TECHNICAL EFFICIENCY OF BAMBARA GROUNDNUT PRODUCTION IN NORTHERN GHANA

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Abstract

Achieving food security under climate change is one of the greatest concerns of governments in developing countries. Due to favourable agronomic characteristics such as drought tolerance and an ability to produce a crop on less fertile soils, a number of underutilised crops, such as bambara groundnut offer potentials to address food insecurity problems in areas impacted by climate change. While efficiency studies have gained popularity in relation to many food crops, very little research has been carried out on the technical efficiency of bambara groundnut production. This study estimated a Translog stochastic frontier to determine the factors that influenced farmers' technical efficiency in the 2013 cropping season in Northern Ghana. It involved 120 farmers selected through a multi-stage sampling technique. Technical efficiency scores ranged from 27% to 97% with a mean of 83%. The significant positive determinants of output and efficiency were farm size, household labour, organic fertilisers as well as education and off-farm activities. The study found that bambara groundnut production can be stepped up by supporting farmers to scale up their farms, form farmer groups, diversify their livelihoods and improve the use of organic fertilizers. Improving opportunities for formal education may also have a positive impact.

Key words: Bambara groundnut, Northern Ghana, Stochastic Frontier Model, Technical efficiency.

Introduction

In Sub-Saharan Africa, per capita food production has failed to consistently increase for the past three decades (Norton, 2004), although population figures continue to increase. In spite of the emphasis that has been placed on the promotion of major crops in the region, the soil and climatic conditions in the continent favour the production of a variety of neglected crops (FAO, 2015). One of such crops is bambara groundnut (bambara groundnut) (*Vigna subterranea* (L.) Verdc.), a member of the

Fabaceae/Leguminosae family. Biodiversity International (2015) noted that bambara groundnut's resistance to harsh conditions makes it one of the most adaptable underutilised food crops. While it is widely understood to thrive well in hot and dry regions and yields better in areas with low rainfall, some landraces perform well in significantly wetter areas such as Indonesia where a number of indigenised landraces form the basis for a small but significant level of commercial production. In addition, the crop is less susceptible to pests and diseases than other crops, and can be cultivated with minimal amount of chemical or biological control.

In terms of consumption in Africa, the pods are often boiled and the seeds consumed roasted or used in soups. The beans are highly nutritious and rich in essential amino acids; when compared to the recommended FAO/WHO provisional pattern, the seeds were superior with respect to aspartic acid, threonine, methionine, leucine, tyrosine, phenylalanine, histidine and arginine, while they were adequate in valine and isoleucine (Mazahib *et al*., 2013). They are also a good source of fibre, calcium, iron and potassium, and have the potential of providing a balanced diet in areas where animal protein is expensive and the cultivation of other legumes is risky because moisture levels are unfavourable (Biodiversity International, 2015). Bambara groundnut is also used as animal feed because the stalk is tasty and the leaves are rich in nitrogen and phosphorous (Rassel, 1960). The crop has also been used for medicinal purposes such as curing diarrhoea, mouth diseases and animal wounds (Biodiversity International, 2015). In addition, FAO (2015) has noted the following positive characteristics of bambara groundnut: it is suitable for the low-input production systems in drought-prone regions where it is grown; and the nitrogen-fixing capabilities of its roots make it suitable in mixed cropping with other crops like maize, millet, sorghum, cassava and yam.

The above positive characteristics and roles notwithstanding, there are some negative perceptions about bambara groundnut. For instance, it is seen as a poor man's food in Zimbabwe. The effect of this stigma is the restriction of the market for bambara groundnut. Also, in some quarters, for instance, in Southern Guinea Savannah regions of Nigeria, Mkandawire and Sibuga (2002) indicated that bambara groundnut is viewed negatively as a women's crop and so of less value, hence its cultivation is restricted to that of a secondary crop grown on marginal lands. As is the case with a number of underutilised crops, the conditions in which bambara groundnut is cultivated and its lack of significance in respect to commodity crop production means that data concerning the levels of its production and utilisation are poor, making efforts to establish the true scale of global production difficult to ascertain. Some sources estimate its annual world production to be approximately 330,000 tonnes of which 45-50% is produced in West Africa (PROTA, 2006; Alhassan and Egbe, 2013). However, according to Biodiversity International (2015), world production of bambara groundnut in 2008 was 79,160 tonnes, compared to 29,600 tonnes in 1961. The study stressed that even though world production level has increased, farm yield remains the same, reflecting a lack of sustained research on the crop and its productivity.

