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Performance of Smallholder Soybean Farmers in Ghana; Evidence from Upper West Region of Ghana

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Abstract

The economic importance of soybean towards poverty alleviation and food security is gaining wider popularity and common acceptance among smallholder farmers in sub-Saharan Africa, especially in Ghana. Commercial soybean cultivation is relatively new in Ghana; hence it has recently benefited from several productivities enhancing innovation/technologies. However, despite these efforts, productivity has remained low. This paper investigates factors affecting production efficiency among commercial soybean farmers, across the three commercial districts of the Upper West region of Ghana. A cross-sectional data collected from 271 soybean farmers were used to investigate technical efficiency of soybean production. The overall mean technical efficiency estimate is 59% with a scale elasticity of 0.89-indicating a huge scope for efficiency improvement. The result shows that, factors affecting technical efficiency are dependent on the farmer's socioeconomic status. With the existing technology and production recourses, soybean farmers can improve their current levels of soybean production by 41% through the adoption of best production practices.

Keywords: Technical efficiency, stochastic frontier analyses, soybean production, Ghana

Background

Like many developing economies, agriculture has a significant role in the socio-economic development of sub-Saharan Africa. The sector accounts for 15% of the Gross Domestic Product (GDP) and employs nearly 80% of the 950 million people in the sub-region. However, food and nutritional securities remain topical issues in the region. Official statistics suggest that 23% of sub-Saharan Africa's population are undernourished, which is expected to increase by 10% before 2050. The slow progress towards food security has partly been linked to low agricultural output resulting from the low adoption of production technologies among smallholder farmers (Food and Agriculture Organisation (FAO), 2016; World Bank 2016; Dessie et al., 2020). Subsequently, efforts to improve agriculture production across the sub-region has focused on introduction of modern crop and livestock technologies in the past years (Asante et al. 2013). However, productivity remains below potential levels (FAO 2016) due to inherent inefficiencies in production among smallholder farmers who constitute about 80.2% of the agricultural system in sub-Saharan Africa (Najjuma, 2016; Dessie et al., 2020). In this paper, we present an empirical evidence of technical efficiency of soybean producers and investigates its antecedents towards improving productivity and production in the Upper West region of Ghana.

Soybean (*Glycine max L*) is one of the most valuable leguminous crops cultivated both in developed and developing economies [Meeusen and Broeck, 1977; Abdulai et al., 2013]. In Ghana, the cultivation of soybean is relatively new (Dogbe et al., 2013). However, its economic importance is gaining wider popularity and common acceptance among farmers in the country (Etwire et al., 2013). Such economic relevance could be market and non-market co-benefits (Plahar, 2006; Dogbe et al., 2013; Biam and Tsue, 2013). Among the non-market benefits are the crop's ability to fix atmospheric nitrogen through Biological Nitrogen Fixation (BNF) (Mpeperek

et al., 2000; Chianu *et al.*, 2009) and the use of the crop's residues as a source of feed for livestock production. The BNF attribute plays a crucial role in reducing cost of production inputs (especially fertilizer) for resource-poor farmers given the nutrient deficiency nature of cultivated soils in Ghana. Furthermore, the cultivation of soybean helps to reduce parasitic weed, *striga hermonthica* which is very noxious to other crops (Giller *et al.*, 2007). Therefore, soybean farming can be viewed as an effective smart agriculture technique that conserves soil fertility for higher productivity of other major staple food crops such as rice, maize, sorghum and millet for rural livelihood sustenance (Njeru *et al.*, 2013).

The market demand for soybean grains is not only limited to domestic use but also for industrial processing into cooking oil and animal feed, especially the poultry industry (Ministry of Food and Agriculture (MoFA), 2011). Domestic demand of soybean grains is in excess of 300,000MTs annually, of which 91% is used for industrial purposes in Ghana. Meanwhile, local supply stands at 144,926MTs with a deficit of more than 150,000MT which is often augmented through importation from countries such as Brazil and China (MoFA, 2011). This supply gap presents an opportunity for poverty reduction and food security in Ghana if appropriate strategies are put in place to enhance domestic production (Dogbe *et al.*, 2013; Mohammed *et al.*, 2016; Etwire *et al.*, 2013; Avea *et al.*, 2016).

