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Assessment of technical efficiency and its determinants among smallholder pepper farmers in Tolon District of Ghana

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ABSTRACT

The main aim of this study was to assess technical efficiency (TE) and its determinants among small-scale pepper farmers in Ghana. The study used a stochastic frontier approach and the translog production function to analyze the TE of selected pepper farmers. The mean technical efficiency was 81.4% implying high efficiency of production among the farmers. Pepper output increased with cost of ploughing and the quantity of seed used at 1% significant level. Furthermore, TE significantly increased with years of education, household size, weeding frequency, fertility of the soil, livestock ownership and access to credit. The study recommends provision of credit to farmers, training on effective weed control and soil fertility management alongside integration of livestock rearing as measures necessary to boost TE of pepper farmers.

***Keywords**: Ghana, Pepper, stochastic frontier analysis, technical efficiency.*

INTRODUCTION

Agriculture remains the mainstay of most rural households in developing nations like Ghana and contributes immensely to the economy of these countries. The level of productivity among small-scale farmers, who produce the bulk of the food consumed in these countries however remains below expected levels (Abdulai *et al*., 2013). The low productivity in smallholder farming has been blamed on inefficiency in production attributable to factors like low level of modern technology adoption, lack of access to credit and irrigation facilities, among others. Efficient utilization of limited resources is necessary to achieve optimum output levels, which in turn is anticipated to raise agricultural earnings, and ensure food security (Anang *et al*., 2016).

Pepper (*Capsicum* spp.) is a key commercial crop produced as a vegetable, spice, and value-added processed product (Kumar and Rai, 2005). Aside from vitamins A and C, pepper is also high in antioxidants (Nadeem *et al*., 2011). Pepper production is popular among smallholder farmers because it is easy to cultivate and tolerates several climatic conditions (Saavedra *et al*., 2014).

Pepper is an important non-traditional crop produced by Ghanaian farm households because of its economic benefits and contribution to household income (Asravor *et al*., 2016). Pepper production provides employment and source of income for farm households. As indicated by Mohammed *et al*. (2016), pepper cultivation by small-scale producers is highly profitable especially in northern Ghana. The lucrative nature of pepper farming is succinctly captured by Asravor *et al*. (2016), referring to the crop as *Green Gold.*

The crop is used for culinary and other industrial purposes, and its cultivation has recently gained popularity among farmers due to good prices and favorable conditions for its production across the country. According to IFPRI (2020), fresh chili production in Ghana stood at 140,000 metric tonnes annually with about 13,700 hectares of land currently under pepper cultivation.

Some of the few studies on pepper production in Ghana include Asravor *et al*. (2016) and Wosor and Nimoh (2012). These studies portray decreasing returns to scale in pepper cultivation. The limited research devoted to pepper production in Ghana warrants further investigation in view of the increasing role of pepper production in the livelihoods of smallholder farm families. Measures to enhance pepper production, particularly regarding efficient resource use in production will significantly aid in promoting the cultivation of the crop to generate income for pepper farmers and foreign exchange earnings from pepper exports to drive economic development. This study therefore fills an important research gap and provides relevant findings necessary to promote efficiency of production of non-traditional crops like pepper.

This study sought to evaluate the technical efficiency (TE) of Ghanaian pepper growers with a focus on the Tolon district. The research is important in two folds. To begin with, the level of TE among small-scale pepper producers in Ghana is largely unknown due to very limited information and research on pepper production. The few studies on TE of pepper farming in Ghana have concentrated on the Volta Region (Asravor et al., 2016; Wosor and Nimoh, 2012). Tsiboe et al. (2019) on the other hand used a nationally representative data from the Ghana Living Standard Surveys (GLSSs) to assess technical efficiency of vegetable production in Ghana, focusing on okra, pepper and tomato. It is hard to come across studies on pepper production in northern Ghana, where pepper production is an important economic activity, hence this study. Pepper has not gained much research attention in productivity and efficiency analysis as compared to crops like maize, rice, soybean, groundnut, yam, among others. Thus, the results of the study are anticipated to highlight the extent to which pepper producers are making judicious use of their limited production resources and how to improve their resource use efficiency. Again, the determinants of TE of pepper farming are largely unknown due to the limited studies in Ghana, hence the need for this study. The result from the study is expected to inform policy makers and other stakeholders in the agricultural sector about ways to enhance the cultivation of non-traditional crops such as pepper.

