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Performance of smallholder minisett seed yam farm enterprises in Cameroon

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Abstract

Access to quality seed yam is a major constraint to yam production in Cameroon. This study evaluated the performance of farm enterprises engaged in seed yam (minisett) production as a source of quality planting material for yam-growing communities. Using cross-sectional data from 131 smallholder seed yam farm enterprises, a translog stochastic production function with inefficiency effects model was estimated. The results show a wide variation in estimated technical efficiency, with an average score of 62%. Access to markets, number of extension visits, expected price of mature tubers, cropping system and training positively and significantly increase the technical efficiency of seed yam production. Our results highlight the importance of technical support and extension services, of improving access to markets and of pricing in order to enhance the productivity of smallholder seed yam farmers in developing countries.

Key words: technical efficiency; production frontier; seed yam; Cameroon

1. Introduction

According to FAOSTAT (2014) data, the mean yam yield for Cameroon (11.3 t/ha) in 2012 was not only lower than the African average (11.8 t/ha), but far below that achieved by neighbouring Nigeria (13.1 t/ha), Benin (13.6 t/ha), Ghana (15.6 t/ha) and, most especially, Mali (22.9 t/ha). Moreover, mean yield in Cameroon is two times smaller than experimental potential yields of up to 32 t/ha (Ndubisi & Okoli 1988; Rodríguez-Monteroa *et al*. 2001). The level of yam production has remained static over the past three decades (Scott 2000) and this has largely been attributed to the scarcity of quality seeds (Acquah & Evange 1991). Low yam yields are often attributed to the use of poor quality planting material and so there is an urgent need for improved seed yam to be disseminated within the yam-growing areas of Cameroon. Producing quality sets in large quantities requires the efficient use of inputs (land, labour, fertilisers, stakes, fungicides and other factors of production). The use of disease-free edible yams in producing "clean" seeds by way of cutting and processing – otherwise known as the improved seed yam (minisett) technology (Ajaga *et al*. 1987; Otoo *et al*. 2001) – was introduced to increase yam production and productivity. To date, little research has been done that examines the performance of seed yam production using the minisett technology in Cameroon or in the other yam-growing countries in sub-Saharan Africa.

This paper focuses on the measurement of the technical efficiency of minisett seed yam production among smallholder yam farmers in Cameroon. We employed data that allowed us to identify the input usage that these smallholders allocate to the production of minisett seed yams as well as the quantity of seed yam produced, with the overall aim of identifying those factors that determine best practice in minisett seed yam production. Our findings are expected to contribute to the literature on the performance of smallholder seed-producing enterprises, in addition to providing information that may be useful for the formulation of public policy geared towards increasing the efficiency with which resources are used in the production of scarce quality planting materials (Ogundari 2014; Kumbhakar *et al*. 2015). Improvement of the performance of smallholder seed enterprises has the potential to lead to large-scale production of scarce quality planting materials (Otoo *et al*. 2001) at viable economic rates (Ezeh 1992). Scaling up minisett production will also help to reduce high seed yam costs, which can account for up to 40% to 70% of the total production cost (Asumugha *et al*. 2008; RIU 2009; Musa *et al*. 2011).

Technical efficiency studies have been carried out in the context of yam (*Dioscorea* spp.) production under different technologies and practices by several authors (Fasasi 2006; Ekunwe *et al*. 2008; Shehu *et al*. 2010; Musa *et al*. 2011; Asante *et al*. 2014; Nmadu & Simpa 2014). However, there are very few technical efficiency studies that focus principally on the technical efficiency of (minisett) seed yam production amongst smallholder farmers. Ironkwe and Asiedu (2014) measured the productivity of seed yam among female farmers in south-eastern Nigeria and Okeke *et al*. (2013) examined the effects of socioeconomic factors on seed yam production in Nigeria using the deterministic semi-log function. In the latter study, Okeke *et al*. (2013) estimated the technical efficiency of yam rather than that of seed yam production. Asante *et al*. (2014) studied the technical efficiency of yam production as affected by the adoption of improved seed yam technology in Ghana. Shehu *et al*. (2010) found that the technical efficiency of yam farmers in Benue state (Nigeria) ranged from 67% to 99%, with an average of 95%. This indicated that yam production could be increased by 5% on average through the better use of inputs such as land, fertiliser, seed yam and family labour. In addition to technical efficiency scores, factors influencing the inefficiency or efficiency of firms or farm enterprises can also be determined. For example, Kuwornu *et al*. (2013) showed that affiliation to farmer-based organisations, training and access to credit were some of the major determinants of the technical inefficiency of maize farmers in the Eastern Region of Ghana.