In recent times, various crop-sector initiatives including the Mennonites Economic Development Associates–Greater Rural Opportunities for Women (MEDA-GROW) and Northern Rural Growth Program (NRGP) [17] were commissioned to improve soybean production in northern Ghana for higher economic welfare of rural farm households particularly women. Smallholder farmers were trained in modern agronomic practices and provided with high yielding varieties, fertilizers, inoculants, pesticides and insecticides. However, issues of soybean production efficiencies

received little attention despite its strong correlation with higher crop productivity (Asante et al., 2013; Donkoh et al., 2013; Tambo & Gbemu, 2010; Avea *et al.*, 2016). Consequently, the impact of the soybean initiatives has been sub-optimal with Upper West region the worst affected in Ghana. Data show that the 194kg ha^{-1} average yield of soybean recorded in Upper West region is the lowest in Ghana which is nearly 80% lower than the average yield of 348kg ha^{-1} for neighbouring Northern region (Avea *et al.*, 2016). To partly address this problem, a better understanding of the underlying factors that influence smallholder farmers' technical efficiency is essential to inform decision making that improves soybean productivity (Hasnain et al., 2015). Our results will highlight the importance of factors, for example farm-specific factors, socio-economic factors and institutional factors for enhancing the productivity of soybean production without an associated increase in productive resources (MoFA, 2011; Mpeperekhi et al., 2000). Furthermore, agribusiness entrepreneurs, farm managers, and policymakers will be equipped with the relevant information for taking vital decisions in resource allocation and formulating relevant policies for enhancing soybean productivity for increased incomes and food security among smallholder farmers in Northern Ghana. This is particularly significant due to the myriads of domestic and industrial uses for the grains as well as its essential role in the government's planting for food and jobs programme. Finally, this paper will contribute to the limited empirical literature on production efficiencies in soybean production in Upper West region (Anang et al., 2016; MoFA, 2011).

The rest of the paper is structured as follows: Section Two presents a literature review on factors influencing technical efficiencies of smallholder farmers. Section Three outlines the theoretical framework that underpins the study while the research methods are described in section Four. Results and discussions are presented in Section Five while Section Six is devoted to conclusions and recommendations

Review of factors influencing technical efficiency

Technical efficiencies of smallholder farmers are strongly influenced by endogenous factors such as farmers' managerial skills and demographic characteristics. However, other uncontrolled factors including institutional and climatic factors may also affect farm productivity (Aigner et al., 1977, Battese 1992, Battese and Coelli, 1995). Many studies have investigated technical issues for numerous crop types in Ghana (Abdul-Kareem 2016, Abdulai et al., 2013, Azumah and Adzawla 2017, Etwire et al., 2013; Abate 2019). However, the factors that influence technical efficiency of soybean production are few and not clearly understood (Asante et al., 2013, Donkoh et al., 2013, Tambo and Gbemu 2010). A better understanding of these factors is important given the economic significance of soybean in rural livelihood¹. This study, therefore, adds to the existing literature by further exploring the effect of other factors such as institutional and economic factors on soybean production.

Recent study by Etwire et al. (2013) estimated the technical efficiency of soybean farms in the Saboba and Chereponi districts of Northern Ghana using the Transcendental logarithmic functional forms. They found evidence of technical inefficiencies among soybean farmers with a mean technical efficiency of 53%. This implies that there is the potential for soybean farmers to increase output by 47% with existing resources and technology. The result further reveals that older farmers are more efficient than younger farmers in soybean production in the Saboba and Chereponi districts of the Northern region of Ghana. They study concludes that access to extension services is of topmost significance for policymakers in enhancing soybean production. In a related study, Mohammed et al. (2016) estimated the technical efficiency of soybean production among

¹Soil improvement through nitrogen fixing as well as important protein source to humans, livestock and industrial use.

smallholder farmers using the translog stochastic production frontier in Northern region of Ghana. Principal findings from the study indicate that farm size significantly influences farmer's efficiency in soybean production. Other factors such as farmers experience, educational level and access to credit had no influence on farmer's production efficiencies. The mean technical efficiency of 0.61 was reported for farmers in the region which supposes that soybean farmers can obtain only 61% of their potential outputs given the available inputs and technology.

In another study, Abdul-Kareem (2016) estimated the technical efficiency of cassava farmers in the Savannah Zone of Northern Ghana and found a mean technical efficiency of 51%. Education was found to correlate negatively with technical inefficiency, meaning educated farmers are more technically efficient than the uneducated ones. Extension service also had a negative influence on efficiency. However, farm size influenced technical inefficiency positively, implying that an increase in farm size increases inefficiency. The study also found technical efficiencies across gender to vary. Hence, the author recommends specialized extension officers training and the establishment of farmer field schools to sharpen farmers' experience.

Theoretical framework

Productivity and efficiency have been examined using either non-parametric or parametric approaches. The most commonly used methods are the non-parametric approaches which include the Data Envelopment Analysis (DEA) where linear programming techniques are used to obtain a non-parametric piecewise surface that describes a frontier of most efficient production that bounds the observed input-output data. The inefficiency of production is hence determined by observed deviations from the efficient frontier (Aigner et al., 1977; Battese 1992; Battese and Coelli 1992). Due to the presence of random errors in addition to the presence of non-negative random effects associated with inefficiency of production, the Stochastic Frontier Analyses (SFA) is largely

considered more appropriate for examining the efficiency and productivity in agricultural production (Aigner et al., 1977), hence the SFA is adopted in this paper for examining the productive efficiency of soybean farmers in the Upper West Region of Ghana.