Nationally, Ghana has been fairly stable in terms of food security, although there are regional differences where pockets of food insecurity situations have been recorded, especially in the three northern regions. The World Food Programme (WFP) (2009) noted that 5% of Ghana's population are food insecure and an extra 8.3% are vulnerable to become food insecure in the event of any man-made or natural occurrence. Like other parts of SSA, nutritional insecurity is more precarious in the region as households depend mostly on cereal and root staple crops for their dietary needs. FAO (2010) however noted that even though the reliance on these crops provides the energy needs of the people, the share of protein and lipids in the dietary energy are lower than recommended levels. In northern Ghana, protein requirement is also highly challenging and is currently dependent on plant based sources. This is because protein from animal sources are more expensive, and besides, even though livestock rearing is more common in the area than in the south, meat is not much patronised, especially in the rural areas.

The environmental factors in Northern Ghana nonetheless favour the cultivation of bambara groundnut. Unlike in the South, Northern Ghana has only one rainy season that starts in May and ends in

October, after which there is a long dry season for the rest of the year. The soils are also less fertile than in Southern Ghana. Northern Ghana is not only less endowed in natural resources than the South, but poverty[1] is more pronounced (GSS, 2014). According to the GSS (2014), Upper West is the poorest region with 70.7% of poor people, followed by the Northern region (50.4%) and the Upper East region (44.4%). This is significantly high considering the fact that the national average is 24.4%. The high levels of poverty are partly as a result of limited socioeconomic activities. Consequently, the percentage of the labour force employed in the agricultural sector is higher than the regions in the south. Against this background, bambara groundnut could make a significant contribution to alleviating poverty and enhancing the food security situation in the area particularly in the North if given adequate attention. To achieve this important role, farmers need to produce bambara groundnut efficiently.

Efficiency involves the production of the highest possible output level under a given production environment, known as technology. Producing at an efficient level therefore means that farmers are able to reduce wastage of inputs or reduce underutilisation of a given technology. In this study, we investigate the levels of technical efficiency in bambara groundnut current production and identify the factors that influence this efficiency. The concept of (in) efficiency is explained in the section that follows.

Materials and Methods

Literature Review

Battese (1992) defined a production function as the "maximum output that can be produced from a specified set of inputs, given the existing technology available to the firms involved." Battese (1992) noted that before Farrell's seminar paper in 1957, most empirical studies used traditional least squares methods to estimate production functions. In this case the focus was on estimating the average performance of a group of firms compared with the desired efficiency level. In 1957, however, Farrell argued in his seminar paper that we could estimate individual firms' performances and compare with the potential. In this case, not only are we able to know those who are doing well and those who are performing badly, we are able to explain the differences in their performances. This makes possible the formulation of the right policies for firms to improve upon their efficiency. The assumption is that the difference between the observed and potential performances is not only due to factors beyond the control of firms and that there are other factors within their control which explain why some firms do better than others. This is as opposed to the estimation of an average response model where the assumption is that the difference between the observed level of average output and the potential output is solely due to factors beyond the control of the firms.