The organization of the remainder of the study is as follows. The methodology, encompassing descriptions of the study area, method of data collection, analytical models, and data analysis is captured under section 2. Section 3 captures the results and descriptions of the key findings while the conclusion and recommendations are provided in section 4.

MATERIALS AND METHODS

Study area, sampling and data collection

The research was carried out in the Tolon district of the Northern Region of Ghana. The district is a major agricultural production area noted for the production of soybean, rice, pepper, and maize (Al-hassan and Jatoe, 2018). The district is located in the country's northern savanna with mainly grassland vegetation mixed with scattered trees. The district has one rainfall regime with average yearly rainfall ranging from

950 mm to 1200 mm (Ghana Statistical Service, 2014) and high daily temperatures particularly during the dry season which can reach about 40 degrees Celsius with very low humidity levels at the height of the harmattan (Anang, 2021). May/June marks the start of the rainy season, which concludes in September/October (Ministry of Food and Agriculture [MoFA], 2010).

Data for the study was solicited from small-scale pepper producers in the district for 2019/2020 farming season. A semi-structured questionnaire was administered to 200 pepper farmers selected using multi-stage sampling method. At the initial stage, purposive sampling of four (4) communities noted for the cultivation of pepper in the district was carried out. The second stage encompassed selection of fifty (50) pepper farmers randomly from each of the chosen communities. Information solicited from farmers included production data, input and output data, marketing information and access to services. Respondents were briefed on the goal of the study and their consent to participate was sought. The interviews were carried out using the local dialect because of the inability of majority of the farmers to read and write.

Analytical and empirical model: the stochastic frontier model

Estimation of TE typically involves the use of two main approaches namely data envelopment analysis **(**DEA) or stochastic frontier analysis (SFA) which are non-parametric and parametric approaches respectively (Anang, 2021; Martey *et al*., 2019). However, this study adopted the latter approach, SFA by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) to analyze the TE of pepper farmers due to its wide usage and robustness. This model captures both the production function and the factors influencing production inefficiency.

The transcendental logarithm (translog) and Cobb-Douglas functional forms are the preferred choices for estimating TE in the literature. With the help of generalized likelihood ratio tests, one can empirically ascertain the suitability of a particular functional form to use (Onumah *et al*. 2010 and Abdulai *et al*., 2013). The key limitation of Cobb-Douglas functional form as noted by Wilson *et al*. (1998) is that it poses limitation on the technology of the firm by limiting the elasticities of production to be constant and the elasticities of input substitution equals one. The translog functional form despite not having these limitations may face multicollinearity challenges (Dawson *et al*., 1991). This study adopted the translog functional form based on its flexibility and wide application in estimating technical efficiency. The likelihood ratio test also supported the use of the translog model as appropriate representation of the data to generate reliable parameter estimates.

The stochastic frontier model compares maximum achievable output to the attained output whilst accounting for the variation of the realized output from the frontier (Anang *et al*., 2017). Following Meeusen and Van den Broeck (1977) and Aigner *et al*. (1977), the stochastic frontier model is expressed as

$$Y_i = f(x_i\,;\beta).exp(v_i - u_i) \qquad (1)$$

where Y_i signifies the maximum pepper output by the i^{th} farmer, $f(x_i\,;\beta)$ denotes the suitable production function of which x_i represents the production inputs while β denotes unknown parameters, v_i captures the symmetric stochastic term reflecting conditions outside the producer’s control and u_i represents a non-negative error term accounting for technical inefficiency.

Technical efficiency, TE_i, is depicted as the ratio of the realized output (Y_i) to the frontier output (Y_i^*) as shown in equation 2.