The remainder of this paper is organised as follows. Section 2 outlines the methodological approach we employed – stochastic frontier analysis (SFA). The empirical model and the choice of the appropriate model used in the empirical analysis are presented in section 3, followed by a description of the data, and the hypotheses that were tested are presented in section 4. The results of the analysis are presented in section 6, and the paper ends with policy-oriented conclusions in section 7.

2. Analytical approaches in measuring technical efficiency

An approach that has been widely used to measure technical efficiency is SFA. This parametric method allows for technical inefficiency and takes into account the fact that random shocks outside of the control of farmers can affect output. Technical efficiency is estimated using a one-sided nonnegative inefficiency error term (u_i), whose properties are discussed below. In the SFA approach, the technical efficiency of each decision-making unit (DMU) is estimated as the ratio of observed output to maximum possible (frontier) output. The estimated output ratio lies between 0 and 1, with an estimated score of 1 representing fully efficient farmers (Kumbhakar & Lovell 2003; Kumbhakar *et al*. 2015).

SFA was independently introduced by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) and can be formulated as:

$$y_i = f(x_i;\beta)\exp(v_i - u_i) \tag{1}$$

where y_i is the output of the *i-th* farm enterprise ($i = 1,\ldots N$), x_i are the input quantities, β are parameters to be estimated, $f(x_i;\beta)$ is a suitable deterministic component of the production function, and v_i is the stochastic component of the production function that accounts for noise or random error factors in the production process. The non-negative technical inefficiency component (u_i), distributed independently of v_i, is part of the asymmetric two-component error term $\varepsilon_i = v_i - u_i$.

The stochastic production function in equation 1 is often presented in the log-linear form. It is estimated using the maximum likelihood method based on the assumption that the error term u_i follows a truncated normal, half-normal, exponential or gamma distribution (Christensen *et al*. 1973; Kumbhakar *et al*. 2015). The two most used log-linear functional forms in empirical studies are the Cobb-Douglas and translog specifications, as presented by Henningsen and Henning (2009) and Coelli (1996).

The technical efficiency (*TE*) (equation 2) of the *i-th* farm at given levels of inputs used is estimated as the ratio of observed output to the output frontier, following Battese and Coelli (1995). The model is specified as:

$$TE_i = f(x_i;\beta)\exp(v_i - u_i) / f(x_i;\beta)\exp(v_i) = \exp(-u_i) \tag{2}$$

where $0 \leq TE \leq 1$ and the other variables are as earlier defined.

The maximum likelihood estimation (MLE) of equation 1 yields estimates for β and variances of the parameters v_i and the one-sided u_i, which are σ_v^2 and σ_u^2 respectively. The overall model variance is σ^2 and is estimated as:

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \tag{3}$$

where $\sigma = \sqrt{\sigma_v^2} + \sigma_u^2$ and $\gamma = \sigma^2 / \sigma_s^2$

The parameter γ has a value in the range 0 to 1, where the value of $\gamma = 1$ implies that deviations from the frontier are completely due to technical inefficiency, whereas a value of $\gamma = 0$ means that deviations from the frontier are completely because of noise effects. Hence, when $0 < \gamma < 1$, output variability is characterised by the presence of both technical inefficiency and stochastic errors (Battese & Corra 1977). The measure of the relative contribution of v_i and u_i to ε_i is lambda (λ) and is defined as:

$$\lambda = \sigma_u / \sigma_v \tag{4}$$

The production inefficiency parameters (u_i) to be estimated are non-negative random variables assumed to be independently distributed, such that u_i is determined by truncation (at zero) of the normal distribution. The inefficiency parameter is assumed to be associated with a set of explanatory variables. Following Battese and Coelli (1995), the technical inefficiency (u_i) model can be presented as:

$$u_i = Z_i\delta + W_i \tag{5}$$

where Z_i are variables that influence the technical efficiency of the *i-th* farmer, δ are parameters to be estimated and W_i is a truncated normally distributed random variable with mean zero and variance σ_u^2.

