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Producer characteristics and determinants of technical efficiency of tomato based production systems in Ghana

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This paper uses cross-sectional data collected from 126 small scale tomato farmers in the forest, forest-savannah transition and the guinea savannah agro-ecological zones in 2011 to examine the characteristics of tomato based producing households in Ghana. It involved a description of the demographic characteristics of sampled farmers and an investigation of the production practices. This study further investigated the determinants of technical efficiency in tomato production among small scale farmers in Ghana. Descriptive statistics was used to present the characteristics of tomato producing households and the stochastic frontier analysis was used to estimate the determinants of technical efficiency and the inefficiency effect models. Results indicated that majority of the sampled tomato farmers were males. Almost half of the farmers had formal education at least up to the basic level. Almost half of the farmers cultivated tomato in both the major and minor seasons. Most of the varieties cultivated are exotic. Pests and diseases were predominant on the farms of majority of the sampled households. Consequently the use of pesticide to control pests and diseases is very common among sampled household. Our analysis further suggests average technical efficiency of 85.4%. In addition, factors such as extension services, land, frequency of weeding and fertilizer positively influenced technical efficiency of tomato farmers. Conversely, factors such as pesticide, labour and the frequency of pesticide application had negative effects on technical efficiency. The findings reveal the need for an effective and sustainable integrated approach to pest and weed management to enhance technical efficiency and productivity in tomato production.

Key words: Tomato, production practice, technical efficiency, stochastic frontier production function, pests, diseases, Ghana.

INTRODUCTION

Tomato, *Solanum lycopersicum* is one of the popular vegetables commonly cultivated by small scale farmers in Ghana (Osei et al., 2010). It is also one of the most important income-generating vegetables produced in Ghana. Tomato cultivation has been a significant economic activity in Ghana especially in the Upper East region. The crop is cultivated continuously throughout the year because apart from the rain-fed system that normally spans between June and November in the southern part of the country, there is the dry-season system between October and April mainly in the north (especially in the Upper East). It is consumed daily by most households as a source of lycopene, vitamins A and C. Tomato production has intensified over the years however, yields continue to remain low due to several production constraints which include biotic and abiotic factors. The abiotic factors are erratic rainfall, high temperature, and poor soils, among others.

Biotic constraints of significant economic importance in tomato production in Ghana include diseases such as tomato yellow leaf curl virus, bacterial wilt, bacterial spot, early blight, and tomato mosaic viruses. Spraying with

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copper fungicides and other pesticides can help control some of these pests and diseases (personal communication). Dependency on chemical products for vegetable production is high compared to other food crops among small scale farmers. Also in Ghana, indiscriminate use of chemical pesticides has been reported (Osei et al., 2008) and this tends to pose potential health risk for farmers, consumers, and other stakeholders besides the attendant environmental effects. One of the main reasons adduced for low productivity in agriculture is the inability of farmers to fully exploit the available technologies (Sreenivasa Murthy et al., 2009). This fact which has been emphasized in many studies, particularly on cereals and pulses (Bagi, 1982; Battese, 1992; Battese and Coelli, 1988, 1992; Battese and Broca, 1997) and pertains to small scale tomato farmers in Ghana. For instance, the area cropped to tomato alone accounted for 69.45% of the total vegetable area cropped in the country in 2010. However, the average yield of tomato was about 7.5 mt which is far below the attainable of 15.0 mt hence leaving farmers with a yield gap of about 7.5 mt (MOFA, 2010). It is also believed that the use of improved seeds and the recommended rate of fertilizer and other key inputs in tomato production will help farmers to reach the maximum attainable yield level (MOFA, 2010). In view of this, efforts has been made by government, non governmental organizations like the international water management institute (IWMI), and other institutions like research and extension to improve tomato production through the development of improved varieties that are disease resistant, high yielding among other desirable attributes. Studies on tomato production in Ghana has mostly focused other aspects rather than investigating producer characteristics and technical efficiency in among tomato based producing households (Osei et al., 2008; Asare-Bediako et al., 2007; Donkoh et al., 2012; Tambo and Gbemu, 2010). Consequently, in addition to characterising tomato farmers in Ghana, it is therefore imperative to investigate the determinants of technical efficiency and productivity in tomato production among small scale farmers. This will unearth the magnitude of the effect to which these inputs and other factors account for these variations in yield. Such information will be handy for farmers, research and policy. This paper seeks to examine the characteristics of tomato based producing households in Ghana. It involved a description of the demographic characteristics of sampled farmers and an investigation of the production practices. This study further investigates the determinants of technical efficiency in tomato production among small scale farmers in Ghana.

METHODOLOGY

Study area

This study was conducted in the forest, forest-savannah transition and the guinea savannah agro-ecological zones in 2011. It involved tomato farmers in the Brong Ahafo, Ashanti and Upper East regions. These regions are the major tomato growing areas in the country. The forest, forest-savannah transition zone is characterized with a bi-modal rainfall regime of 1300 to 2200 mm per annum and therefore two distinct growing seasons (major and minor seasons). The guinea savannah has a uni-modal rainfall pattern (May to August) with an average of 1100 mm per annum. It also has a long dry season (November to March). Major tomato growing districts and communities within these agro-ecological zones were selected for the survey. Farming is the major economic activity and tomato cultivation is the main cash crop in these communities. The districts and communities included in this study are presented in Table 1.