To empirically examine technical efficiency of soybean production, the general stochastic frontier production model is estimated and the model for technical inefficiency proposed by Battese and Coelli (1993, 1995) is adopted to investigate the technical inefficiencies of soybean production. Aigner et al. (1977) and Meeusen and van den Broeck (1977) introduced the stochastic production frontier based on parametric technique (Trujillo and Iglesias 2013) to estimate a firm's technical efficiency. Prior to estimating the model, we tested between the Cobb-Douglas and translog functional forms and the test results rejected the Cobb-Douglas indicating that translog functional form fits the data adequately.

Model specification

Following Battese (1992), the translog stochastic production frontier for investigating the technical efficiency of soybean production in the Upper West Region is defined by:

$$Y_i = f(X_i; \beta) \exp(\varepsilon_i) = f(X_i; \beta) \exp(V_i - U_i), i = 1, 2, \dots, N \quad (1)$$

where, Y denotes output, X and β are vectors of inputs and parameter estimates, respectively. V_i is the stochastic error or statistical noise outside the influence of the farmer. It is assumed to be half normally distributed as $N(0, \delta^2_v)$ and independent of U_i . Conversely, U_i is a non-negative random variable associated with technical inefficiency which is under the control of the producer. It is assumed to be independent and identically distributed non-negative truncation of the $N(0, \delta^2)$ and independent of V_i .

162 The TE as posited by Battese (1992) is the ratio the of frontier output to the observed output,
 163 consequently TE is stated as:

$$164 \quad TE_i = \frac{Y_i}{Y^*_i} = \frac{f(X_i, \beta) \exp(V_i - U_i)}{f(X_i, \beta) \exp V_i} = \exp(-U_i) \quad (2)$$

165 Since U_i represent a non-negative random variable accounting for technical inefficiency and are
 166 within the farmer's control, factors that affect such inefficiency are stated as:

$$167 \quad U_i = \gamma_0 + \sum_{j=1}^j \gamma_j Z_{ij} + \varepsilon \quad (3)$$

168 Where γ denotes parameters and Z_i are socio-economic and other factors under the control of the
 169 farmer influencing efficiency. The variance parameters are expressed as:

$$170 \quad \delta^2 = \delta_v^2 + \delta_u^2 \text{ and } \gamma = \frac{\delta_u^2}{\delta} \quad (4)$$

171 Farmers' individual efficiency levels are also obtained as:

$$172 \quad E[\exp(-U_i) / e_i] = \frac{1 - \phi(\delta_A + \frac{\gamma e_i}{\delta_A})}{1 - \phi(\frac{\gamma e_i}{\delta_A})} \exp(\gamma e_i + \frac{\delta_A^2}{2}) \quad (5)$$

173 The translog stochastic frontier (SF) is thus represented as:

$$174 \quad \ln Y = \beta_0 + \sum_{j=1}^m \beta_j \ln X_{ij} + 0.5 \sum_{j=1}^m \sum_{k=1}^m \beta_{jk} \ln X_{ij} \ln X_{ik} + V - U \quad (6)$$

175 The values of the explanatory variables in the translog SF model in equation (6) were normalized
 176 by their respective sample means such that the first-order coefficients of the input variables
 177 estimate the partial output elasticities for each input at mean input values. Consequently, the sum

of the output elasticity from the input variables is the scale elasticity (ε) which is defined as the degree of responsiveness of output to input changes.

Methodology

Study area

The study was carried out in three districts of Upper West region of northern Ghana namely, Sissala West, Wa East and Daffiama Bussie Issa (DBI). The districts have a combined total land area of 21,844.3 square kilometers and are the major soybean producing zones in the region. The ecological zone of the districts exhibits the Guinea savannah vegetation characteristics. The rainfall pattern is uni-modal in nature which usually spans from May to October. The annual mean rainfall of the districts is about 1100mm reaching its peak in August. Relative humidity is between 70% and 90% in the rainy season but is as low as 20% in the dry season with temperatures between 25°C to 40 °C (GSS, 2012). Agriculture is the main occupation of the people employing between 80% to 90% of the population. Food crop production remains largely subsistence with lower output levels. Food (maize, soybean, groundnuts, and cowpea) and cash crops (cotton and soybean) production, as well as animal rearing, are the main agricultural activities [GSS, 2012].