The marginal effect of the *k-th* variable of $z_{u,i}$ (equation 6) on $E(u_i)$ (Wang & Schmidt 2002) is estimated as:

$$sign\frac{\partial E(u_i)}{\partial z[k]} = sign(w[k]) \tag{6}$$

The sign of the coefficient of equation 6 indicates the direction of the impact of Z_i on $E(u_i)$. A negative sign indicates a decrease in technical inefficiency, on average, at given levels at which Z_i increases and vice versa (Kumbhakar *et al*. 2015).

3. Specification of empirical model

In order to determine the appropriate functional form of the general production function specified in equation 1, two functional forms – the Cobb-Douglas and translog stochastic production functions – were specified and estimated using STATA version 14. A likelihood ratio test rejected the null hypothesis that Cobb-Douglas adequately represents the data in favour of the translog function (a test statistic of 23.95 was obtained with six degrees of freedom, which is greater than the 99% critical value of the Chi-squared distribution of 16.81). Thus, the empirical model is specified to have a translog production function, given as:

$$\ln y_i = \beta_0 + \sum_{j=1}^{3}\beta_j \ln x_{ji} + 0.5\sum_{j=1}^{3}\sum_{k=1}^{3}\beta_{jk}\ln x_{ji}\ln x_{ki} + \varphi_1 D_{1i} + v_i - u_i \tag{7}$$

where *ln* is the natural logarithm, subscript *i* refers to the observation of the *i-th* farmer, y_i is the quantity of seed yam produced (in kilograms), x_1 is the area of land allocated for minisett production (in hectares), x_2 is the number of labour hours for minisett production, x_3 is expenditure on inputs (in FCFA, and including chemicals, fertilisers, stakes and baskets), and D_i are dummy variables for input expenditure (as per the logic set out below) and location.

The choice of the variables used was informed by the literature and is consistent with production function specifications in previous studies. Within the sample, some smallholders (10) reported zero expenditure on inputs. To avoid having to drop these observations from the analysis a dummy variable was included in the model which takes a value of 1 if an observation is zero for x_3 and is zero otherwise. The variable x_3 is then adjusted so that it takes the value of the maximum of the dummy variable or the original value for x_3. This follows the approach proposed by Battese (1997).

In order to examine the factors affecting the level of technical efficiency we employed the approach developed by Battese and Coelli (1995), hence:

$$u_i = \delta_0 + \delta_i \sum_{i=1}^{7} Z_i + W_i \tag{8}$$

where u_i is the technical inefficiency of the *i-th* farmer, Z_1 is the number of visits made by the extension service over the previous year, Z_2 is the distance (in km) from the homestead to the main market outlet, Z_3 is the price/kg (FCFA) of the major yam variety, Z_4 is the number of years of adoption of the minisett technique, Z_5 = 1 if the seed production system is mixed and 0 otherwise, Z_6 = 1 if the respondent was trained formally by the extension, academic and research institutions and 0 otherwise, and Z_7 = 1 if the farmer has access to credit and 0 otherwise.

A single-step model using the maximum likelihood method was preferred to a two-step procedure for the estimation of the exogenous factors influencing inefficiency (Wang & Schmidt 2002; Kumbhakar et al. 2015). This is because a two-step method provides biased estimates (Battese & Coelli 1995; Wang & Schmidt 2002). The one-step procedure consists of parameterising the distribution function of u_i as a function of exogenous variables (Z_i), together with the efficiency variables (x_i) of the model using the maximum likelihood method. The parameterisation of u_i and v_i (equations 9 and 10) is assumed to follow the half-normal distribution (Caudill & Ford 1993; Caudill *et al*. 1995; Kumbhakar *et al*. 2015):

$$\sigma_{u,i}^2 = \exp(Z_{u,i}^{'} W_u) \tag{9}$$

$$\sigma_{v,i}^2 = \exp(Z_{v,i}^{'} W_v) \tag{10}$$

where W_u and W_v are the corresponding constant parameter vectors (Kumbhakar *et al*. 2015).