Figure 1 illustrates Farrell's concept of technical efficiency. He assumed that firms use two inputs (x_i and x_2) to produce a single output (y), and operate under constant returns to scale. He also assumed that we have knowledge of the unit isoquant of fully efficient firms. In Figure 1 the horizontal axis represents the (vector of) input X, while the vertical axis represents output, Y. The observed input-output values are below the production frontier, given the technology available. It can be seen that some are closer to the frontier than others. Those who are closer represent a more efficient use of the inputs than those that are far away. A measure of the technical efficiency of the firm which produces output, Y, with inputs, X denoted by, say, A is given as y/y^* where y^* is the frontier output or the potential output. Thus in this present study, the essence of estimating technical efficiency of bambara groundnut is first to measure the performances of individual bambara groundnut farmers against the potential output levels and then investigate the socioeconomic factors that explain why some are doing better done others.

[1] This is the headcount index (P), also called the poverty incidence. This measures the proportion of the population that is poor. Thus, households whose per adult expenditure on both essential food and non-food consumption per year fell below the upper poverty line of 1, 314.00 Ghana Cedis.

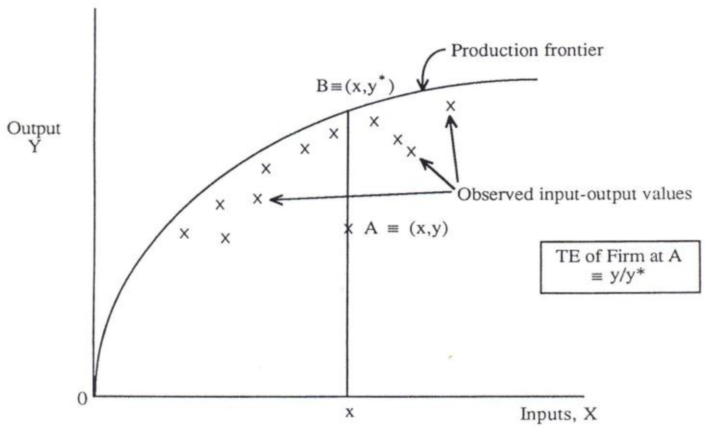

Figure: 1. Technical Efficiency of firms in Input-output space
Source Adopted from Battese (1992, p.4)

Measuring technical efficiency

Given the general production frontier model,

$$y_i = f(x_i\beta)exp\ (v_i).TE \tag{1}$$

where y_i is a scalar output of producer *i*, x_i is a vector of inputs, β is a vector of technology parameters that must be estimated, v_i is assumed to be identically and independently distributed as $N(0,\sigma_v^2)$ random variables, and $f(x_i\beta)exp\ (v_i)$ is the stochastic production frontier. From this equation, TE is defined as:

$$TE_i = \frac{y_i}{f(x_i\beta)\ exp\ (v_i)} \tag{2}$$

By this equation, we defined technical efficiency as the ratio of the observed output to the maximum feasible output, given bambara groundnut production environment characterised by $\exp(v_i)$. Therefore, a bambara groundnut producer, y_i achieves its maximum feasible value of $f(x_i\beta)\exp(v_i)$ if and only if TE_i is equal to one. But if TE_i is less than one then the observed output is not at maximum. This shortfall is known as technical inefficiency (Okon *et al*., 2010).

From equations 1 and 2, we obtain the following equations:

$$\ln(y_i) = X_i^{'}\beta + v_i - u_i \tag{3}$$

$$TE_i = w_i^{'}\delta + e_i \tag{4}$$

where δ is a vector of parameters to be estimated, e_i is a two sided error term with $N(0,\sigma_{e_2}^2)$ and u_i is equals to TE_i The other variables are as defined above.

Two functional forms of a production function mostly estimated in stochastic frontier analysis are the Cobb Douglas and the Translog Production functions. The former is simple but it is restrictive. However, the latter is flexible which implies that it does not impose assumptions about constant elasticity of production nor elasticities of substitutions between inputs. The problem with the Translog Production function is that it can cause multicollinearity problems (a case in point is Dawson *et al*., 1991). But this can be resolved by removing the squared terms. In this present study, we estimated the translog functional form.

Tests of hypotheses

A number of studies have estimated both the Cobb-Douglas and the translog functional forms and then tested the null hypothesis that the former is an adequate representation of the data, given the specification of the Translog functional form. The test is conducted using the generalised likelihood-ratio test (Coelli, 1995).