Sampling technique

Multi-stage sampling was used for this study. Purposive sampling was first employed to select the five (5) districts in the major tomato growing regions of the country. Six communities were further selected purposively from the districts. A total of 126 tomato farmers regardless of acreage were then selected randomly from the communities with at least 19 farmers per district. The distribution of the respondents by the districts is presented in the Table 2.

Data collection and analysis

Both formal and informal approaches were employed to collect data for the survey. Participatory Rural Appraisal (PRA) was used to generate information on tomatoes from small scale farmers at the community level. Each group consisted of at least 40 tomato farmers with almost equal proportions of males and females. In addition, triangulation was applied to the groups to test the robustness of the responses from the groups. This was followed by a formal survey with the use of structured questionnaires. This enabled individual farmers to express their own views without any community influence. During the interview, useful demonstrations and drawings were frequently used to illustrate difficult points. Data collected included demographic characteristics, farm characteristics and farming practices including weed and pest control practices. Descriptive statistics such as graphs, charts, tables and diagrams were used to summarise the data and present a description of the characteristics of sampled tomato producing households and other summaries of production practices. The technical efficiency of tomato producers was estimated using the stochastic frontier production function, details of which have been discussed in the next section.

Methodological framework

Measurement of efficiency draws on the seminal work of Farell (1957) in which Farrell suggested that the efficiency of a firm consists of two components: technical and allocative efficiency. Technical efficiency is a measure of the ability of a firm to obtain maximum output from a bundle of inputs given the best available technology. In estimating the determinants of technical efficiency, two broad approaches are generally been proposed: parametric and non-parametric methods (more details of these methods are in Lovell, 1993; Coelli et al., 1998; Zhu, 2003; Ray, 2004). For the purpose of this study, the parametric approach is preferred to the nonparametric one because the production environment in which our respondents operate is prone to exogenous shocks.

The parametric approach specifies some functional form to represent the relationship between output and inputs. A preferred

Table 1. Districts and communities included in the study.

District	Communities
Bongo	Goo, Gori, Gor Kuakua and Gori Tengre
Navrongo	Nagal Rinia, Tono and Yigwama
Offinso North	Akumadan
Talensi Nabdam	Pawlugu, Yindowli and Moori
Techiman	Tuobodom, Tanoso, Epishya. Asuobrofo and Pinkyem

Table 2. Distribution of respondents by district.

District	Frequency
Bongo	22
Navrongo	19
Offinso North	22
Talensi-Nabdam	21
Techiman	42
Total	126

functional form exhibits the properties identified by Coelli et al. (2005) as flexibility, linearity in parameters, regularity and parsimony. Both the A Cobb-Douglas and the transcendental logarithmic (translog) function developed by Christensen et al. (1973) satisfy these properties and it is widely used in econometric estimation. A transcendental logarithmic (translog) functional form was considered to represent the production model. However, a hypothesis test result suggests that it is not an adequate representation of the data given the assumptions of the translog stochastic frontier model and was therefore not employed in this study.

Following Battese and Coelli (1995), Cobb-Douglas production function can be specified as follows:

$$\ln Y_i = \beta_0 + \sum_{j=1}^{2} \beta_{0j} D_{ji} + \sum_{j=1}^{8} \beta_j \ln X_{ji} + V_i - U_i \quad (1)$$

, *i*=1,2,3,…..,N

Where the subscript *i* indicate the *i*-th farmer in the sample: Y represents the quantity of tomatoes harvested for the sampled farmer (in kilograms). D_1 is the dummy variable which has a value of 1 if the farmer planted an exotic seed and 0 if otherwise (hereafter, Seed dummy). D_2 is the dummy variable which has a value of 1 if the farmer has access to extension services, and 0 if otherwise (hereafter, Extension dummy). X_1 is the total area (in Acres) planted to tomato (hereafter, Land). X_2 is the total labour (in man days) used in tomato cultivation (hereafter, Labour). X_3 is the quantity of fertilizer (in kilograms) used in tomato cultivation (hereafter, Fertilizer). X_4 is the quantity of pesticides (in kilograms) used in tomato cultivation (hereafter, Pesticides). X_5 is the quantity of seeds (in grams) used in tomato cultivation (hereafter, Seed). X_6 is the frequency of fertilizer application per season (hereafter, Fertilizer frequency). X_7 is the frequency of weeding per season (hereafter, Weeding frequency). X_8 is the frequency of pesticide application (hereafter, Pesticide frequency).

The V_i^s are the random errors, assumed to be independent and identically distributed as $N(0, \sigma^2)$.

The U_i^s are the non-negative technical inefficiency effects assumed to be independently distributed among themselves and between the V_i^s, such that U_i^s is defined by the truncation of the $N(\mu_i, \sigma^2)$ distribution, where μ_i is defined by:

$$\mu_i = \delta_0 + \delta_{01}^{*} D_1 + \sum_{j=1}^{3} \delta_0 Z_{ji} \quad (2)$$

Where: D_1 is the dummy variable which has a value of 1 if the farmer is a male and 0 if otherwise (hereafter, Gender dummy). Z_1 represents age (in years) of the farmer (hereafter, Age); Z_2 represents the level of formal education (in years) of the farmer (hereafter, Education); Z_3 represents experience in tomato cultivation (in years) (hereafter, Experience); N denote the number of sampled rice farmers involved

The variation in output levels largely depends on the quantity of inputs used in production while differences in technical efficiencies are explained by productivity-enhancing factors. The dependent variable is the total quantity of tomato fruits harvested. The explanatory variables included in the frontier production function comprise area or land, quantity of seed, quantity of pesticides, access to extension, quantity of labour, frequency of fertilizer application, frequency of pesticide application, frequency of weeding and the type of seed planted. These variables are important physical inputs used in tomato production. The variables for extension and type of seed planted were included in the model to assess their effects on technical efficiency.