Hypotheses tests

A number of hypotheses were tested using the likelihood ratio (LR) test, based on the maximum likelihood test statistics defined in equation 11 below:

$$LR = -2[L(H_0) - L(H_1)], \tag{11}$$

where $L(H_0)$ is the LR value for the restricted model and $L(H_1)$ that for the unrestricted stochastic frontier model. The LR ratio test has an approximate chi-square distribution with degrees of freedom equal to the number of independent constraints. However, if $\gamma = 0$ is involved in the null hypothesis (as it is in test 1), then the LR ratio statistic asymptotically has a mixed chi-square distribution (Coelli 1995a). The critical value for this test is taken from Kodde and Palm (1986:1246; Table 1). The null hypotheses that were tested are:

1. H_0: $\gamma = \delta_0 = \delta_1 \ldots \delta_7 = 0$: It is hypothesised that there is no technical inefficiency in improved seed yam production and that all deviations are due to statistical noise;
2. H_0: $\delta_1 \ldots \delta_7 = 0 = 0$: The variables included in the inefficiency effects model have no effect on the level of technical inefficiency;
3. H_0: $\beta_1 = \beta_2 \ldots \beta_3 = 0$: The three inputs used do not have any joint influence on the technical efficiency of improved seed yam production in Cameroon;

4. H_0: $\beta_1 = \beta_2 \ldots \beta_9 = \varphi_1 = \ldots \varphi_4 = 0$: The three inputs used and specific farm enterprise factors do not have any influence on technical efficiency.

4. Data

4.1 Sampling and data collection

The study was carried out in the North West region of Cameroon, which is located in the Western Highlands agro-ecological zone of the country where the minisett technique has been disseminated since the mid-1980s. The Western Highlands is one of the five agro-ecological zones of Cameroon in which different yam varieties are cultivated. The agro-ecological area of interest lies between latitude 5°40′ North of the equator and longitude 10°8′ to the east of the Meridian. The area is characterised by a mountainous relief, with high altitudes ranging from 1 350 m to 1 900 m above sea level. The average annual rainfall is estimated at 2 400 mm and temperatures range between 15°C and 32°C, with an average of 23°C (Ndoh *et al*. 2016).

Multistage and purposive sampling techniques were employed to select one (out of five) agro-ecological zones, as described above, and administrative localities (regions and divisions) where the data were collected between February and April 2015. The choice of these localities was guided by information from the extension service, which identified these places as major yam-growing areas where the minisett technique was being used. Three divisions in the North West region of Cameroon were chosen: Momo, Mezam and Ndonga-Mantung. A total of 394 yam farmers (including both adopters and non-adopters of the minisett technique) were randomly selected from the major yam-growing divisions as guided by the extension services. The empirical analysis was restricted to those households (131) that adopted the improved seed yam production technique. The 131 adopters were interviewed using a structured questionnaire and were distributed between the divisions as follows: 32 in Mezam, 89 in Momo and 10 in Ndonga Mantung. The summary statistics for this data are presented in the section that follows.

4.2 Summary statistics of variables

Table 1 provides the descriptive statistics for variables used in the joint estimation of the production function and inefficiency effects models of seed yam production.

Table 1: Summary statistics of variables used in the empirical model (n = 131)

Variable	Description	Mean	Std. dev.	Min	Max
Dependent variable					
Y	Quantity of seed yam produced (kg)	156.887	338.266	6	2 500.00
Production function variables					
X_1	Area (ha)	0.156	0.207	0.01	1.04
X_2	Labour (hours)	80.984	106.636	3.00	830.00
X_3	Inputs (FCFA)	17 342.75	27 284.27	0.00	180 000.00
D_1	Dummy expenditure inputs (1 = zero expenditure)	0.076	0.267	0.00	1.00
D_2	Dummy location (1 = Mezam division)	0.244	0.431	0.00	1.00
D3	Dummy location (1 = Momo division)	0.679	0.469	0.00	1.00
Inefficiency variables					
Z_1	Extension visits (number)	2.557	2.912	0.00	18.00
Z_2	Distance to market (km)	5.718	13.265	0.25	150.00
Z_3	Price/kg of yam	401.101	117.986	167.00	769.00
Z_4	Years of adoption	3.847	4.096	0.90	30.00
Z_5	Mixed cropping (1 = yes)	0.298	0.459	0.00	1.00
Z_6	Formal training (1 = yes)	0.947	0.226	0.00	1.00
Z_7	Access to credit (1 = no access)	0.321	0.469	0.00	1.00