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{f(x_i\,;\beta).exp(v_i - u_i)}{f(x_i\,;\beta).exp(v_i)} = \exp\,(-u_i) \quad \text{where } 0 \le TE_i \le 0 \qquad (2)$$

Empirically, the translog production function was expressed as:

$$lnY_i = \beta_0 + \beta_1 lnx_1 + \beta_2 lnx_2 + \beta_3 lnx_3 + \beta_4 lnx_4 + \beta_5 lnx_5 + \beta_6 lnx_6 + \frac{1}{2}\beta_{11}(lnx_1)^2 + \frac{1}{2}\beta_{22}(lnx_2)^2 + \frac{1}{2}\beta_{33}(lnx_3)^2 + \frac{1}{2}\beta_{44}(lnx_4)^2 + \frac{1}{2}\beta_{55}(lnx_5)^2 + \frac{1}{2}\beta_{66}(lnx_6)^2 + \beta_{12} lnx_1 lnx_2 + \beta_{13} lnx_1 lnx_3 + \beta_{14} lnx_1 lnx_4 + \beta_{15} lnx_1 lnx_5 + \beta_{16} lnx_1 lnx_6 + \beta_{23} lnx_2 lnx_3 + \beta_{24} lnx_2 lnx_4 + \beta_{25} lnx_2 lnx_5 + \beta_{26} lnx_2 lnx_6 + \beta_{34} lnx_3 lnx_4 + \beta_{35} lnx_3 lnx_5 + \beta_{36} lnx_3 lnx_6 + \beta_{45} lnx_4 lnx_5 + \beta_{46} lnx_4 lnx_6 + \beta_{56} lnx_5 lnx_6 + v_i - u_i \quad (3)$$

where ln = natural logarithm, Y_i = output of pepper farmers in kilograms, X_i refers to the input quantity variables such that X_1 = land, X_2 = labour, X_3 = seed, X_4 = fertilizer, X_5 = ploughing cost, X_6 = capital; β_i = unknown parameters, $v_i - u_i$ = the composite error term (ε_i) where v_i captures the symmetric stochastic term reflecting conditions outside the producer's control and u_i is as previously defined.

Technical inefficiency, u_i is modelled as a function of the factors assumed to influence TE. The equation for the factors affecting technical inefficiency is given as:

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \ldots\ldots + \delta_{10} Z_{10} \quad (4)$$

where u_i = technical inefficiency; $Z_1 - Z_{10}$ refer to the factors distressing technical efficiency; $\delta_0 - \delta_{10}$ = unknown parameters.

In the literature, the sources of production inefficiencies in developing country smallholder farm systems can be classified as characteristics specific to the farmer, the household, the farm, and institutional and support services. Thus, for the inefficiency model, the study included variables such as respondent's age, sex, educational attainment, and participation in off-farm employment; household size and its quadratic term; soil fertility status, frequency of weeding, and livestock ownership; as well as access to credit, in line with the existing literature (Anang, 2021; Nkegbe, 2018; Martey *et al*., 2019). The quadratic term for household size was included to explore the non-linear relationship between household size and TE.

In the study context, the effects of farmer characteristics like age, sex, education, and engagement in off-farm work have been severally examined with various justifications and outcomes. For example, farmers' age has been proven to affect the rate of improved production technology adoption with the consensus being that younger farmers tend to adopt new technologies more readily (Donkoh *et al*., 2019; Anang *et al*., 2020; Damba *et al*., 2020). Higher technology adoption in turn positively influences the TE outcomes of smallholder crop production (Abdulai *et al*., 2018; Anang *et al*., 2022).

Similarly, gender issues have consistently shaped the debate on women's roles and access to productive resources in smallholder farming (Doss & Morris, 2000; Doss *et al*., 2018; Danso-Abbeam *et al*., 2020). In pepper production in Ghana, Asravor *et al*. (2016) and Tsiboe *et al*. (2019) both considered gender a consequential variable in their analysis. In both studies, male farmers were more technically efficient than their female colleagues. Asravor *et al*. (2016) however observed that female farmers were more allocatively efficient than their male counterparts.