Besides describing the relationship between inputs and rice output, this paper is also concerned with those factors that influence farmers' technical inefficiency in their decisions making. The model for the technical inefficiency effects contains variables related to human capital, such as age, years of schooling, gender and experience in tomato production. These variables have been used in the models for the technical inefficiency effects in several previous studies, Oduol et al. (2011), Villano and Fleming (2006), Sriboonchitta and Wiboonpongse (2004a, b), Battese et al. (1996, 1997), Battese and Broca (1997), and all the variables have been clearly described and explained in the model.

Descriptive statistics of variables

The models presented in the previous section are applied to the cross sectional of tomato farmers in Ghana. Basic summary statistics of the key variables used in the stochastic frontier models are presented in Table 3. The average production of tomato was approximately 3975.03 kg per household, which translates to a mean yield of approximately 1967.84 kg ha^{-1}. Tomato output was highly variable, ranging from 260 kg to a maximum of 17940.0 kg per household. Average fertilizer use was 69.5 kg ha^{-1}. The average labour use was approximately 51 person-days per hectare. The

Table 3. Descriptive statistics of variables in the stochastic frontier production models and inefficiency models.

Variable	Mean	SD	Minimum	Maximum
Output (kg)	3975.03	2526.01	260.0	17940.0
Land (Acres)	2.02	1.28	0.2	6.0
Labour (man-days)	1190.98	1801.07	3.0	8662.0
Fertilizer (kg)	69.05	23.96	25.0	100.0
Pesticides (l)	1.88	1.08	0.0	6.5
Seed (g)	9.27	1.19	5.0	12.0
Fertilizer frequency (number)	2.71	0.54	1.0	4.0
Weeding frequency (number)	2.67	0.80	1.0	4.0
Pesticide frequency (number)	4.18	1.30	0.0	5.0
Age (years)	41.59	10.42	20.0	70.0
Education (years)	6.87	4.43	0.0	16.0
Experience (years)	12.50	7.96	1.0	40.0

coefficient of education is expected to have a negative sign because a higher level of educational attainment would result in lower inefficiency. The educational attainment of the farmer is a proxy for human capital. The sign on the coefficient of the age of the farmer could be negative or positive. If older farmers were not willing to adopt better practices whereas younger farmers were more motivated to embrace better agricultural production practices that reduce technical inefficiency effects, then the coefficient would be positive (greater technical inefficiency). However, if older farmers have more experience and knowledge of the production activities and are more reliable in performing production tasks, then the coefficient would be negative. The technical efficiency of the i-th farmer given the specification if given by:

$$TE_{it} = \exp(-U_{it}) \quad (3)$$

Where $-U_{it}$ is defined by the specification of the inefficiency model in Equation (2).

The prediction of the technical efficiencies is based on its conditional expectation, given the observable value of $(V_{it} - U_{it})$ (Jondrow et al., 1982; Battese and Coelli, 1988). The technical efficiency index is equal to 1 if the farm has an inefficiency effect equal to zero and it is less than 1 if otherwise.

Estimation procedure

To estimate the determinants of technical efficiency in tomato production, the stochastic frontier production functions, defined by equation (1), and the technical inefficiency model, defined by equation (2), are jointly estimated by the maximum likelihood method using Frontier 4.1 (Coelli, 1996). Various tests of null hypotheses for the parameters in the frontier production functions and in the inefficiency models are performed using the generalized likelihood ratio test statistic defined by:

$$\lambda = -2\{\ln[L(H_0) / \ln[L(H_1)]\}, \quad (4)$$

Where L (H_0) and L (H_1) denote the values of the likelihood function under the null (H_0) and alternative (H_1) hypotheses, respectively. If the null hypothesis is true, the test statistic has approximately a chi-squared or a mixed chi-squared distribution with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. If the inefficiency effects are absent from the model, as specified by the null hypothesis, $H_0: \gamma = \delta_0 = \delta_{01} = \delta_{02} = \delta_3 ..... = \delta_8 = 0$, then λ is approximately distributed according to a mixed χ2 distribution with at least 4 degrees of freedom. In this case, critical values for the generalized likelihood ratio test are obtained from table 1 of Kodde and Palm (1986).