The averages of the input variables show a wide range of variation that can be attributed mostly to the scale of seed yam production. The area allocated for seed yam production varies from a minimum of 0.01 ha to a maximum of 1.04 ha, with an average of 0.156 ha. This mean area corresponds closely to the average of 0.17 recorded in Nigeria by Ironkwe and Asiedu (2014). The number of hours of labour (family and hired) used in seed yam production varies from three to 830, with an average of 81 hours. On average, seed farmers spent approximately FCFA 17 342.75 on inputs (fertilisers, chemicals, stakes and baskets). The number of *Extension visits* made by extension service workers to seed farm enterprises is expected to improve the efficiency of seed yam production. The sign of the parameter is therefore expected to be negative, indicating an increase in the efficiency of seed yam production as more extension visits are made. Those trained by the subject matter specialists (from extension services, research bodies and academia) are expected to perform better than those trained by other farmers or private sector service providers. The sign of *Formal training* in the inefficiency model is therefore expected to be negative. Thirty percent of the farmers grow minisett seed yam together with other crops, such as maize, beans and cocoyam. The sign of *Mixed cropping* of seed yam could be either negative or positive. A positive sign could arise in a situation where there is mixed cropping, for example seed yam may be competing with other crops for nutrient uptake and this might give rise to inefficiency. Conversely, good agronomic practices in seed yam production and spill-over effects from the maintenance of other crops grown alongside the seeds may instead lead to yield increases and hence an increase in technical efficiency. Farmers who have *Access to credit* are expected to have acquired the capability to purchase inputs for seed yam production and hence are likely to be more efficient than those who do not. Farmers with a greater number of *Years of adoption* are expected to be more efficient than those with fewer years of technology adoption, as a result of the experience that they have gathered over the years. However, it might also be possible that this variable is a proxy for farmer's age and that older famers are less efficient than younger farmers. Where market opportunities exist, the efficiency of seed yam production is expected to be higher. These opportunities may be in the community in which the farmer resides, or further away. This variable (*Distance to market*) may be positive or negative, depending on the availability of, and distance to, market outlets. Finally, higher *Prices* for the previous year's final product (yam) will drive seed farmers to be more efficient, as they expect to earn more income from the sale of seeds. It therefore is expected that previous year's price of yam will have a positive and significant effect on the efficiency of seed yam production the following year.

5. Results

5.1 Test of hypotheses

The preferred model, as previously discussed in section 4, was the translog stochastic frontier production function model. Table 2 provides the results of the different hypotheses based on this and tested at $p < 0.05$. The section that follows and the subsequent findings are all based on the results of the translog production function.

The results of the *first test* reject the null hypothesis (H_0: $\gamma = \delta_0 = \delta_1 \ldots \delta_7 = 0$) of no inefficiency in the stochastic production function. The *second hypothesis*, namely that the variables included in the inefficiency effects model have no effect on the level of technical inefficiency ($\delta_1 \ldots \delta_7 = 0 = 0$) is strongly rejected at $p < 0.05$. The *third hypothesis*, that the three inputs do not have any joint effect on the technical efficiency of improved seed yam production in Cameroon, was also rejected at $p < 0.05$. In fact, the three inputs used and the specific farm enterprise dummies jointly have a significant influence on the efficiency of seed yam production, as shown by the results of the test pf the *fourth hypothesis* (Table 2).

Table 2: Likelihood ratio hypotheses tests for translog stochastic frontier model specifications and statistical assumptions

Null hypothesis	λ	Critical value	Decision
H_0: $\gamma = \delta_0 = \delta_1 \ldots \delta_7 = 0$	53.8	11.9*	Reject H_0
H_0: $\delta_1 \ldots \delta_7 = 0 = 0$	38.3	3.8	Reject H_0
H_0: $\beta_1 = \beta_2 \ldots \beta_3 = 0$	23.6	7.8	Reject H_0
H_0: $\beta_1 = \beta_2 \ldots \beta_9 = \varphi_1 = \ldots \varphi_3 = 0$	97.1	12.6	Reject H_0

*Source: Table 1 (Kodde & Palm 1986) using 5% level of significance

5.2 Production frontier estimates

The maximum likelihood estimates of the Cobb-Douglas and translog production functions, estimated in a single-step procedure together with the inefficiency effects model, are presented in Table 3. The signs and magnitude of the Cobb-Douglas and translog production functions are consistent. The preferred model, as discussed previously in section 4, is the translog stochastic frontier production function model, following a likelihood ratio test that rejected the null hypothesis that the Cobb-Douglas adequately represents the data. Hence, the sections that follow, and the subsequent findings, are based on the results of the translog production function. The values of the inputs used in estimating the first-order coefficients in the translog production function were mean corrected and hence are estimates of output elasticities (Villano & Fleming 2006; Kuwornu *et al*. 2013). The estimates of all the first-order coefficients in the translog model fall between zero and one, indicating that the monotonicity condition is satisfied and that all the marginal products are positive and diminishing at the mean of inputs.