Sampling procedure and size

A multi-sampling technique was used to sample 271 soybean farmers for the study (see Table 1 below). At stage one, purposive sampling was used to select three (3) districts (Sissala West, Wa East, and DBI) based on importance in soybean production. A simple random selection was applied at the second stage to select nine (9) communities for data collection. Finally, the 271 soybean farmers were selected through simple random selection from a sample frame provided by the agricultural extension officers at each community. Proportional sampling was used to

determine the sample size of each community in the various districts. Illustrated in Table 1 are the distribution of respondents by districts and communities.

Table 1 Distribution of respondents by districts and communities

District	Communities	Population of soybean farmers	Sample Size
Sissala West	Nyimati	135	43
	Bullu	71	23
	Jawia	100	32
Wa East	Goripie	119	38
	Bunaa	121	39
	Viehaa	52	17
Dafiama Busie Issa	Fian	111	35
	Chebaa	34	11
	Tabiesi	102	33
TOTAL	9	845	271

Method of Data Collection and Analysis

This paper used primary quantitative data collected through a formal survey using a structured questionnaire. The data collected included specific data on farmer and production-related factors such as input and output quantities, personal characteristics and institutional factors. The data was analyzed using STATA version 14.0. Descriptive statistics such as frequencies and means were used to summarize the data. The translog stochastic frontier model was used to examine technical efficiency of soybean production.

Empirical model

Following from equations (3) and (6), the empirical model for technical efficiency of soybean production and inefficiency are explicitly expressed in equations (7) and (8) as:

$$\ln Output_i = \beta_0 + \beta_1 \ln seed + \beta_2 \ln Ino + \beta_3 \ln lab + \beta_4 \ln Fert + \beta_5 \ln Agro + \beta_6 \ln Fsize + \beta_7 \ln (seed)^2 + \beta_8 \ln (Ino)^2 + \beta_9 \ln (lab)^2 + \beta_{10} \ln (Fert)^2 + \beta_{11} \ln (Agro)^2 +$$

$$\begin{aligned}
& \beta_{12} \ln(Fsize)^2 + \beta_{13} \ln(seed * Ino) + \beta_{14} \ln(seed * lab) + \beta_{15} \ln(seed * Fert) + \\
& \beta_{16} \ln(seed * Agro) + \beta_{17} \ln(seed * Fsize) + \beta_{18} \ln(Ino * lab) + \beta_{19} \ln(Ino * Fert) + \\
& \beta_{20} \ln(Ino * Agro) + \beta_{21} \ln(Ino * Fsize) + \beta_{22} \ln(Lab * Fert) + \beta_{23} \ln(Lab * Agro) + \\
& \beta_{24} \ln(Lab * Fsize) + \beta_{25} \ln(Fert * Agro) + \beta_{26} \ln(Fert * Fsize) + \beta_{27} \ln(Agro * Fsize) + \\
& \mu_i
\end{aligned} \tag{7}$$

and

$$\begin{aligned}
\mu_i = & \theta_0 + \theta_1 Sex + \theta_2 Education + \theta_3 Age + \theta_4 Household + \theta_5 Credit + \theta_6 Extension + \\
& \theta_7 Experience
\end{aligned} \tag{8}$$

where the *output* is the yield of soybean measured in $kg\ ha^{-1}$ and U_i is a non-negative random variable associated with technical inefficiency. The explanatory variables are explained in Table 2.

Table 2 Detailed description of variables used in translog model

	Measurement	Type of Data	A-priori Expectation
<i>Input-output variables</i>			
Land size	Hectares	Continuous	+
Fertilizer	Kg	Continuous	+
Agrochemicals	Liters	Continuous	+
Labor	Man days	Continuous	+
Seed	Kg	Continuous	+
Inoculants	G	Continuous	+
Output	Kg	continuous	+
<i>Socio-economic attributes</i>			
Age	Years	Continuous	+/-
Household size	Persons	Continuous	+/-
Soy Farming experience	Years	Continuous	+/-
Education	Years	Continuous	+
Gender			
Male1	1 = male farmer	Dummy	+/-
Female0	0 = otherwise		

Extension access	Number frequency of extension contacts	Continuous	+
Credit access1 Otherwise0	1 = access to formal credit 0 = otherwise	Dummy	+

Results and discussion

Socioeconomic Characteristics of Respondents

Summary of demographic characteristics of soybean farmers as well as summary overview of statistics of key variables used in the technical efficiency models are presented in Table 3. The result shows a mean seeding rate of soybean of 33.9 Kg ha^{-1} which is slightly below the recommended seeding rate of 39-40 Kg ha^{-1} (Giller and Dashiell, 2007). Similarly, the use of other inputs such as fertilizer (19.94Kg ha^{-1}), inoculants (65.65g ha^{-1}) and agrochemicals (3.49L ha^{-1}) was found to be low. These findings corroborate with studies by Zoundji et al. (2015), Avea et al. (2016), Dogbe et al. (2013) and Mohammed et al. (2016) who reported low fertilizer and other input usages by soybean farmers across various sub-Sahara Africa countries. The observed low fertilizer and inoculants utilization by farmers in the study area could be attributed to the negative perception that soybean does not need fertilizer to improve growth and yield. Inoculants, on the other hand, comes with complicated handling requirements and specifications which are quite difficult for farmers to manage. Conversely, the use of family labor (46 Man-days ha^{-1}) was found to be high compared with hired labor (27 Man-days ha^{-1}). However, Avea et al. (2016) reports mean man-days of 38 employed per hectare of soybean farm in northern Ghana.