The generalised likelihood-ratio test statistic is of the form:

$$\lambda = -2\{\ln[L(H_O)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (5)$$

Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypothesis H_0 and H_1 respectively. If the given null hypothesis is true then λ has approximately a chi-square (χ^2) (or a mixed chi-square distribution). On the other hand, if the null hypothesis involves $\gamma = 0$, then the asymptotic distribution involves a mixed Chi-square distribution (see Coelli, 1995). The generalised likelihood-ratio can also be used to conduct other tests such as whether the model contains the technical efficiency term u and whether the inefficiency-effect variables are significant in determining technical efficiency. These tests are also conducted in the present study. The concept of efficiency and its measurement have been well espoused in Battese (1992), Coelli et al (1998), Farrell (1957) and Kumbhakar and Lovell (2000). Studies such as Amoah *et al*. (2014); Al-Hassan (2012); Asante *et al*. (2013); Adzawla *et al*. (2013); Yiadom-Boakye *et al.* (2013) and Donkoh *et al*. (2010) have estimated technical efficiency in Northern Ghana. However, these studies focused on cereals and vegetables. To the best of our knowledge efficiency studies on groundnut in the study area is completely missing in the literature.

Empirical Model

Given equations 3 and 4 the empirical model to be estimated to determine the technical efficiency scores and the factors influencing them may be stated as follows:

$$InOutput = \beta_0 + \beta_1 Inx_1 + \beta_2 Inx_2 + \beta_3 Inx_3 + \beta_4 Inx_4 + \beta_5 Inx_5 + \beta_6 Inx_1 Inx_2 + \beta_7 Inx_1 Inx_3 + \beta_8 Inx_1 Inx_4 + \beta_9 Inx_1 Inx_5 + \beta_{10} Inx_2 Inx_3 + \beta_{11} Inx_2 Inx_4 + \beta_{12} Inx_2 Inx_5 + \beta_{13} Inx_3 Inx_4 + \beta_{14} Inx_3 Inx_5 + \beta_{15} Inx_4 Inx_5 + \beta_{16} \, {}^1/_2 \, Inx_1^2 + \beta_{17} \, {}^1/_2 \, Inx_2^2 + \beta_{18} \, {}^1/_2 \, Inx_3^2 + \beta_{19} \, {}^1/_2 \, Inx_4^2 + \beta_{20} \, {}^1/_2 \, Inx_5^2 + v_i \quad (5)$$

Where x_1 is family labour (the total number of household members who worked on the farmer's farm); x_2 is hired labour (the total number of persons hired to work on the farm); x_3 is farm size (the total number of hectares of bambara groundnut cultivated by a farmer during the 2013 cropping year); x_4 is seed (the total quantity of bambara groundnut seed in kilograms, used in planting); and x_5 is organic fertiliser (the total quantity of organic fertiliser used on the farm measured in kilograms).

$$u = \delta_0 + \delta_1 Age + \delta_2 Age\ sq. + \delta_3 Sex + \delta_4 Marital\ status + \delta_5 Education + \delta_6 Extension\ visit + \delta_7 Research\ contact + \delta_8 Intercropping + \delta_9 Off-farm\ activity + \delta_{10} Farm\ size + \delta_{11} Distance\ from\ home\ to\ farm + \delta_{12} Distance\ from\ farm\ to\ nearest\ input\ shop + e_i \quad (6)$$

where age is the number of years from birth of a farmer, sex is a dummy variable capturing male (1) and female (0); marital status is a dummy variable measuring married (1) and single (0); education is the total number of years a farmer had been in formal education; extension visit is the total number of times a farmer had contacts with extension officers either at home or on farm; research contact is the total number of times a farmer had contact with research officers; intercropping is a dummy variable measuring mono-cropping (1) and mixed cropping (0); off farm activity is a dummy variable measuring non off-farm engagement (1) and off-farm engagement (0); distance from home to farm and from farm to the nearest input shop are distance variables measured in kilometres; and farm size is as defined earlier.