The estimated coefficient for area (0.260) was found to be positive and very significant at $p < 0.01$. Land has widely been shown to have a positive and significant effect on agricultural crop production, as is the case in our findings. Reuben and Barau (2012), Villano and Fleming (2006), Ogundari and Brümmer (2011), Obasi *et al*. (2013), Ani *et al*. (2014), Izekor and Alufohai (2014), Shehu *et al*. (2010) and Villano and Fleming (2006) all found that an increase in farm size significantly improved agricultural crop output, especially for yam production. However, a smaller number of studies have found contrasting results. Ironkwe and Asiedu (2014) found that farm size had no significant influence on minisett production in southern Nigeria, which is in contrast to our findings. Similarly, Oyekale and Idjesa (2009) also came to the conclusion that farm size had no significant influence on the technical efficiency of improved maize seed in the Rivers State of Nigeria. Simpa *et al*. (2014) found a similar result for cassava production in Kogi State in Nigeria.

Estimated coefficients for labour and inputs were positive but not significant. The result for inputs was in contrast with the findings reported by Morse and McNamara (2015), who showed that the use of chemicals significantly increased the output of minisett seed yam. The use of chemicals (pesticides, insecticides and fungicides) has been shown to significantly improve yam output (Morse *et al*. 2009; Ani *et al*. 2014; Donkor & Owusu 2014) and their use is likely to be particularly important, since Njukeng *et al*. (2014) have reported a high incidence of yam mosaic virus in the study area. However, the large, negative and statistically significant estimated parameter on the dummy variable for zero expenditures on inputs indicates that those smallholders who use no chemical or fertiliser inputs produce a much lower output of seed yam than those who do use these inputs. Whilst this result appears to contradict the small and insignificant parameter estimate on x_3, it may be the case that the levels of usage of these inputs within our sample were only sufficient to maintain output levels, and that usage needs to be increased above current levels in order to produce a more significant increase in yield.

Table 3: MLE parameter estimates for the production frontier and inefficiency effects models

Variable[a]	Parameter	Translog		Cobb-Douglas	
		Coefficient	Standard errors	Coefficient	Standard errors
Constant	β_0	5.135***	0.295	5.357***	0.397
Area	β_1	0.260***	0.055	0.249***	0.060
Labour	β_2	0.061	0.080	0.0784	0.088
Inputs	β_3	0.104	0.115	0.428***	0.080
Area^2	β_4	0.090	0.0780		
Area*Labour	β_5	0.014	0.021		
Area*Input	β_6	-0.073***	0.024		
Labour^2	β_7	-0.003	0.006		
Labour*Input	β_8	0.008	0.007		
Input^2	β_9	0.413***	0.092		
Dummy input	φ_1	-14.008***	4.123	4.157***	0.821
Dummy location (1 if Momo division)	φ_2	-0.818***	0.285	-0.857**	0.192
Dummy location (1 if Mezam division)	φ_3	0.706**	0.300	-0.463	0.339
Inefficiency effects model					
Constant		6.679***	1.536	7.831***	2.541
Extension visits/year	δ_1	-0.195**	0.07	-0.141	0.155
Distance to market	δ_2	-0.440***	0.126	-0.396**	0.176
Price/kg of yam	δ_3	-0.006***	0.002	-0.009*	0.005
Mixed cropping	δ_4	-2.155***	0.852	-1.697	1.143
Formal training	δ_5	-2.270**	1.070	-2.267*	1.395
Access to credit	δ_6	0.112	0.415	0.192	0.643
Years of adoption	δ_7	-0.103	0.089	-0.453	0.423
N		131		131	
Variance parameter		1.616		0.773	
Gamma (γ)		0.999***		0.999***	
Loglikelihood		-141.911		-153.887	
AIC		327.821		339.774	
BIC		391.076		385.777	

NB: [a] Values of continuous variables are in natural logs; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.3 Technical efficiency estimates

Figure 1 shows the distribution of the estimated efficiency scores, with a majority of the enterprises (63%) having scores of 0.60 and above. The estimated mean technical efficiency is 0.62, but there is a large range of individual scores, from a low of 0.08 to a maximum score of 1. This indicates that there are prospects for the average farmers to increase output by up to 38% by emulating the most efficient farmers in the study area.