In estimating the elasticities of the model, since the variables of the Cobb-Douglas model were mean-corrected to zero, the first-order coefficients are the estimates of elasticities at the mean input levels. The elasticity of mean rice output with respect to the *j*-th input variable is defined by the following expression (Battese and Broca 1997):

$$\frac{\partial \ln E(Y_i)}{\partial \ln X_{ji}} = \{\beta_j + \beta_{jk} \ln X_{ki}\} - C_i \left(\frac{\partial \mu_i}{\partial \ln X_{ji}} \right) \quad (5)$$

where μ_i is defined in (2); C_i is defined by

$$C = 1 - \frac{1}{\sigma} \left\{ \frac{\phi\left(\frac{\mu_i}{\sigma} - \sigma\right)}{\Phi\left(\frac{\mu_i}{\sigma} - \sigma\right)} - \frac{\phi\left(\frac{\mu_i}{\sigma}\right)}{\Phi\left(\frac{\mu_i}{\sigma}\right)} \right\}$$

And ϕ and Φ represent the density and distribution functions of the standard normal random variable, respectively.

RESULTS AND DISCUSSION

Characteristics of sampled farmers

Majority of the respondents were males. Almost half of the farmers were educated up to the basic level (middle/JHS) and majority were married (Table 4). Further analysis on education suggests male dominance at both extremes of no formal education (70%) as well as at the tertiary level (75%) (Figure 1). Age distribution by gender of farmers demonstrates that most of the age catogories were dominated by males. The maximum

Table 4. Demographic characteristics of the respondents.

Variable	Percent
Sex	
Male	81.0
Female	18.3
Educational level	
No formal education	21.4
Primary	14.3
JHS/Middle	43.7
Secondary	14.3
Tertiary	3.2
Marital status	
Single	9.5
Married	84.1
Divorced	4.8
Widowed	1.6

proportion of females is 35% which is in the age group 61 to 70 (Figure 2).

Farm level characteristics

Half of the farmers were operating on farm sizes ranging between one and two acres, 22.2% were farming on less than one acre and the remaining 27% had farms greater than two acres (Table 5).

Over 50% of the farmers cultivated only exotic tomato varieties whiles 16.7% cultivated only local varieties. The remaining 23.8% cultivated both local and exotic varieties (Figure 3). Most of the exotic varieties were cultivated by female farmers (73.9%). However, there is no association between the varieties cultivated by males and females. This as illustrated by the chi square was not significant (Table 6).

About 45.2% of the local varieties were cultivated by farmers in the forest savannah transition agro-ecological zone. With over 91.9% of exotic varieties cultivated in the Guinea Savannah, there was no local variety cultivated in this zone. In the forest zone however, a combination of both varieties were cultivated (Table 7). There is a strong relationship between the Agro-ecological zone and type of varieties cultivated (Chi-Square sig. 0.000)

Figure 4 shows how farmers acquired tomato seeds for cultivation. Sixty-seven percent of the farmers obtained their tomato seeds from agro- input shops, 26% of them use seeds from their previous harvest whiles 7% obtained seeds from other farmers. More than half of females were cultivating farm sizes below one (1) acre whiles the males were cultivating farm sizes of between 1 and 2 acres. There is a strong relationship between farm size and gender of the farmers (Table 8).

Most of the farmers in all three zones cultivate between 1 to 2 acres of land. However, about 36% of farmers in the forest zone are cultivating more than two acres. The correlation between farm sizes of households and agro-ecological zones is significant (Table 9)

In general, more of each of the categories was allocated to the exotic variety. However, most (82%) of this variety was planted in farm sizes less than one acre. The local variety was planted more on 1 to 2 acres of land. The relationship between farm size and planted variety is strong (Table 10).

Tomato production practices

About 53.2% of the respondents applied the slash and burn method of field preparation, while 43.7% of them carried out ploughing and harrowing (mechanized) and 2.4% employed the zero tillage (use of herbicides) to prepare their field (Table 11). About 96.8% of the farmers applied fertilizer on their tomato field with over 70% applying three times per season. About 23.8% of the farmers applied fertilizer twice per season while 3.2% of them only once. Almost half of the farmers (46.8%) irrigated their farms once during the rainy season planting, 31.0% did not irrigate at all, 16.7% irrigated three times and 5.6% irrigated twice. However, during the dry season, 97.6% of the farmers irrigated more than thrice and the rest only thrice. About 50.0% of the farmers utilized the furrow irrigation system, 46.0% used manual irrigation, while 2.4% employed the drip irrigation system. About 44.4% of the farmers weeded their farms twice before harvesting, 34.9% weeded three times whereas 17.5% weeded four times. Weed control was predominantly manual (99.2%) with less than 1% herbicide use. Almost all the farmers (93%) reported of effective weed control practices.

Pests and diseases management

Over 99% of the farmers encountered pests and diseases in their farms and the use of pesticides was widespread in all agro-ecological zones. More than 70% of the farmers sprayed more than four times during the growing season whilst 0.8% sprayed only once (Table 6), 13.5% sprayed thrice per planting period and 15.1% sprayed four times (Table 6). Almost all the farmers (96.8%) encountered diseases in their farms.