Formal educational attainment drives farmers' capacity to manage their farms. For example, competence in literacy and arithmetic gained through formal schooling may enable a farmer to harness and apply improved production technologies to increase farm productivity. This explains the ubiquity of this variable in almost all the cited studies on TE estimation in this study.

One of the inevitable consequences of agricultural development in developing countries is the diversion of excess labour to non-farm employment (Norton, 2004). This phenomenon resembles a process more than a sudden event. In northern Ghana, the unimodal rainfall pattern and long dry season dictate that farm households allocate labour both to farm and off-farm work. The question then becomes whether engagement in off-farm work complements or competes with agricultural production. Here, Asravor *et al*. (2016) and Appiah-Twumasi *et al*. (2020) assert a complementary effect whiles Pfeiffer *et al*. (2009) reported a negative effect of off-farm income on farm output but a positive effect on production efficiency.

Whether a farm household can participate in off-farm work depends, largely, on the size, skill, and willingness of its members. Able-bodied household members are the primary source of farm labour, particularly in northern Ghana's rural areas where under-developed labour markets characterize the local agricultural structure (Owusu *et al*., 2011). To this end, this study examined the influence of household size on technical inefficiency of vegetable production. In order to explore the effect of surplus family labour on TE, the quadratic term for household size was introduced.

Farm characteristics like soil fertility status, uptake of good agronomic practices (GAPS), and integration of livestock rearing into households' crop production all have the potential to determine the productivity of pepper production. As the medium that supports plant growth, the state of soil fertility has fundamental effects on the success of any smallholder production. Also, farmers' practice of GAPS like timely weeding reduces the stress of weed competition on pepper seedlings and in turn, enhances the likelihood of successful production outcomes. This variable is a good proxy for farmers' managerial acumen and was included in this study to measure its effects on reducing technical inefficiency. In this study, the inclusion of livestock ownership serves two key purposes: it describes the level of integration of the household production system and, like in Anang *et al*. (2022), serves as a proxy for measuring household wealth.

Finally, access to production credit facilitates participation in input and produce markets by reducing the liquidity challenges that beset such endeavours (Akudugu, 2012; Anang *et al*., 2016). According to Akudugu (2012), credit-constrained rural farmers in northern Ghana are usually caught in a vicious cycle of ever-worsening farm returns and reduced farm investments due to limited financing options. Thus, the elimination of this roadblock to agricultural investment funds through credit provision creates the converse of this situation: this offers positive benefits for agricultural growth and productivity as well as technical efficiency of production. Despite the spate of literature on the effects of credit access on Ghanaian agriculture, there has been limited analysis of its effects on TE of pepper production. Thus, its inclusion in the SFA model in this study will not only help in informing policy but also contribute to fill this literature gap.

Likelihood ratio tests

The generalized likelihood ratio test was carried out to determine the appropriateness of the functional form for the production function as well as test for the presence of the inefficiency effects in the model (Stevenson, 1980). The log-likelihood ratio is presented as follows:

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

where $L(H_0)$ is the value of the likelihood ratio under the null hypothesis and $L(H_1)$ is that under the alternate hypothesis. λ has approximately a chi-squared or mixed chi-squared distribution and the degrees of freedom are the difference in the number of parameters between the null and alternate hypotheses (Martey et al., 2019; Appiah-Twumasi et al., 2022).

Description of the data

Descriptions of the variables in the study can be found in Table 1. The variables include the socioeconomic variables hypothesized to drive changes in production inefficiency, realized output levels of pepper production in the study area, as well as traditional input variables like land, labour, seed, fertilizer, ploughing costs, and value of other capital inputs.