Equations 5 and 6 are estimated by maximum likelihood, using the computer program, FRONTIER version 4.1 (Coelli, 1996). Battese and Coelli's (1993, 1995) one-step/simultaneous estimation procedure is used. The maximum likelihood estimation yields consistent estimators for β, δ, γ, and σ_s^2, where $\gamma = \sigma^2 / \sigma_s^2$ and $\sigma_s^2 = \sigma_v^2 + \sigma^2$.

Study area

The study area is the three northern regions of Ghana; Northern, Upper West and Upper East where temperatures are higher than the other parts of the country and where there is only one rainy period in the whole year. As noted earlier, unlike the Southern part of the country where there are two cropping seasons annually, farming in the northern regions is limited to one season. The combined population of the three regions represents 17.1% of the country's total 24,658,823 population (GSS, 2012). Of the 17.1%, as high as 74.3% are located in rural areas. The major economic activity of this rural population is agriculture as it employs 71.9% of the workforce (GSS, 2012). Some of the crops grown in these areas are maize, millet, rice, yam, sorghum, groundnut, cowpea and bambara groundnut. One significant tool used in crop farming is the hoe except for very few farmers who used animal traction (donkey/bullocks) or tractors for land preparation. Agrochemicals are also applied since the lands are marginal and not as fertile as those in the south.

Sampling procedure and Data

The study used a multi stage sampling procedure in selecting the respondents as follows: (1) purposive sampling was used to select the three northern regions as a result of their relative environmental advantages in bambara groundnut production; (2) simple random sampling was used to select two districts from each region making up six districts in all. Out of each district, a simple random sampling was again used to select two communities involved in bambara groundnut production; (3) simple random sampling was finally used to select 10 bambara groundnut farmers from each community and so 40 farmers from each region. In total, therefore, the study involved 120 bambara groundnut farmers from 12 communities[2]. The data collection process involved administering a semi-structured questionnaire to farmers during the 2013 farming season.

Results and Discussions

Descriptive statistics of the variables

The descriptive statistics of the variables used in the estimation of the model are given in Table 1. The mean farmer age from the study is 40 years and 3 months. The level of education is low among the farmers, considering the mean estimate of 2.4 (lower primary education), although there were some farmers with tertiary education. These are higher than estimated by Etwire *et al*. (2013) where soya beans farmers on the average were 40.1 years old and having 1.8 years of formal education. Farmers' numbers of years of group membership as well as the number of times of extension worker and researcher contacts were also low with mean values of 1.33, 1.10 and 2.29 respectively. Also, on average, a farmer travelled for between 3.06 and 5.78 kilometres from their homes to their farms and from their farms to an input shop respectively. The average input levels were as follows: 0.69 hectares of farmland; 5 family labourers; 3 hired labourers; 5.45 kilogrammes of seed; 185.42 kilograms of organic fertiliser; 0.08 litres of insecticides; and 1.05 litres of weedicides. These were used to produce a mean output of 363.33 kilogrammes. From Danso-Abbeam et al. (2015), groundnut farmers in Northern region on the average cultivated 1.12 hectares of land using 43.9 kilogrammes of seed, 2.7 litres of herbicides and 132.2 man days in producing an average output of 207.1 kilogrammes. In Etwire *et al*. (2013) also, an average soya beans farmer in Northern Ghana cultivated 0.8 hectares.

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[2] This study is part of a broader study that involved a sample size of 360. The total sample size relevant for the current study was 120.

