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Organic and conventional vegetable production in northern Ghana: farmers' decision making and technical efficiency

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Abstract Increasing consumer affluence and concerns over food safety have led to a reemergence of consumers' appetite for organic food as a way of achieving nutritional security. This research estimates the farmers' decision making into organic or conventional vegetable production and their technical efficiency. A total of 200 each of organic and conventional vegetable producers were selected through multistage sampling technique, and the data was collected through semi-structured questionnaires. A stochastic frontier model (SFM) with sample selection was employed to correct for selectivity bias in estimating the effect of organic vegetable farming on vegetable output and technical efficiency. The results show that farmers' education, ability, and ownership of resources to farm throughout the year (ARCAY), ability to make own inputs (AMOI), membership in a farmer-based organisation (FBO), access to extension services and access to external credit support (AECS) significantly explained the probability of engaging in organic vegetable production. Organic vegetable farming had a positive significant effect on the technical efficiency of vegetable farmers. The study concluded that organic farming is an important source of insurance for farmers to increase vegetable production and reduce inefficiencies. However, institutional factors such as extension delivery, group formation, and credit provision should be enhanced to promote organic agriculture among vegetable farmers in the region.

Keywords Conventional vegetables · Organic vegetables · Technical efficiency · Endogeneity · Northern Ghana

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Introduction

The consumption of vegetables is widely known to have nutritional benefits for human health (International Agency for Research on Cancer, IARC, 2003; Rapley and Coulson, 2005). Current disease patterns in Ghana indicate a shift towards chronic non-communicable diseases. Because of this, the Ministry of Health has introduced the Regenerative Health Programme which advocates for a deliberate consumption of organically grown vegetables (Ghana statistical service (GSS), Ghana Health Service (GHS), and Inner-City Fund (ICF) Macro (2009). Moreover, with the increasing health awareness and concerns over the use of agrochemicals in vegetable farming, studies suggest that there is a growing public appetite for

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organic products. The Coalition for the Advancement of Organic Farming (CAOF (2011)) and Osei-Asare (2009) have shown that the demand for organic products far outstrips supply in Ghana.

Owusu and Anifori (2013) and Setboonsarng and Markandya (2015) defined organic vegetables as vegetables produced without agrochemicals. Organic vegetables are produced using organic fertilisers such as compost, farmyard manure (FYM), green manure, poultry droppings, and cow dung to improve and maintain soil fertility, whereas under conventional agriculture, agrochemicals are used for producing vegetables (Setboonsarng and Markandya, 2015). Liu et al. (2013) and Zhang et al. (2002) referred to a safe and green food as those produced under an ecologically sound food-production system where only a slight or harmless amount of agrochemical residue is found. Generally, USDA indicated that the standards of an organic crop include its production on lands with prohibited substance three years to the harvest of the organic crop, under soil fertility and nutrients management through practices such as tillage and cover crops, control of pests and diseases through physical, mechanical and biological processes, use of organic planting materials and no use of genetic engineering processes (USDA Organic, 2016). Organic crop production requires few inputs (Dabbert, 2006; Hole et al., 2005; Thapa and Rattanasuteerakul, 2010). Most smallholder farmers in Ghana engage in organic farming by default but lack certification that would allow them to sell in the international market (Opoku et al., 2020). Organic certification bodies in Ghana include Ecocert, SmartCert, AfriCert, SGS, and Control Union. In this study, farmers are defined as organic producers not because they necessarily hold organic certification but because their vegetable production processes involved organic production methods as defined by USDA. In addition to domestic demand, the motivation for venturing into organic farming includes its high international market demand, particularly, in Europe and the United States of America (USA) (Osei-Asare, 2009) where there is a high market premium between 9 and 40% for organic agricultural products (Owusu and Anifori, 2013; Norman 2007). Organic vegetable production also contributes significantly to job creation, wealth, and poverty reduction in Ghana (Nouhoheflin et al., 2004). It serves as valuable ingredients for the local food industry, particularly, restaurants and supermarkets throughout the country. Unfortunately, conventional agricultural products rather predominate in Ghana, and possibly, rendering consumers and producers themselves to the health hazards from improper use of agrochemicals among farmers. This situation can be counteracted by promoting organic vegetable production and fostering technical competence in the subject.

As of 2003, about 5,453 hectares of land was under organic cultivation in Ghana (Research Institute of Organic Agriculture and International Federation of Organic Agriculture Movements (FiB and IFOAM, 2006; Willer and Kilcher, 2011). This increased to 26,000 hectares (0.18% of Ghana's total land) by 2010. According to Osei-Asare (2009), organic farms are mainly owned by private individuals, even though there are also large-scale organic farms with or without outgrowers, mostly funded and managed by external partners. Similarly, not only do local entrepreneurs rely on external funding, but also most of the organic products are exported. There is a high market demand for organic vegetables in northern Ghana (CAOF, 2011). Osei-Asare (2009) indicated that Ghanaian consumers are willing to pay up to 20% premium on organic products, while more males (88%) than females (12%) engage in organic farming with higher ratio of female (75%) to male consumers (25%). The educational background of organic vegetable producers is generally lower than that of its consumers.