From the summary statistics, about 54% of the respondents interviewed had access to credit for the 2019/2020 season. Thus, close to half of the respondents used their own source of finance to carry out their production activities. Regarding farmers' personal characteristics, a typical farmer in the sample is a male of about 43 years who has completed five (5) years of formal education and owns livestock. The reported average age reflects the relative youthfulness of the sampled pepper farmers and resonates with the results of Martey *et al*. (2019) relating to farmers in northern Ghana as well as the estimated national average reported by the Ghana Statistical Service (GSS, 2020).

Meanwhile, the finding that more than 80% of households own livestock attests to the savanna nature of the local climate. Joint engagement in livestock and crop production helps farm households diversify their incomes, mitigate their exposure to biological and climate risks, and increase their resilience to food security shocks (Ansah *et al*., 2021). About 23% of the respondents participated in off-farm employment. Taken together, these highlight the scope of economic activities households engage in to generate income for agricultural investment. As indicated, labour allocation decisions at the household level rests on the availability of skilled and willing household members. The mean household size is about 8 members. This figure is greater than the national, regional (Northern Region), and district (Tolon) averages (3.6, 5.2, and 6.3 members respectively) reported by GSS (2021).

Table 1: **Descriptive statistics of variables**

Variable	Measurement	Mean	S.D.
Access to credit	1 if yes; 0 otherwise	0.540	0.500
Age	Age in years	42.53	11.73
Sex	1 for male; 0 otherwise	0.790	0.408
Household size	Number of household members	8.280	3.031
Education	Years of formal education	5.035	3.956
Livestock ownership	1 for ownership of livestock; 0 otherwise	0.810	0.393
Off-farm work	1 for participation; 0 otherwise	0.230	0.422
Fertility of soil	1 for fertile soil; 0 otherwise	0.685	0.466
Frequency of weeding	Number of times weeding was carried out	2.785	0.412
Output	Pepper output in kilogramme	672.8	322.6
Land	Land area in hectares	1.149	0.472
Labour	Labour quantity in man-days	18.68	4.727
Seed	Seed quantity in kilogramme	1.411	0.768
Fertilizer	Fertilizer quantity in kilogramme	67.00	39.92
Ploughing cost	Cost of ploughing in Ghana cedi	77.28	59.83
Capital	Value of farm capital in Ghana cedi	382.8	142.8

S.D. means standard deviation. 1.0 Ghana cedi = 0.18 US dollars in 2020.

This study's measure of soil fertility used respondents' subjective reports of the states of their plots. The statistics in Table 1 indicate that about 69% of respondents perceived the soils on their pepper plots as sufficiently fertile. This has potential effects on some production decisions such as quantity of fertilizer applied (about 67 kg) and amounts invested in other capital inputs (GHS 382.8 or US$69), all of which can shift the production frontier and affect pepper output (Coelli *et al*., 2002).

With regards to the other traditional inputs, the average farmer cultivated about 1.14 ha of pepper – this is very comparable to the figure (1.10 ha) estimated by Tsiboe *et al*. (2019) who used five nationally representative cross-sectional datasets on Ghanaian agriculture spanning 30 years (1987-2017). Farmers spent about GHS 77 (US$14) on hiring tractor to plough their plots; employed about 19 man-days of labour and planted about 1.4 kg of seeds. These culminated in an estimated average pepper output of 672.8 kg. Some of the variables, such as output, fertilizer quantity, ploughing cost, capital, among a few others have relatively high standard deviations, which reflects the diversity between the respondents' input and output quantities. Bearing this in mind, the data were subjected to diagnostic tests such as multicollinearity, heteroskedasticity and normality tests prior to the analysis. The data were also checked for outliers that could affect the results.

RESULTS AND DISCUSSION

The likelihood ratio test of the functional specification of the production function and the presence of technical inefficiency in the model are shown in Table 2. The study rejects the null hypothesis of the restricted Cobb-Douglas functional form in favour of the more flexible translog form. The test result also rejected the null hypothesis of absence of technical inefficiency in the model, signifying that the model contains the non-negative error term u_i , which measures technical inefficiency. Thus, it would be inappropriate to use ordinary least squares (OLS) or the traditional average response model for this analysis.