Smallholder farmers' experience of 4.43 years in soybean cultivation was found to be low. The finding is consistent with Dogbe et al., 2013; Rusike et al., 2016; Avea et al., 2016 who report that

the cultivation of the soybean is new to Ghanaian farmers who may encounter production challenges. The study shows 88% of the respondents have access to extension services with an average visit of 22 per production circle. Such a high regular extension visits is critical for improved productivity given the high illiteracy rate (69%) and low farming experiences among the farmers. The frequent and timely provision of extension services can enhance farmers' knowledge on improved farming practices and thus improve production and yield.

The average household size of 11 persons is similar to the observation made by Avea et al. (2016) in northern Ghana. The relatively larger household size may denote increase labour availability for farm and other related activities. The respondents' mean age of 42 years is higher than the 36 years reported by Avea et al. (2016) but similar to the 44years observed by Dogbe et al. (2013). The farmers' age implies youthful exuberant in soybean production to carry out the drudgery activities of soybean production process. Similarly, the high youthful involvement in soybean production may infer sustainability of the crop cultivation in the area and could serve as an important employment avenue. The result also reveals that majority of soybean farmers across the three districts are females as they account for 80% of the sample size.

Table 3. Farm and non-farm attributes of farmers

	District			
	Sissala West	Wa East	DBI	Total
Farm Attributes	Means (Std [#])	Means(Std)	Means(Std)	Means(Std)
Soy Yield (kg)	969.67 ^a (397.99)	953.16 ^b (428.91)	594.42 ^c (412.54)	854.55(444.33)
Farm Size (ha)	0.79 ^a (0.54)	0.87 ^b (0.81)	0.46 ^c (0.29)	0.72(0.62)
Seed (kg)	35.50 ^a (9.08)	35.95 ^b (11.28)	29.48 ^c (10.79)	33.90(10.73)
Inoculants (g)	16.21 ^a (56.46)	119.65 ^b (121.73)	63.14 ^c (121.99)	65.65(111.62)
Fertilizer (kg)	26.58 ^a (58.94)	24.68 ^b (66.54)	5.17 ^c (14.38)	19.94(56.30)
Agro-chemical (L)	6.04 ^a (2.48)	4.32 ^b (2.41)	6.58 ^c (3.85)	3.49(2.47)
Hired Labor (man-days)	22.35 ^a (27.11)	34.53 ^b (36.49)	30.35 ^c (39.12)	27(35)
Family Labor (man-daysHa ⁻¹)	57.27 ^a (46.80)	37.20 ^b (36.54)	50.98 ^c (47.65)	46(44)
Farmer Attributes	Means (Std)	Means(Std)	Means (Std)	Means (Std)
Age	41.53 ^d (11.69)	41.89 ^d (9.79)	42.76 ^d (9.91)	42.01(10.52)

Household Size	9 ^a (3.14)	12 ^b (6.52)	12 ^c (5.48)	10.90 (5.48)
Education(Years)	2.67 ^d (4.43)	1.57 ^d (2.96)	2 ^d (3.78)	2.07 (3.80)
Extension (No. of Visits)	34 ^a (36.43)	14 ^b (13.18)	14 ^c (12.51)	21.97 (26.62)
Experience(Years)	5.07 ^a (2.36)	5.44 ^b (3.53)	2.44 ^c (.73)	4.43 (2.85)
	N (%)	N (%)	N (%)	N (%)
Male	34(35)	15(16)	4(5)	53(20)
Female	64(65)	79(84)	75(95)	218(80)
Education0	62(63)	67(71)	59(75)	188(69)
Educatio1	36(37)	27(29)	20(25)	83(31)
Access to credit1	59(60)	7(7)	18(23)	84(31)
Access to credit0	39(40)	87(93)	61(77)	187(69)

[#] Std denotes standard deviation while means with different superscripts are significant at 5% level and same superscripts denote means are not different.

Frontier estimates

A number of tests of significance for the functional forms and models specifications are presented in Table 4. The first hypothesis states that the explanatory variables have no joint effect on soybean output, i.e. $H_0 : \beta_1 = \dots \beta_5 = 0$. This hypothesis is rejected at the one percent level suggesting that in deed farm specific input factors included in the model jointly influence soybean output.