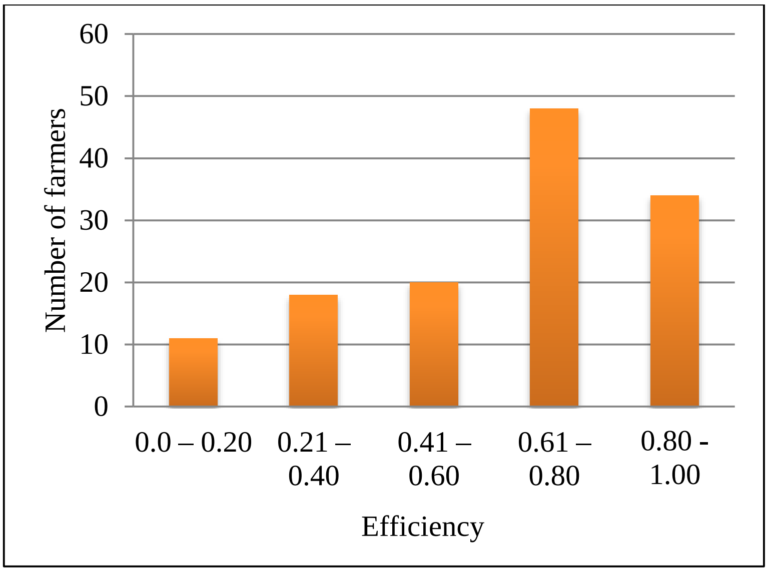

Figure 1: Distribution of farmers according to efficiency score

5.4 Determinants of technical inefficiency

Estimated parameters for the variables in the technical inefficiency effects model and their marginal effects are presented in Tables 3 and 4 respectively. The estimated coefficients of the model give an indication of the direction of their effect on inefficiency, and the marginal effects indicate the magnitude of that effect. All the coefficients of the inefficiency model (Table 3), with the exception of the coefficient for the access to credit variable, have consistent negative signs. This indicates that increases in the levels of these variables decrease inefficiency, thereby improving the efficiency of seed yam production.

The results show that those farmers with more years of experience (as proxied by the variable *years of adoption*) are more efficient than those with fewer years of experience. However, this result is not significant. Experience (often proxied by farmer's age in other studies) has been shown to account significantly for the production efficiency of agricultural crop production in the works of Oyekale and Idjesa (2009), Simpa *et al*. (2014) and Ani *et al*. (2014). This is probably why Ironkwe and Asiedu (2014) recommend that experienced female farmers should be targeted if the productivity of seed yam must be increased among female farmers in south-eastern Nigeria.

Table 4: Marginal effects of the variables included in the inefficiency model (n = 131)

Variable	Parameter	Marginal effects	
		Coefficient	SE[a]
Extension visits/year	δ_1	-0.064**	0.004
Distance to market	δ_2	-0.145***	0.000
Price/kg of yam	δ_3	-0.002***	0.000
Mixed cropping	δ_4	-0.861**	0.105
Formal training	δ_5	-0.748**	0.210
Access to credit	δ_6	0.037	0.019
Years of adoption	δ_7	-0.034	0.034

[a] bootstrap standard errors with 2 500 replications; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The efficiency of seed yam production increases within *mixed cropping* systems, the estimate of the parameter on this variable is significant at $p<0.05$ thereby showing that growing seed yam in association with other crops such as cereals (maize and beans) and other root crops (cassava and cocoyams) increases efficiency. Crop association creates excellent biophysical conditions for agricultural production and hence increases yield (Yengoh & Ardo 2013). Similarly, Oyekale and

Idjesa (2009) concluded that cover crops significantly improve the efficiency of improved maize seed production in Nigeria.