Generally, vegetable production in Ghana is hindered by several challenges. Key among them is the risk of pest infestation, especially, concerning exotic vegetables and the use of pesticides to forestall harvest and income loss (Lund et al., 2010; William et al. 2008). Though there is insufficient data on the risk of exposure to pesticides, the practice has raised concerns over the health implications on consumers. Vegetables produced in Ghana are contaminated with pesticide residues exceeding regulatory standards (Amoah et al., 2006). Challenges specific to organic vegetable production include the non-availability of an exclusive market for organic products, the absence of premium price in the local market, low recognition for organic produce, and vague policy direction for organic farming. To mitigate these challenges, the implementation of sustainable agricultural production practices will encourage farmers to rely on renewable resources to reduce the cost of production, produce safe vegetables, and protect the environment. Improving organic vegetable production therefore requires a strong organic producer–consumer coalition that will champion the cause of organic agriculture. In 2007, CAOF was formed by a group of civil society organisations (CSOs) and individual organic farmers in the Upper East and Northern Regions of Ghana. The coalition aimed to advocate the identification, development, and promotion of best organic or conservation practices as alternative to the use of agrochemicals in agricultural production (CAOF, 2011). It is indistinct if this has been achieved. Evidently, there are pockets of empirical studies on organic farming in Sub-Sahara Africa (Sodjinou et al., 2015) and Ghana (Opoku et al., 2020; Owusu and Anifori, 2013; Probst et al., 2012; Nouhoheflin et al., 2004). However, these do not provide information on the efficiency impacts from the decision into organic vegetable production. Considering the significance of organic agriculture, there is the need to provide appropriate information backed by empirical data on the production decision and efficiency of organic and conventional vegetable production in Ghana. This study specifically addresses the question of what influences farmers' decision into organic and conventional vegetable production and what the effects of this decision are on their technical efficiency of vegetable production.

Methodology

Study area

The study was conducted in the Northern region (now divided into three regions as Northern, North East and Savannah regions) of Ghana (Fig. 1). The region borders with Cote d 'Ivoire at its west, Togo at its east, Upper East and Upper West regions at its north, and Brong Ahafo region at its south. Farming is the main economic activity of the region. The area have a very high agricultural prospect, being the region with the largest landmass in Ghana of which 75% is suitable for crop production. The production of food crops such as cereals, legumes, tuber, and vegetables is increasingly integrated with ruminants and poultry production in the region. The most common vegetables grown in the region include tomatoes, cucumber, sweet and hot pepper, green beans, carrot, cabbage, spring onion, okra, amaranthus, roselle (bra), white jute (ayoyo), okra, and spring onion.

Sampling and data collection

A multi-stage sampling technique was used to select vegetable farmers for this study. In the first stage, purposive sampling was used to select four Municipal, Metropolitan and District Assemblies (MMDAs) in the Northern region of Ghana. The selected MMDAs were Tamale Metropolis, Tolon, Kumbugu, and West Mamprusi. These were selected purposively due to high concentration of organic and conventional vegetable production in the area. In the second stage, probability proportion by size was employed to randomly select three (3) to seven (7) communities from each MMDA, depending on the respective concentration of organic vegetable farmers in a community. In all, twenty (20) communities were subsequently selected for the study. In the third stage, vegetable farmers in each selected community were stratified into two as organic vegetable farmers and conventional vegetable farmers. In the final stage, convenience sampling technique was used to select 20 respondents (10 organic and 10 conventional vegetable producers) from each of the selected communities. This was done by allowing the research assistants to go into the sampled communities to select the farmers without any predefined condition except for their involvement in vegetable production and willingness to participate in the research. In all, 400 farmers were selected, at equal proportion of 200 each for organic and conventional vegetable farmers, from the four MMDAs. The respondents were interviewed using semi-structured questionnaire that allowed to obtain both quantitative and qualitative information on vegetable production in the region.

Estimation technique

The study employed Greene's (2010) stochastic frontier sample selection model (SFSSM) to estimate the effect of organic farming on vegetable output and technical efficiency. The SFM as independently propounded by Aigner et al. (1977) and Meeusen and van den Broeck (1977) has been used widely in