Table 2: Likelihood ratio Test of Hypotheses

Null hypothesis	LL(H_0)	LL(H_1)	LR test statistic	Critical value*	Decision
Production function is Cobb-Douglas	-116.7	-77.85	77.8	32.67	Reject H_0
Inefficiency model does not explain technical inefficiency: H_o: $\delta_0 = \delta_1 = \ldots = \delta_{10} = \gamma = 0$	-77.14	-11.64	131	19.05	Reject H_0

*Chi-squared critical value for the inefficiency model obtained from Kodde and Palm (1986).

Maximum likelihood estimates of the translog stochastic production frontier model

The maximum likelihood estimates of the translog stochastic production frontier model are depicted in Table 3. The sigma square value for the estimated model indicates that the model was well fitted and that the assumptions about the composite error term are valid. In addition, the gamma (γ) parameter indicates the presence of technical inefficiency among the pepper farmers. This confirms that the one-sided error component is present in the model and shows that an average response model or OLS estimation does not adequately represent the data.

Table 3: Maximum likelihood estimates of the translog stochastic frontier production function

Variable	Coefficient	Std. Error	P-value
Land	0.262	0.233	0.260
Labour	0.022	0.120	0.852
Seed	0.121***	0.041	0.003
Fertilizer	0.005	0.053	0.924
Ploughing	0.513***	0.098	0.000
Capital	-0.312**	0.124	0.012
Land squared	0.174***	0.063	0.006
Labour squared	0.218	0.188	0.246
Seed squared	0.070	0.065	0.287
Fertilizer squared	-0.001	0.010	0.933
Ploughing squared	0.045***	0.009	0.000
Capital squared	-0.140	0.230	0.544
Land*Labour	-0.769**	0.296	0.010
Land*Seed	0.003	0.107	0.980
Land*Fertilizer	0.036	0.075	0.635
Land*Ploughing	-0.004	0.021	0.837
Land*Capital	0.000	0.001	0.771
Labour*Seed	0.193	0.184	0.293
Labour*Fertilizer	-0.090	0.303	0.766
Labour*Ploughing	-0.069*	0.037	0.059
Labour*Capital	0.229	0.279	0.412
Seed*Fertilizer	0.136*	0.082	0.095
Seed*Ploughing	-0.003	0.016	0.828
Seed*Capital	0.187	0.157	0.234
Fertilizer*Ploughing	-0.028	0.018	0.112
Fertilizer*Capital	-0.080	0.136	0.556
Ploughing*Capital	-0.049*	0.028	0.078
Constant	0.144***	0.039	0.000
Variance parameters			
Sigma squared (σ^2)	0.385***	0.043	0.000
Gamma (γ)	0.314***	0.025	0.000
Loglikelihood	-11.64		

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

All the production inputs had the expected positive sign except capital. Although the negative elasticity of capital is unexpected, it might be a sign that most of the respondents are still employing obsolete, less productive equipment. The production function revealed that seed, capital and cost of ploughing had significant influence on pepper production. Ploughing cost had the highest elasticity among the production inputs. The input variables were mean corrected by dividing the input quantities by their means so that the estimated parameters indicate elasticities. The sum of the input elasticities which measures the returns to scale indicates that the respondents operate at decreasing returns to scale similar to the result obtained by Asravor *et al*. (2016).

The quadratic term of the ploughing variable is positive and significant inferring that output increases at an increasing rate with the cost of ploughing. In technical efficiency analysis, when both the level and quadratic terms of an input are positive, it means that the input-output relationship exhibits a non-linear relationship. Thus, as more input is used, output level keeps increasing. This implies that there might be an optimal level of input, above which any increases might not provide output increases that are proportionate.

Similarly, land squared has a positive and significant coefficient indicating that output increases at an increasing rate with land area under pepper cultivation. The negative sign of the interaction between land and labour indicates that the two inputs are substitutes in pepper production. Similarly, labour and ploughing cost as well as capital and ploughing cost, are substitutes in pepper production. However, seed and fertilizer are complementary resources in pepper cultivation among the sampled farmers.