Significantly, the use of chemicals to control diseases was noticeable, involving 108 farmers representing over 80% (Table 12). The term pesticide is comprehensive for all chemicals used to control pests such whiteflies, thrips etc (weeds inclusive) and diseases such as tomato yellow leaf curl virus, bacterial wilt, nematodes etc. Generally farmers sprayed four times or more per planting period. However, the majority of farmers (85.7%)

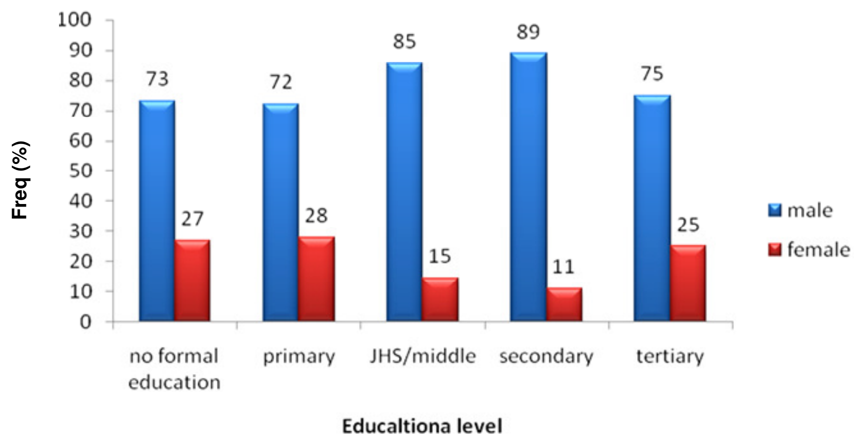

Figure 1. Education level of households by gender.

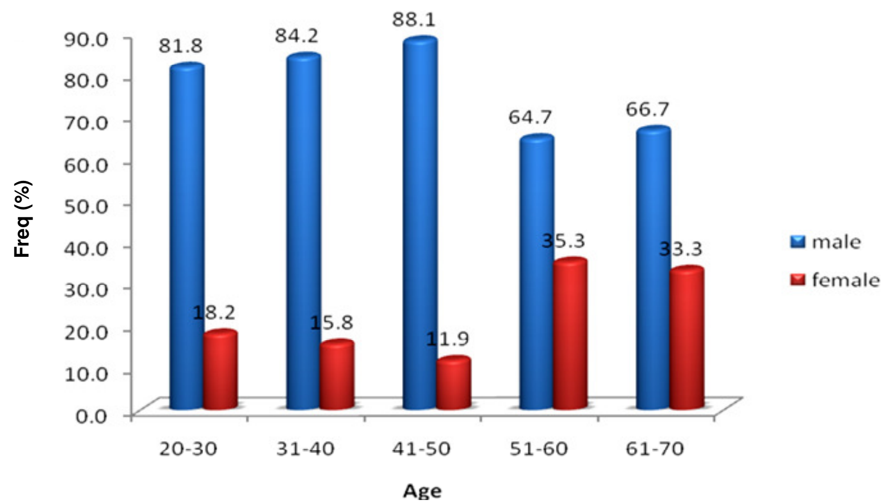

Figure 2. Age of households by gender.

Table 5. Distribution of Respondents by farm size.

Size (acre)	Frequency	Percent
<1	28	22.2
1-2	64	50.8
>2	34	27.0
Total	126	100.0

Table 6. Cross tabulation of gender and type of variety cultivated.

Gender	Type of variety (%)		
	Local	Exotic	Both
Male	19.6	55.9	24.5
Female	4.3	73.9	21.7

Chi-Square: 3.692, Asymp. Sig. (2-sided): 0.158.

Table 7. Cross tabulation of agro-ecological zone and type of variety cultivated.

Agro-ecological zone	Type of variety (%)		
	Local	Exotic	Both
Forest	9.1	27.3	63.6
Forest savannah transition	45.2	28.6	26.2
Guinea savannah	0.0	91.9	8.1

Chi-Square: 74.421, Asymp. Sig. (2-ided): 0.000.

Table 8. Distribution of farm size by gender.

Gender	Farm size (%)		
	<1 acre	1-2 acres	>2 acres
Male	14.7	55.9	29.4
Female	56.5	26.1	17.4

Chi-Square: 18.953, Asymp. Sig. (2-sided): 0.000.

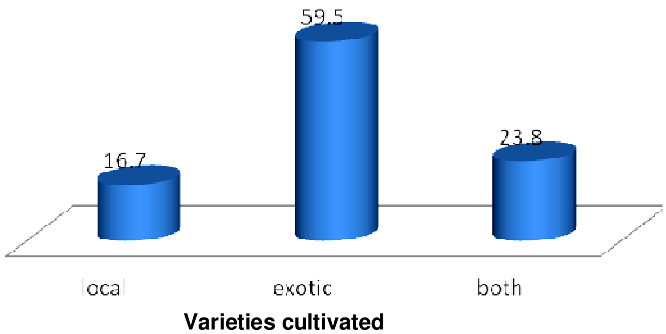

Figure 3. Varieties cultivated by respondents.

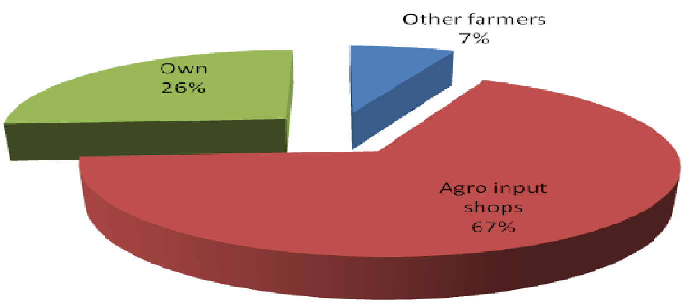

Figure 4. Source of seeds.

Table 9. Farm sizes of households in different agro-ecological zones.