The second hypothesis in Table 4 states that the second-order coefficients in the translog production function have zero values; i.e. $H_0 : \beta_{jk} = 0$, indicating that, the Cobb-Douglas production function fits the data appropriately. This hypothesis is also rejected at the 1% level signifying that indeed the Cobb- Douglas functional form is not an adequate representation of the data given the assumption for the translog functional form hence the translog functional form is adopted for the study.

Table 4 Tests of hypothesis and model specification

No.	Null Hypothesis	Statistic	Decision Rule
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1	Explanatory variables have no joint effect on soybean output $H_0 : \beta_1 = \dots \beta_5 = 0$	Wald Chi-square 836.89*** (0.0000)	Reject null hypothesis at 1%
2	Cobb-Douglass is best fit for the data $H_0 : \beta_{jk} = 0$	Likelihood-ratio Chi-square 43.22*** (0.0029)	Reject null hypothesis at 1%
3	Absence of inefficiency $H_0 : U_1 = 0$	Likelihood-ratio Chi-square 28.71*** (0.0000)	Reject null hypothesis at 1%

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

The third hypothesis that technical inefficiency effects are absent from the model at every level $H_0 : U_1 = 0$, implying that the deterministic production function is desirable is also rejected at 1% significance level. This indicates that the stochastic production frontier approach applies.

Presented in Table 5 is the maximum likelihood estimates of the translog stochastic frontier production model. The results show that significant effects of seed, labor, farm size and fertilizer on soybean output. These factors play an important role in determining soybean outputs among farmers in the Upper West Region. Improving productive efficiency of soybean will require enhancing farmers access to improved seeds and fertilizers. In addition, the square of seed, fertilizer, farm size, and interactive terms for seed*labour, seed*fertiliser, inoculants*labour, and seed*farm size are also significant at various probability levels, however, seed*farm size, had negative effect on soybean yield. The positive and significant effect of seed*farm size implies that land productivity increases with increasing use of seed. In other words, increasing seed and farm size have complementary effects on productivity of soybean production. The negative effect of seed*labour and seed*fertilizer implies that seed productivity in soybean production increased with decreasing labour and fertilizer productivity. This suggests that after certain quantity of seed is used increasing the use of fertilizer or labour do not necessarily increase overall soybean productivity. Similar explanations go for inoculants*labour.

The Wald Chi-square statistic is significant at 1%, implying that the inputs jointly explain the variation in soybean output. The high gamma value of 0.94 for soybean farmers in the study area signifies the presence of technical inefficiencies in soybean production among the sampled farmers. The gamma value indicates that about 94% of the variation in the output of soybean farmers from the translog frontier output was due to inefficiency in production. That is 94% of the variation in composite error term was attributed to the inefficiency component.

Table 5 Maximum likelihood estimates of the stochastic translog production model

Variable	Parameters	Coefficients	Standard Error	z-statistic	P> z
Cons	β_0	0.165	0.090*	1.840	0.066
LnSeed(kg)	β_1	0.211	0.096**	2.190	0.028
LnIno (g)	β_2	-0.100	0.092	-1.090	0.275
LnLabour(man-days)	β_3	0.193	0.193**	2.280	0.022
LnFert (kg)	β_4	-0.154	0.093*	-1.660	0.098
LnAgro (ltr)	β_5	0.058	0.058	0.770	0.439
LnFsize (Ha)	β_6	0.679	0.132***	5.14	0.000
0.5 (LnSeed) ²	β_7	-1.738	0.695***	-3.29	0.012
0.5(LnIno) ²	β_8	0.205	0.182	-2.500	0.261
0.5(LnLabour) ²	β_9	0.442	0.470	1.120	0.346
0.5(LnFert) ²	β_{10}	0.263	0.133**	1.970	0.048
0.5(LnAgro) ²	β_{11}	0.471	0.485	0.970	0.331
0.5(LnFsize) ²	β_{12}	-3.338	1.015***	0.940	0.001
LnSeed* LnIno	β_{13}	0.050	0.100	0.490	0.621
LnSeed*LnLabour	β_{14}	-1.083	0.590*	-1.840	0.066
LnSeed*LnFert	β_{15}	-0.387	0.197**	-1.970	0.049
LnSeed*LnAgro	β_{16}	-0.324	0.396	-0.820	0.412
Lnseed*LnFsize	β_{17}	2.622	0.656***	4.000	0.000
LnIno*LnLabour	β_{18}	-0.170	0.104*	-1.640	0.102
LnIno*LnFert	β_{19}	0.027	0.029	0.930	0.353
LnIno*LnAgro	β_{20}	0.001	0.060	0.020	0.985