Table 1: Descriptive statistics of the variables

Variable	Minimum	Maximum	Mean	Std. Deviation
Age	19	75	40.30	12.96
Education	0	16	2.41	4.17
Years of group membership	0	10	1.33	2.18
No. of times of researcher contact	0	9	1.10	1.79
No. of extension worker contacts	0	12	2.29	2.92
Distance from home to farm	0.1	20	3.06	3.78
Distance from farm to input shop	0.6	35	5.78	5.12
Output	50	4000	363.33	456.50
Farm size	0.2	8.9	0.69	0.89
Family labour	1	20	4.62	2.88
Hired labour	0	20	3.11	3.32
Seed	0.5	16	5.45	3.00
Organic fertiliser	0	2000	185.42	331.50
Insecticides	0	5	0.08	0.53
Weedicides	0	10	1.05	1.64

Test of hypotheses

In section 2.3 three (3) hypotheses were set out to be tested. These were as follows: (1) there is no inefficiency effect in the model; (2) the Cobb-Douglas is the appropriate functional form; (3) the inefficiency effects are not significant in influencing technical efficiency. All the three hypotheses are rejected at 1% significance since the chi square (x^2) values fall outside the critical range. This is shown in Table 2 below. This implied that (1) using OLS (an average response function) for the estimation would not provide adequate information on bambara groundnut production in the area, instead the frontier should be used; (2) the translog functional form specification provided an adequate representation of technical efficiency of bambara groundnut production in the area as opposed to the Cobb-Douglas; and (3) the socio-economic characteristics of the farmers included in the model have a significant effect on farmers' efficiency.

Table 2: Hypothesis testing results

Null hypothesis	Log likelihood	x^2	Critical region	Decision
$H_0: \delta = 0$	-28.44	44.85	10.384(4)	Rejected; OLS is inappropriate
$H_0: \beta_6 + \cdots + \beta_{20} = 0$	-27.51	43.00	8.542(3)	Rejected; Cobb-Douglas is inappropriate

$H_0: \delta_1 = \cdots = \delta_{12} = 0$	-28.21	44.39	3.841(1)	Rejected; the farmer specific factors affect farmers efficiency.

Note: Number of restrictions are in parenthesis

Determinants of bambara groundnut output

Table 3 below shows the results from the maximum likelihood estimation of the stochastic frontier model. Family labour, farm size and organic fertilizer were the significant factors among the first order terms. Among the interaction terms, family labour and farm size; hired labour and farm size; and seed and organic fertilizer were significant. The squared terms that were significant also included the square of family labour, square of farm size and square of organic fertilizer. The negative coefficient of the family labour variable and the positive coefficient of the squared value of the variable mean that output would reduce initially if more family labour was used but would increase later with an increasing usage of the input. The same applies to organic fertilizer and its squared value. However, in the case of farm size, the positive coefficient of the variable, as well as the squared value, indicated that at both the initial stage and the continuous use of the input, more of it is required if output is to be increased. The marginal productivities of the inputs (see Table 4) also showed that all the inputs, except farm size, are non-positive inputs under current bambara groundnut production.

While the first order terms show their individual effects when holding all other terms constant, the interaction terms (the product of two inputs) measure the effect on output of combining two inputs. A positive coefficient of an interaction term therefore means that the two inputs can be used together to increase output (i.e. the two inputs are complements). A negative coefficient on the other hand suggests that while one variable is increased, the other must be decreased in order to increase output (i.e. the inputs are substitutes). From the results, family labour and farm size; and seed and organic fertilizer had a positive sign while hired labour and farm size had a negative effect on bambara groundnut output. This means that family labour and farm size, as well as seed and organic fertilizer, are complementary while hired labour and farm size are substitutes.

Table 3: ML estimates of Translog production frontier.