Agro-ecological zone	Farm size (%)		
	<1acre	1-2acres	>2acres
Forest	9.1	54.5	36.4
Forest savannah transition	4.8	64.3	31.0
Guinea savannah	38.7	40.3	21.0

Chi-Square: 19.752, Asymp. Sig. (2-sided): 0.001.

Table 10. Distribution of farm size and type of variety cultivated by households.

Farm size	Type of variety (%)		
	Local	Exotic	Both
<1acre	7.1	82.1	10.7
1-2acres	26.6	46.9	26.6
>2acres	5.9	64.7	29.4

Chi-Square: 14.606, Asymp. Sig. (2-sided): .006.

in the Forest Savannah Transition sprayed more than four times.

Table 11. Tomato production practices employed by farmers in the study area.

Frequency of fertilizer application per season	Percent
Once	3.2
Twice	23.8
Thrice	72.2
More than thrice	0.8
Frequency of irrigation (rainy season)	
Once	46.8
Twice	5.6
Thrice	16.7
None	31.0
Frequency of irrigation in (dry season)	
Thrice	2.4
More than thrice	97.6
Type of irrigation system applied	
Manual	46.0
Drip	2.4
Furrow	50.0
Frequency of weeding	
Once	3.2
Twice	44.4
Thrice	34.9
Four times	17.5
Weed control methods	
Manual(weeding)	99.2
Chemical (use of weedicides)	0.8
Effectiveness of existing weed control methods	92.9
Type of field preparation	
Zero tillage(use of herbicides)	2.4
Ploughing and harrowing(mechanized)	43.7
Slashing and burning(manual)	53.2
Fertilizer application	96.8
Production seasons	
Wet season	2
Dry season	45
Both wet and dry seasons	53

Empirical results of determinants of technical efficiency of small scale tomato farmers

The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic frontier production function are presented in Table 14. The maximum likelihood estimates of the parameters of the inefficiency models for the rice producers are also presented in Table 15. The values of the explanatory variables in the Cobb-Douglas stochastic frontier model were mean-corrected by subtracting the means of the variables so that their averages were zero. This approach dictates that the first-order parameters are estimates of output elasticities for the individual inputs at the mean values.

Table 12. Pest and disease prevalence.

Status	Percent
Incidence of pests on farm	99.2
Use of pesticides	99.2
Frequency of spraying per season	
Once	0.8
Thrice	13.5
Four times	15.1
More than four	70.6
Incidence of diseases on farm	96.8
Use of pesticides for control	85.7

All estimated first-order coefficients in the model fall between zero and one, satisfying the monotonicity condition that all marginal products are positive and diminishing at the mean of inputs. The results indicate that land, labour, fertilizer and pesticides are essential factors for tomato production and the impacts of these variables on the mean tomato outputs are significant. Labour, quantity of pesticides, frequency of pesticide application and the use of exotic seeds had a negative effect on tomato output. Conversely, a positive relationship was found between tomato output and land, fertilizer frequency of weeding and access to extension services.

The positive effect of the land on tomato output indicated that increasing the land results in lower technical inefficiencies in tomato production. This is so because increases in area cultivated to tomato has been a major factor to increase in tomato output over the years. In addition, the extension dummy has positive effect on technical efficiency and was highly significant. This indicates that increased access to extension services is likely to increase technical efficiency. Farmers with access to extension services are more likely to be abreast with current good practices in tomato production and technical advice from extension officers and are likely to be more technically efficient in their production. The results of the inefficiency effects model are presented in Table 15. These results further suggest the age variable has a negative association with technical inefficiency, indicating that older farmers tend to be more inefficient in tomato production. This is not surprising due to the labour and capital intensive nature of tomato cultivation. In addition, experience in tomato cultivation also negatively influenced technical inefficiency, indicating that more experienced farmers are likely to be more efficient that less experienced one. Gender was found to have a negative effect on technical inefficiency, this indicates that male farmers are more likely to have low levels of inefficiency that their female counterparts.

Socio-economic variables and other covariates included in both the technical efficiency and the inefficiency models such as formal education, age, gender, household size, extension contacts etc. have widely been employed in the literature (Oduol et al., 2011; Chaovanapoonphol et al., 2009; Villano and Fleming, 2006; Sriboonchitta and Wiboonpongse 2004a, b; Battese and Ceolli, 1995).

This result is supported by the second hypothesis test in which the null hypothesis, $H_0: \gamma = \delta_0 = \delta_{01} = \delta_{02} = \delta_3 ... = \delta_8 = 0$, indicates that the inefficiency effects in the frontier model are not present. If γ=0 and all the δ-coefficients are zero, and that the stochastic frontier production function is the same as the mean production function that does not account for the inefficiency effects.

From Table 16, it can be seen that this null hypothesis is rejected at the 5% level of significance. This rejection indicates that the traditional production function is not an adequate representation of the data given the assumptions of the stochastic frontier model.

The first null hypothesis, $H_0: \beta_{ij} = 0$ for all $i \leq j = 1, 2, ..., 8$, states that the second-order coefficients in the translog production function have zero values and so, if this hypothesis is true, then the Cobb-Douglas production function applies. This null hypothesis is not rejected, even if the size of the test is as small as 5% level of significance. This implies that the Cobb-Douglas production function is an adequate representation of the data given the assumptions of the stochastic frontier model.