LnIno*LnFsize	β_{21}	-0.060	0.134	-0.450	0.655
LnLabour*LnFert	β_{22}	0.032	0.118	0.270	0.788
LnLabour*LnAgro	β_{23}	0.000	0.304	0.000	0.999
LnLabour*LnFsize	β_{24}	0.586	0.722	0.810	0.416
LnFer*LnAgro	β_{25}	0.032	0.084	0.390	0.698
LnFert*LnFsize	β_{26}	0.125	0.164	0.760	0.447
LnFsizeLnAgro	β_{27}	0.192	0.486	0.400	0.692

Sigma_v (σ_v), 0.086 (0.018)	sigma_u (σ_u), 0.362(0.026)	sigma2 (σ^2), 0.139(0.017)
lambda (λ), 4.221(0.094)	Gamma(γ), 0.943	Log-likelihood, 26.275
Wald Chi-square, 836.90***		

Note: ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

*Figures in parenthesis are Standard errors

The results of the estimated elasticities of the factor inputs at mean output values are illustrated in Table 6. The data reveals a scale elasticity of 0.89 implying that soybean farmers in the Upper West region of Ghana are operating within stage II of the production possibility curve often referred to as the 'economic zone. It means that the output of soybean is increasing at a decreasing rate and hence employing additional unit of all resources results in less than an additional unit of output. it further implies that, soybean production in the study area is inelastic. In other words, a percentage increase in input use leads to a lesser percentage corresponding increase in output. Despite this, farmers are expected to use more additional inputs until maximum output is reached. The finding corroborates with Mugabo et al. (2014) who report a scale elasticity of 0.98 for soybean farmers in Rwanda, which implies such farmers operate within stage II of the production possibility curve and thus experiencing decreasing returns to scale.

Table 6 Elasticities of inputs at mean output values

Input	Elasticity
Land (farm size)	0.679***

Fertilizer	-0.154*
Inoculants	-0.100
Agrochemicals	0.058
Seed	0.211**
Labour	0.193**
Elasticity of production (EP)	0.89

***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

The elasticity of farm size (0.68) is positive and significant at 1% probability level. The coefficient suggests that a percent increase in farm size leads to a 0.68% increase in soybean output, all things being equal. Therefore, the result confirms the assumption that an increase in cultivated farmland increases the output of soybean. The result is consistent with findings by Avea et al. (2016) and Etwire et al. (2013) in northern Ghana who report a positive relationship between soybean farm size and output. Similarly, the elasticity estimate of seed is significant and positive conforming to the expected sign. The result implies that as a farmer increases the quantity of seed used in the production of soybean, output tends to increase, *ceteris paribus*. For every percent increase in seed rate of soybean, output increases by 0.21%. The result is in sync with Anang et al. (2016) and Abdulai et al. (2013) who report a positive relationship between rice and maize seeds, and yields but disagrees with Etwire et al. (2013) who report an inverse relationship between seed and soybean yield in northern Ghana.

Technical efficiencies

The results of the distribution of technical efficiency scores of soybean production across the selected districts are presented in Table 7. The results show that the mean technical efficiency across the districts differs significantly. The overall mean technical efficiency level of soybean farmers in the Upper West region was estimated at 59%. The implication is that soybean farmers

in the Upper West region of Ghana can still increase output levels by 41% without having to increase the current inputs used. Soybean production in the three districts can thus be increased by 41% by adopting good agronomic practices in soybean farming. The finding corroborates Etwire et al. (2013) and Mohammed et al. (2016) who report a mean technical efficiency of 53% and 61% among smallholder soybean farmers in northern Ghana, respectively. However, the result contradicts with Avea et al. (2016) who report a higher mean technical efficiency score of 89% among smallholder soybean farmers in Northern Ghana.

Table 7 Distribution of technical efficiency score of soybean farmers

Efficiency Score (%)	Districts							
	Sissala West		Wa East		DBI		Total	
	N	%	N	%	N	%	N	%
0-10	0	0	0	0	1	1.3	1	0.4
11-20	1	1	3	3.2	6	7.6	10	3.7
21-30	5	5.1	0	0	9	11.4	14	5.2
31-40	4	4.1	6	6.4	12	15.2	22	8.1
41-50	13	13.3	16	17	11	13.9	40	14.8
51-60	12	12.2	16	17	19	21.1	47	17.3
61-70	22	22.4	19	20.2	9	11.4	50	18.5
71-80	26	26.5	20	21.3	8	10.1	54	19.9
81-90	15	15.3	14	14.9	3	3.8	32	11.8
91-100	0	0	0	0	1	1.3	1	0.4
Mean		63		62		49		59
Min		19		13		6		6
Max		89		88		91		91
Std.Dev		17		17		20		19