Variable	Coefficient	Standard Error	T-Ratio
Constant	3.230	0.428	7.538
Family labour	-1.299*	0.721	-1.802
Hired labour	-0.331	0.493	-0.671
Farm size	1.295**	0.601	2.156
Seed	-0.258	0.592	-0.436
Organic fertilizer	-0.553***	0.171	-3.237
Family labour X Hired labour	0.215	0.391	0.549
Family labour X Farm size	1.058**	0.521	2.029
Family labour X Seed	-0.586	0.629	-0.932
Family labour X Organic fertilizer	0.066	0.100	0.662
Hired labour X Farm size	-1.125***	0.352	-3.196
Hired labour X Seed	0.092	0.408	0.226
Hired labour X Organic fertilizer	-0.020	0.073	-0.278
Farm size X Seed	-0.724	0.532	-1.362
Farm size X Organic fertilizer	0.049	0.088	0.556

Seed X Organic fertilizer	0.309***	0.110	2.812
Family labour Squared	2.440***	0.751	3.250
Hired labour Squared	0.211	0.520	0.406
Farm size Squared	1.928***	0.503	3.836
Seed Squared	0.225	0.631	0.357
Organic fertilizer Squared	0.180*	0.101	1.791

NOTE: *, **, and * are significant levels at 1%, 5% and 10% respectively.**

Table 4: Marginal productivity of inputs

Variable	Elasticity	Std. error
Family labour	-0.324*	0.172
Hired labour	-0.078	0.072
Farm size	0.039*	0.020
Seed	-0.236	0.289
Organic fertiliser	-0.235***	0.071

Technical efficiency levels among the farmers

The estimated mean technical efficiency was 83%, ranging from 27% and 97% (Table 5). However, out of the 120 sampled farmers, 89 (74.2%) had their efficiency levels at least equal to the average efficiency level. Thus, generally the bambara groundnut farmers were efficient, although there was 17% room for improvement. The following were the estimated mean technical efficiency of similar studies: Danso-Abbeam *et al*. (2015) on groundnut production in Northern region of Ghana (83.9%); Etwire *et al*. (2013) on soya bean production in two districts of northern Ghana (53%); Awunyo-Vitor *et al.* (2013) on cowpea production in the Ashanti region (66%). Outside Ghana, Korr *et al.* (2011) estimated a mean of 38.4% for Bambara groundnut farmers in Western Kenya; Nurudeen and Rasaki (2011) and Yusuf *et al.* (2015) estimated a mean of 66.1% and 76% respectively for cowpea farmers in Nigeria; Otitoju and Arene (2010) estimated 72.7% mean technical efficiency for soya bean farmers in Nigeria; while Ibrahim et al. (2014) estimated 40% mean efficiency among groundnut farmers in Sudan. Although there are differences in both location and time between these studies and the present study, making comparison difficult, it formed basis for further target and development of bambara groundnut in the region and beyond.

Table 5: Technical efficiency levels of the farmers

Levels	Frequency	Percentage
20-29	1	0.8
30-39	3	2.5
40-49	2	1.7
50-59	4	3.3
60-69	3	2.5
70-79	7	5.8
80-89	52	43.3
90-99	48	40.0
Total	120	100.0

Minimum	27
Maximum	97
Mean	83

Determinants of technical efficiency

The conventional inputs discussed in Table 3 shift the production frontier away or contrast it. On the other hand, the inefficiency effects variables draw farmers to the frontier or move them away from it. Thus, both sets of variables are important in discussing the determinants of technical efficiency in bambara groundnut production. It should be noted that the significance of Gamma (γ) means that the variations in the output levels were also due to variation in the variables within the control of the farmers and not entirely due to natural factors outside the control of the farmers. This is consistent with the test result of Hypothesis 3.

It should be noted that in the inefficiency effect model the explanatory variables are determinants of inefficiency and not efficiency. This means that a variable with a negative coefficient has a negative relation with inefficiency but a positive relation with efficiency. The opposite is the case for a variable with a positive coefficient. From the result in Table 6, while marital status, education and distance from home to farm had a positive significant relationship with efficiency, research contact, intercropping, off-farm participation, farm size as well as distance from farm to input shop had a negative effect on technical efficiency.