Factors affecting technical efficiency of pepper farmers

The inefficiency model presented in Table 4 depicts the factors affecting TE of pepper farmers in Ghana's Tolon district. The signs of the coefficients are reversed in the explanation of the inefficiency model because a decrease in inefficiency implies an increase in TE. For the farmer-specific characteristics, the results indicate that only years of education had an influence on TE of pepper production. An increase in years of education enhances technical efficiency of pepper production at 5% level. The result is supported by Kibret and Abebo (2019) and Hayran and Gul (2019) who found education to positively influence TE of pepper production in Ethiopia and Turkey, respectively. Farmer characteristics like age, sex, and engagement in off-farm work showed no statistically significant effects on the outcomes of the pepper grower.

Table 4: Determinants of technical efficiency of pepper production

Variable	Coefficient	Standard Error	P-value
Age of farmer	0.040	0.028	0.158
Sex of farmer	0.272	0.438	0.535
Years of formal education	-0.104**	0.051	0.040
Household size	-0.663**	0.300	0.027
Household size squared	0.022	0.014	0.115
Access to credit	-2.508***	0.934	0.007
Off-farm work	0.356	0.594	0.549
Livestock ownership	-1.296***	0.411	0.002
Frequency of weeding	-1.292**	0.527	0.014
Fertility of soil	-1.913***	0.512	0.000
Constant	3.113**	1.207	0.010

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

Size of the farm household and its quadratic term were included in the model to capture the effects of farm household characteristics on pepper production efficiency. Although the estimated coefficients depicted the switching effect signs associated with short- and long-run relationships, only the level variable was statistically significant. Thus, the effect of an increase in household size on technical efficiency is that it reduces inefficiency of pepper production in the short run but is nullified as household sizes get larger. This finding is instructive for household decision-making on allocating labour to the various available economic enterprises.

All three variables associated with farm characteristics of the respondents showed statistically significant effects on pepper production efficiency. Specifically, livestock ownership enhanced technical efficiency of pepper farmers at 1% level. The result agrees with that of Anang *et al*. (2016) who showed that herd ownership increases technical efficiency of Ghanaian rice farmers. As indicated, farming systems characterized by crop-livestock integration tend to be more sustainable and more likely to be efficient. Identical findings were reported by Mussa *et al*. (2011) and Tesema (2021) for Ethiopia and Fang *et al*. (2021) for China.

Adoption of good agricultural practices (GAPS) has been reported to improve crop production outcomes in African smallholder farming systems (Anang *et al*., 2020). The results in Table 4 confirm this by showing that practicing regular weeding increased TE of pepper production at 5% significance level which agrees with Anang *et al*. (2020). Regular weed control enhances technical efficiency because it aids in controlling noxious weeds that compete with food crops for both soil nutrients and moisture.

Additionally, soil fertility status is positively related to TE at 1% level, indicating that respondents who self-report their farmlands to be fertile have higher TE. This is in line with the finding of Dokyi *et al*. (2021) for maize growers in Ghana. Furthermore, access to farm credit – the variable describing availability of institutional support – had a significantly positive effect on TE at 1% significance level. The result is consistent with Siaw *et al*. (2020), Tsiboe *et al*. (2019), Nkegbe (2018), and Abdallah (2016) in their studies in Ghana. Promoting smallholders' access to credit is therefore a vital policy instrument to improve farm efficiency and subsequently the productivity and incomes of farmers (Martey *et al*., 2019). Access to credit enables smallholder farmers to finance the purchase of critical farm inputs and make farm investments to increase efficiency and productivity.