Across districts, Sissala West recorded the highest mean efficiency of 63%, followed by Wa East (62%) and 49% for DBI. This means that farmers in Sissala West, Wa East, and DBI can still increase the production level by 37%, 38%, and 51%, respectively without an increase in the current level of inputs used. Further, it is evidenced from the data that 41.8% of farmers in the Sissala West district operate within an efficiency level of 70% and above while that of Wa East is 36.2%. Meanwhile, only 15.2% of such farmers from the DBI district operate at this efficiency

level. The implication is that farmers in the Sissala West district are more efficient than their counterparts in Wa East and DBI, with the latter being the least efficient. The high-efficiency level recorded for farmers in the Sissala West district could be attributed to their high experience in soybean farming. On a whole, about 32% of the soybean farmers in the study area operate above an efficiency level of 70%.

Estimates of technical inefficiency in soybean production

The determinants of technical inefficiency among soybean farmers is shown in Table 8. Negative coefficients mean a reduction in inefficiency and thus enhance farmers' efficiency. Even though formal education, household size, access to credit, sex and extension service retained the expected negative sign on as hypothesized, none is significant at 10% significant level except farmers' experience in soybean production. The data, therefore, support the hypothesis that farmer's experience in soybean production positively influences their efficiency levels. Experienced farmers are usually better farm managers because they might have gone through different phases of challenges and overcome them in production of soybean. The finding agrees well with Mohammed *et al.* (2016), Biam *et al.* (2015) and Onumah *et al.* (2013).

Table 8. Estimates of technical inefficiency in soybean production

Variables Output	Parameters	Coefficients	Standard Errors	Z-Statistics	P> Z
Constant	θ_0	0.557	0.603	0.92	0.355
Sex	θ_1	-0.217	0.283	-0.77	0.443
Age	θ_2	-0.002	0.010	-0.18	0.859
Education	θ_3	-0.013	0.074	-0.18	0.860
Household Size	θ_4	-0.018	0.016	-1.13	0.258
Access to credit	θ_5	-0.027	0.226	-0.12	0.903
Extension services	θ_6	0.230	0.325	0.73	0.466
Experience	θ_7	-0.223***	0.043	-5.13	0.000

*** denotes significant at 1% level

367

368 **Conclusions and recommendations**

369 The paper examines the technical efficiency of soybean production among smallholder farmers in
370 the Upper West region of Ghana. Using cross-sectional data from 271 randomly selected farmers,
371 this paper employs the translog stochastic frontier production model to estimate the technical
372 efficiency of soybean production and examines the factors influencing technical inefficiency. The
373 results indicate that the mean technical efficiencies of soybean output were 63%, 62% and 49%,
374 for Sissala West, Wa East, and DBI, respectively with an overall mean of 59% for the entire region.
375 This implies that farmers in the Sissala West, Wa East, DBI and the entire region are operating
376 37%, 38%, 51%, and 41 %, respectively, below the optimal soybean output attainable given the
377 available technology and inputs. Generally, soybean farmers in the region can increase outputs by
378 41 percent using the available technology and inputs. Furthermore, experience in soybean
379 production was found to be a key factor influencing technical inefficiency in production.

380 The results further show that major factors that contributes to soybean output include land, labor,
381 fertilizer and seed. Positive effects were found with land, labor, seed and soybean outputs, while
382 fertilizer has a negative effect. To improve efficiency in soybean production in the Upper West
383 region of Ghana will require policies that enhance farmers access to land, labour and improved
384 seeds. Similar of such programmes include the planting for food and jobs programme being
385 implemented by the Government of Ghana, which include facilitating access to improved seeds
386 and fertilizer. However, such strategy can be enhanced by the government through private
387 partnership arrangements with seed companies should provide subsidized certified soybean seeds
388 for farmers to improve production. Finally, there is the need for policy to enhance access to easy

arable lands through active engagements with the chiefs and elders in production communities especially for women farmers.

Lists of Abbreviations

AEAs	Agricultural Extension Agents
FAO	Food and Agriculture Organisation
GSS	Ghana Statistics Service
GDP	Gross Domestic Product
MEDA-GROW	Mennonites Economic Development Associates–Greater Rural Opportunities for Women
SPSS	Statistical Package for Social Science
MoFA	Ministry of Food and Agriculture
BNF	Biological Nitrogen Fixation
NRGP	Northern Rural Growth Program
DEA	Data Envelopment Analysis (DEA)
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
DBI	Daffiama Bussie Issa (DBI).

Declarations

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interest

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Authors' Contribution

FAA wrote the proposal, collected the data, analysed it and wrote the paper. FA also participated in the data collection and performed the analysis. FN, BOA and AM edited and reviewed the manuscript. All the authors read and approved the manuscript for publication.

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