowledge and importance of AI technology for its effective dissemination is important. Further investigation is needed on the effectiveness of AI service and extension service strategy in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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