Finally the third null hypothesis that is considered is, $H_0: \delta_{01} = \delta_1 = \delta_2 = \delta_3 = 0$, which indicates that all the coefficients of the explanatory variables in the inefficiency model are equal to zero (technical inefficiency effects have half-normal distribution). If this hypothesis is true, then the explanatory variables in the inefficiency model do not influence the technical inefficiencies of tomato production. This second null hypothesis is also rejected. This means that the technical inefficiency effects have a truncated normal distribution indicating that the coefficients of the explanatory variables in the inefficiency model are not equal to zero and thus influence the level of inefficiency in tomato production.

Elasticities and returns to scale

The estimates of the elasticities of output with respect to inputs of production are presented in Table 17. For the Cobb-Douglas model, the elasticities of mean tomato output with respect to the different inputs depend on several parameters and values of the inputs.

The empirical results show that from the estimates of the Cobb-Douglas production function model, the estimated elasticities of mean tomato output with respect to land, labour, fertilizer, pesticide and seed at mean input values, are 0.130, -0.052 , 0.124, -0.001 and -0.376, respectively, at the mean input values.

This indicates that if the amount of land and fertilizer were to be individually increased by 1%, then the mean production of tomato is estimated to increase by 13.0 and 12.4%, respectively. However, the estimated labour, seed and pesticides elasticities were found to be elasticity is found to be negative. This suggests that if the amount of seeds planted with the required quantities of pesticide application and labour were to be individually increased by 1%, then the mean production of tomato is estimated to decrease by 37.6, 0.1 and 5.2%, respectively.

The returns to scale estimates, evaluated at the mean input values is -0.175 as presented in the bottom of Table 17. This value is significantly less than one, which indicates decreasing returns to scale in tomato production in Ghana.

Technical efficiency indexes

Table 18 presents the distribution of the predicted technical efficiencies of the sampled tomato producers. The mean technical efficiency was estimated to be 0.78, with the maximum of 0.95 and the minimum of 0.40. This implies that, on the average, the tomato farmers were producing tomato about 79% of the potential (stochastic) frontier production levels, given the technology currently being used. Thus, in the short run, there is capacity for increasing tomato production by 22% by adopting and using techniques used by the best practice tomato farms in the country. In the present study, in general, more than half of tomato producers had a mean technical efficiency in the range of 0.81 to 0.99. The remaining proportion of the tomato producers had mean technical efficiency ranging from 0.51 to 0.80. This means that generally, most of the sample tomato producers on the average are technically efficient in the allocation and use of inputs.

Characteristics of tomato producers and production system

Over 99% of the farmers encounter pests in their farms and almost all the farmers use pesticides to control pest in their farms hence the importance of pests in tomato cultivation in Ghana. Over 70% of the farmers spray their farms more than four times per planting period. Recognisance survey conducted revealed that most of the farmers even spray their farms just before harvesting because buyers believe the fruits are fresh when they see traces of the pesticide on it. The high incidence of pest and disease in the forest savannah transition accounts for high intensity of spraying than the other agro-ecological zones. In most cases, farmers do not adhere to recommended rates and practice during spraying. Abuse of agrochemicals; the use of unrecommended and heavy doses of even recommended pesticides endanger the lives of consumers. This might account for the non-significance of these two variables. Likewise, frequency of irrigation was not significant at 10%. Farm size was identified as insignificant at 10%. The adaptability and performance of the local varieties in the forest savannah transition as well as the exotic ones in the guinea savannah accounts for their dominance in these agro-ecological zones. However, the smaller acreages allocated to the production of the exotic varieties could be because it requires much care with its attendant high capital requirement which farmers may not be able to meet on larger acreages.

Factors influencing technical efficiency and productivity in tomato production

The coefficient of the education variable in the inefficiency model has a negative sign, which implies that more educational training acquired by farm operators is associated with higher technical efficiency of tomato production. Further, education improves farmers' ability to read and understand basic instructions on rates of application of agrochemicals, fertilizer, seeds and other inputs, since there instructions in most cases are written in the English language. This means tomato production requires at least some level of basic education for farmers to be efficient producers. Apart from experience, the ability to process information about an innovation is enhanced by the educational status of a person. In addition, the educated understand more the need for information and are better motivated to look out for innovations which can improve their tomato production. Certainly, the design of agricultural interventions should consider promotion of education as a major component in the short term. However, in the long term, the country needs to develop procedures to ensure the citizens have at least basic education. Our findings are consistent with earlier studies by Weir and Knight (2000) and Solis et al. (2009), which found that education enhances the ability of the farmers to acquire and make judicious use of information about production inputs, thus improving efficient use of the inputs.

The inefficiency effects model indicated a negative effect of gender on technical inefficiency in tomato production. The intensive nature of tomato production accounts for why males are dominating in tomato production. This situation is however not different across ago ecological zones (Table 13). However, preliminary investigation shows that, the females provide support to their male counterparts in most tomato production activities. The observed male dominance in the tomato production, Ghana is in consonance with what Wiredu et al. (2011) argues as an obvious and unique characteristic of the agricultural based production systems in the country.

This research was conducted among small scale tomato farmers who own just small piece of land therefore

Table 13. Distribution of spraying frequency by agro-ecological zone.