Table 6: ML estimates of the determinants of technical efficiency

Variable	Coefficient	Standard –Error
Constant	-1.922	1.015
Age	0.032	0.035
Age squared	0.000	0.000
Sex	-0.068	0.167
Marital status	-0.409 *	0.231
Education	-0.036 **	0.017
Group membership	-0.067	0.051
Research contact	0.543 *	0.325
Intercropping	0.424 *	0.228
Off-farm	0.440 **	0.193
Farm size	0.303 ***	0.049
Distance from home to farm	-0.146 ***	0.019
Distance from farm to input shop	0.034 ***	0.013
sigma-squared (σ_v^2)	0.169 ***	0.049
Gamma (γ)	0.739 ***	0.099

NOTE: *, **, and * are significant levels at 1%, 5% and 10% respectively.**

Marital status had a negative coefficient and this is plausible considering the fact that a married farmer can combine his/her resources with the partner or they can practice division of labour to increase efficiency, as opposed to a single farmer. Similarly, the sign of the education variable underscores the importance of formal education in enhancing farmers' capacity to increase efficiency on their farms. This finding is similar to the works of Awunyo-Vitor *et al*. (2013), Donkoh *et al*. (2013) and Shehu *et al.* (2010). Furthermore, farmers who were farther away from their homes were more efficient than those who had their farms close to their homes. This is contrary to our *a priori* expectation since it is often thought that if a farmer has to walk a long distance to the farm before working, exacting costs in terms of time, energy and flexibility. However, it has been observed that more committed farmers do not have their farms close to their homes but at the outskirts; the reason being that they aim at more fertile lands and besides, some of them are settler farmers who may not have access to nearby lands. The positive coefficient of the intercropping variables means that efficiency is greater for mixed cropping farmers than for mono cropping farmers. MOFA (2011) noted that intercropping is done by most food crop farmers in Ghana whereas mono cropping is mostly associated with large scale commercial farming. Also, Ibeawuchi (2007) and Rashid *et al.* (2007) reported that farmers do intercropping due to factors such as population pressure that decreases the available land to a farmer, climatic variability, and as a way of making efficient use of land resources and managing risk.

Another finding that is in contrast with our *a priori* expectation is the positive coefficient of the off-farm activity variable. It should be noted that the variable was defined as a dummy variable where the value takes zero if the farmer was engaged in at least one off-farm activity and one (1) otherwise. The positive coefficient means that farmers who were engaged in off-farm activities were more technically efficient than those who concentrated solely on their farming work. This may reflect the often argued fact that farmers who engage in off-farm activities stand a better chance of financing their farms with returns from their off-farm activities. Similarly, contrary to our expectation, farmers who had contact with research officers were rather less efficient than those who did not have any research contacts. Again this is contrary to our *a priori* expectations. Given the relatively peripheral status of underutilised crops, further research could usefully focus on the specific impact of extension interventions on underutilised crop cultivation.

Considering the tedious nature of cultivating bambara groundnut, especially with respect to harvesting, it did not come as a surprise to find that farmers with small farms were more technically efficient than their counterparts with large farms. This finding is also consistent with that of Taphee and Jongur (2014). Furthermore, farmers who had their farms close to an input shop were predictably more efficient than their counterparts who had their farms far from an input shop. This is also plausible, because proximity to an input shop means that farmers are able to access the needed inputs for their farm work. Also, farmers are able to access expertise from the shops and other farmers who interact there.

Summary, Conclusions and Recommendations

The study estimated a translog stochastic frontier to determine the factors that influenced farmers' technical efficiency in the 2013 cropping season in Northern Ghana. It involved 120 farmers selected through multi-stage sampling technique. We found that while technical efficiency levels of the farmers ranged from 27% to 97%, overall levels were high with a mean of 83%, which was exceeded by 74.2% of all bambara groundnut farmers. The study identified the farm inputs that were important in increasing bambara groundnut output to be family labour, farm size and organic fertilizer. Technical efficiency was also enhanced by education, off-farm activities and mixed cropping. We recommend that farmers should be encouraged to form farmer groups as a source of farm labour and the use of organic fertilizer are promoted in the study area. Also, formal education must be stepped up and farmers supported to diversify their livelihoods.

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