Other positive (and statistically significant) influences on the efficiency of seed yam production were *number of extension visits*, *distance to the market*, *price of yam* in the previous year and *formal training*. The results show that the technical inefficiency of seed yam production decreases as the distance to commercial market outlets increases. This corroborates the findings of Lubis *et al*. (2014), who showed that an increase in distance to markets decreases the technical inefficiency of pineapple production; and those of Hailu *et al*. (2015), who showed that the inefficiency of teff production in Ethiopia also decreased with increases in distance to markets. Similarly, the technical inefficiency of maize- and rice-producing households in Ghana and Vietnam decreased with increasing market distances (Linh *et al*. 2015; Martey *et al*. 2015). In the latter case, this phenomenon was attributed to transaction costs that motivated farmers' attitudes towards the acquisition and use of inputs at lower prices at distant markets. In our case, the fact that farmers sell seed yams locally to travelling middlemen potentially reduces their transaction costs, as they do not have to travel to markets.

The estimated coefficients for the marginal effects of the variables *formal training* and *extension visits* both have the expected signs and are statistically significant. The positive influence of extension visits corroborates the findings of Simpa *et al*. (2014) and Ogundari and Brümmer (2011), who concluded that extension services contribute significantly to explaining the levels of technical efficiency of cassava production in Kogi State in southern Nigeria. Extension visits are meant to build the capacity of farmers. The significance of the estimated marginal effect of training is an indication that the training provided to farmers gives them an adequate understanding of the technology, and this contributes significantly to the improvement of their technical efficiency. This is in line with the findings of Ani *et al*. (2014) and Ogundari and Brümmer (2011), who found that education contributes significantly to the technical efficiency of yam and cassava production in Nigeria. Other studies did not establish any effect of training on technical efficiency. In the estimation of the technical efficiency of yam production in Ghana, Asante *et al*. (2014) found that training had the expected sign, but that it contributed insignificantly to the production efficiency of yam.

Estimated coefficients for the marginal effects of the variables *years of adoption* and *access to credit* are negatively and positively signed, although neither of them is statistically significant.

The two dominant factors affecting the level of inefficiency are mixed cropping and training. The results show that farmers who practise mixed cropping are 86% less inefficient than those who do not.[1] Similarly, the level of technical inefficiency decreases by 75% if the farmer is trained in seed yam production. The levels of technical inefficiency reduce significantly (statistically and in terms of the magnitude of effect) if farmers are located further from market outlets or have more contact with extension officers, or in response to an increase in the price of yam in the previous year.

6. Conclusion and policy recommendations

This study has examined the performance of minisett seed yam production using a stochastic translog frontier production function. The model allows us to jointly estimate the frontier production function and the inefficiency effects model that accounts for the sources of inefficiency in minisett seed yam production in Cameroon.

[1] Since the mixed cropping, access to credit and training variables are expressed as dummy variables in the inefficiency effects model, the estimated marginal effects represent once-off shifts in efficiency.

The results reveal that the mean level of technical efficiency of seed yam producers for our sample stands at 62%, hence the efficiency of seed yam production could be improved significantly without increasing input use by 38% if the average farm could emulate those farms operating at the frontier.

Surprisingly, the results from the inefficiency effects model show that those farmers who are located further from market outlets are likely to be more efficient. Whilst this result has also been observed in other studies, it is counter to what might be expected intuitively – it might be expected that farmers who have easy (and cheap) access to markets would be more efficient (because they would be able to achieve higher prices for their product). We posit that our result arises because of the significant transactions costs that arise in getting seed yams to the market (i.e. transport costs and/or time costs). In our study region, farmers who are far from market outlets sell their produce to travelling middlemen, which may significantly lower the transactions costs associated with retailing. Furthermore, higher technical efficiency levels could be attained if farmers adopt good agronomic practices that might enable them to increase the productivity and efficiency of seed yam production. These practices may include mixed cropping of seed yam with other crops, and the use of chemical and fertilisers inputs.

Our results also show that extension service support, training and the price of yam in the previous year contribute to the improvement in the technical efficiency of smallholder seed yam farmers at a statistically significant level. Access to credit and years of adoption were shown not to have a significant effect on levels of inefficiency. We suspect that the results found for access to credit may arise from the crude way in which we incorporated this variable into the model (as a dummy variable), although it may be the case that farmers are unable to access sufficient amounts of credit in order to have a measurable impact upon output. However, this is a question that requires further research (and data) in order to establish if it is the case.

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