Table 5: Distribution of technical efficiency scores of pepper production

Efficiency score	Frequency	Percent
≤ 0.30	6	3
0.31 – 0.40	16	8
0.41 – 0.50	6	3
0.51 – 0.60	7	3.5
0.61 – 0.70	7	3.5
0.71 – 0.80	31	15.5
0.81 – 0.90	15	7.5
0.91 – 1.00	112	56
Total	200	100
Mean efficiency	0.814	
Minimum efficiency	0.190	
Maximum efficiency	0.985	

Distribution of TE scores

The distribution of the TE scores indicates that pepper farmers in the study area produced at 81.4% efficiency level, with a minimum of 19% and a maximum of 98.5% as shown in Table 5. The result is in sync with that of Asravor *et al*. (2016) and Hayran and Gul (2019) who revealed the existence of inefficiency in pepper production among Ghanaian and Turkish farmers, respectively. Judging from the efficiency score, the respondents are making good use of their scarce resources in pepper production.

The results indicate that 14% of the farmers produced at TE level up to 50% while 79%

produced at efficiency levels greater than 70%. Hence, the respondents are deploying their resources fairly well, even though there is scope to enhance the TE of pepper farmers in the Tolon district by 18.6% using the same level of inputs and technology. This outcome is consistent with similar studies on pepper cultivation by Asravor *et al*. (2016) and Rosli *et al*. (2020) who found majority of pepper farms in Ghana and Malaysia, respectively, to be operating below the maximum achievable yield. The need for productivity and efficiency-enhancing programmes are recommended to exploit the full potential of this important horticultural crop which is used in almost every household in the country and exported as a non-traditional export crop.

CONCLUSION AND POLICY IMPLICATIONS

The study evaluated the TE of pepper production in the Tolon District of Ghana. Smallholder pepper farmers in the Tolon district operate at 81.4% technical efficiency and have the potential to enhance TE by 18.6% through the judicious use of their scarce resources. Also, the pepper farms in the study area operate at decreasing returns to scale implying that the marginal increase in output as the scale of production increases is less than the marginal increase in input. Even though the cost per unit of output is rising, the farmers can still produce with little waste if they can maintain a high degree of TE. Therefore, a farm may continue to have high mean TE even in the face of diminishing returns to scale.

The study identified several policy options to enhance TE of pepper growers. First among these options is farm credit which enables farmers to acquire critical and limiting farm inputs and ensures their optimal use to enhance efficiency and productivity. Farm credit also ensures timely farm operations through the acquisition of important inputs timeously. Thus, efforts by governmental and non-governmental organization as well as other stakeholders to expand smallholders' access to farm credit should be supported to improve farm output and efficiency. Notable among these are the local and international non-governmental financial service providers, para-state organizations and rural and community banks serving the financial needs of farmers.

Training of pepper farmers on soil fertility management is another important policy measure necessary to enhance technical efficiency of pepper farmers. Farmers who self-reported their farms to be fertile were more technically efficient. Furthermore, training farmers on weed management techniques is required to ensure that efficiency is increased. Weed control is a major challenge to crop production hence, measures to enhance smallholders' capacity to effectively control weeds will go a long way to promote efficiency. In this regard, staff of the agricultural extension department should be adequately resourced to carry out regular training of farmers on proper agronomic, weed and soil fertility management.

Smallholder pepper producers should also be motivated to rear livestock as alternative means of income since livestock ownership correlated positively with technical efficiency. Livestock serve as financial reserves of farm household and are relied upon in times of liquidity constraints. Hence, integrating livestock production with crop production is an important policy measure necessary to improve the efficiency of smallholder farmers, while improving household income and food security. On this score, the Ministry of Food and Agriculture (MoFA) should make conscious efforts to step up and promote the Rearing for Food and Jobs initiative to stimulate livestock rearing especially among smallholder farmers.

Additionally, expanding and encouraging access to education in rural areas will improve the human capital and raise the level of technical efficiency. This could be supplemented with informal and non-formal education through farmer-field schools, demonstrations, and extension education with emphasis on efficient pepper production methods and credit accessibility. This can be achieved through the collaborative efforts of the agricultural extension department, and other stakeholders such as local and international non-governmental organizations that work with farmers to improve their livelihoods.

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CONFLICT OF INTEREST

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