Agro-ecological zone	Type of variety (%)			
	Once	3 times	4 times	More than 4
Forest	0.0	9.1	22.7	68.2
Forest savannah transition	0.0	2.4	11.9	85.7
Guinea Savannah	1.6	22.6	14.5	61.3

Chi-Square: 12.271 Asymp. Sig. (2-sided): 0.056

Table 14. Maximum-likelihood estimates for parameters of the Cobb-Douglas stochastic frontier production model for small scale tomato farmers in Ghana.

Variable	Parameter	Coefficient	SE
Constant	β_0	2.294	0.510[ns]
Seed Dummy	β_{01}	-0.032	0.049[a]
Extension dummy	β_{02}	0.019	0.072[a]
Land	β_1	0.130	0.206[a]
Labour	β_2	-0.052	0.037[a]
Fertilizer	β_3	0.124	0.120[a]
Pesticides	β_4	-0.001	0.017[a]
Seed	β_5	-0.376	0.014[ns]
Fertilizer freq	β_6	0.899	0.111[ns]
Weeding freq.	β_7	0.213	0.132[b]
Pesticide freq.	β_8	-0.018	0.026[a]
Gamma	γ	0.07	0.006
Variance parameters	σ^2	0.309	0.051
Log likelihood function		7.35	

[a], [b,] and [c] denote significance at the 1, 5 and 10% level, respectively, and [ns] denote not significant.

Table 15. Maximum likelihood estimates for parameters of the inefficiency effects model of the Cobb-Douglas stochastic frontier production function for tomato farmers in Ghana.

Variable	Parameter	Coefficient	SE
Constant	δ_0	-1.699	0.340
Gender dummy	δ_{01}	-1.129[b]	0.128
Age	δ_1	-0.001[a]	0.009
Education	δ_2	-0.034[b]	0.011
Experience	δ_3	-0.006[a]	0.016

[a,] and [b] denote significance at the 1 and 5 level, respectively.

increasing farm sizes is not of prime interest to the farmers. In spite of this, farm size is positively related to technical efficiency implying that farmers with larger farm sizes tend to be more technically efficient in tomato production. Exploiting economies of scale in cultivating large outputs could account for this result.

Further, the results suggest a positive effect of fertilizer application and its frequency on technical efficiency. Continuous cropping and its resultant depletion of soil fertility resulting in lower yields without fertilizers application could account for this finding. In addition, most of these farmers have been cultivating on the same piece of land for a long time for various reasons such as unavailability and high cost of land rent, proximity of a piece of land to water source etc, hence fertilizer application is one of the major ways through which farmers are able to increase yield. In addition, the frequency of weeding also positively affected technical efficiency of tomato production. These findings compare with that of Chaovanapoonphol et al. (2009), and Villano and Fleming (2006), who found a positive effect of fertilizer on technical efficiency in their various studies.Both the quantity of pesticide and the frequency of application were found to be negatively related with technical efficiency. This indicates that farmers are not applying pesticides efficiently in tomato production. This findings is consistent with Osei et al. (2008) who reported on the indiscriminate of use of pesticides.

Conclusion

Prevalence of pests and diseases was common on most farms and the major means of control is the use of agrochemicals. In addition, regardless of the fact that most farmers spray with pesticides and copper fungicides, dependency on these chemical products is very high. Key factors influencing technical efficiency of tomato production include farm size or land, labour pesticide and the frequency of pesticide application, fertilizer and the frequency of fertilizer application, frequency of weeding, and extension services. A positive effect was found between extension services, land, frequency of weeding and fertilizer on technical efficiency. However, other factors such as pesticide labour and the frequency of pesticide application had negative effects on technical efficiency. Efforts towards

Table 16. Tests of null hypotheses for parameters in the stochastic frontier production function and the inefficiency effect models for tomato farmers in Ghana.

Null hypothesis	λ	Critical value[a]	Decision
$H_0: \beta_{ij} = 0$ for all $i \leq j = 1, 2, ..., 8$	21.23	24.4	Do not reject H_0
$H_0: \gamma = \delta_0 = \delta_{01} = \delta_1 = \delta_2 = \delta_3 = 0$	32.63	16.3	Reject H_0
$H_0: \delta_{01} = \delta_1 = \delta_2 = \delta_3 = 0$	15.42	5.14	Reject H_0

Table 17. Output elasticity estimates for inputs in the stochastic frontier production functions.

Input	Estimated output elasticity
Land	0.13 (0.206)
Labour	-0.052 (0.037)
Fertilizer	0.124 (0.120)
Pesticides	-0.001 (0.017)
Seed	-0.376 (0.014)
Returns to scale	-0.175 (0.394)

Standard errors are in parenthesis.

Table 18. Percentages of technical efficiencies of tomato farmers in Ghana within decile ranges.

Interval	Percentage
<0.5	4.6
0.51-0.60	3.1
0.61-0.70	10.3
0.71-0.80	19.6
0.81-0.90	52.6
0.91-1.00	9.8
Total	194
Mean	0.78
SD	0.10
Maximum	0.95
Minimum	0.40

increasing tomato production should be targeted at these factors. These must not come alone but with appropriate training in good tomato management practices through research, extension and NGOs and existing farmer based organisations. An integrated approach to pest and disease management is recommended to manage tomato farmers' persistent dependence on pesticides and other agro chemicals in their production activities.

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