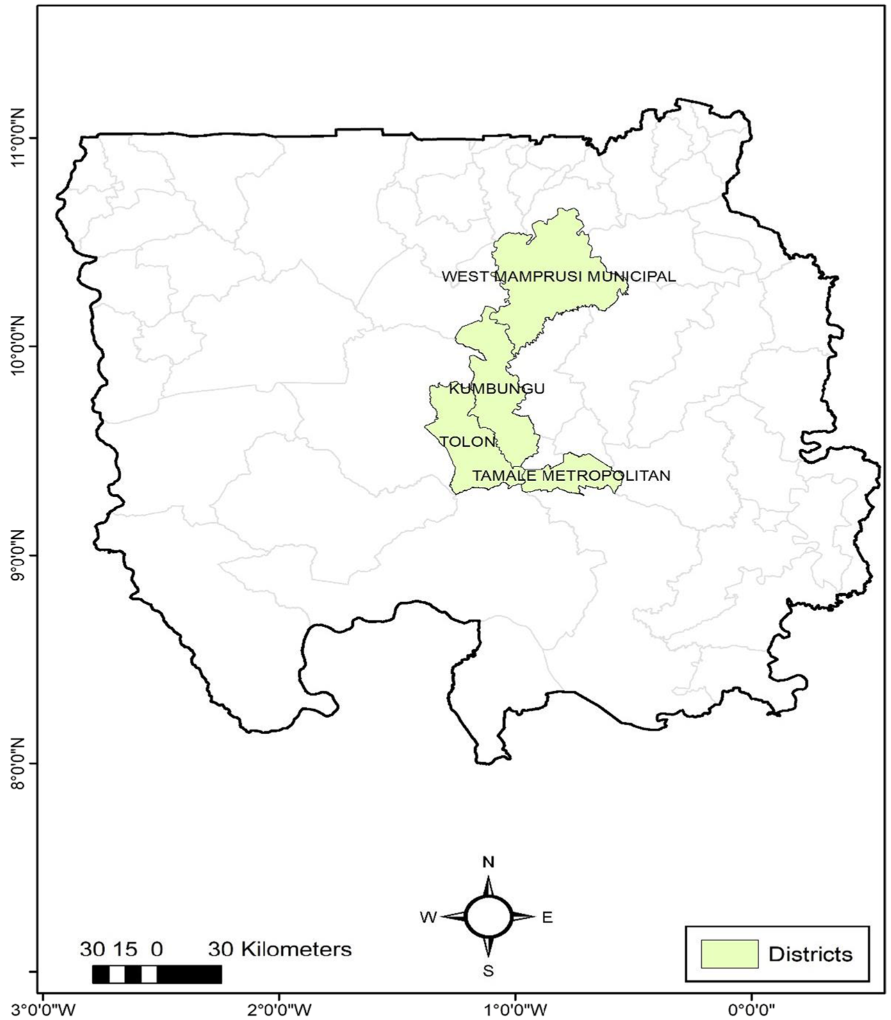

Fig. 1 Map of northern Ghana showing the selected MMDAs

agricultural economics especially for the analysis of farm productivity. SFM uses maximum likelihood estimation (MLE) to estimate the parameters of a linear model by separating inefficiency effects from random noise (Coelli, 1995; Cooper et al., 2006). The inefficiency effect which is strictly nonnegative takes care of any technical and managerial constraints of the farmer while the random noise addresses any exogenous shock on vegetable production and which is outside the farmer's control, for instance, weather and measurement errors. The inefficiency effect arises when the actual or observed production value from a given resource mix is less than the maximum possible or achievable output.

According to Battese and Coelli (1995), the production frontier and inefficiency effects must be estimated simultaneously. The SFM specification depends on a functional form that reflects the relationship between output and a set of inputs used in its production. In econometric estimation, the transcendental logarithmic (translog), and the Cobb–Douglas production functional forms (Christensen et al., 1973) are commonly used parametric functional specifications of the SFM. The translog frontier function allows the inclusion of input variables and their squares and cross-product terms to boost the model's fitness (Coelli, 1995). On the other hand, the Cobb–Douglas SFM is simple and estimates the elasticity of the inputs directly. The choice of a particularly functional form requires test, most through a likelihood ratio test. In this study, the Cobb–Douglas SFM best fit the data and presented as:

$$lnY_i = \beta_o + \sum_{i=1}^{n} lnX_i' + V_i - U_i \quad (1)$$

where *In* denotes natural logarithm, Y is the dependent variable representing the value of vegetable output, X denotes a vector of production inputs, β is a vector of unknown parameters to be estimated, V represents the random noise, and U is inefficiency. From Eq. 1, technical inefficiency is expressed as the ratio of the observed output to the corresponding frontier output, conditioned on the level of inputs used by the farm. Thus, TE is given as:

$$TE_i = \frac{q_i}{q_i^*} = \frac{f(X_i\beta)exp(V_i - U_i)}{f(X_i\beta)exp(V_i)} = exp(-U_o) \quad (2)$$

where q_i is the observed value of vegetable output and q_i^* is the frontier value of vegetable output. If U_i =1, then $q_i = q_i^*$ suggesting that the observed output is on the frontier, and thus technically efficient. Hence, given the level of inputs or production technology, the farm achieves its full potential output only on the frontier. Therefore, TE is defined as $exp(U_i)$.

$$U_i = \gamma_o + \sum_{i=1}^{n} Z_i'\gamma + e_i \quad (3)$$

where U_i denotes technical inefficiency; Z denotes a vector of explanatory variables such as socio-demographic, economic, farm-specific, or institutional characteristics; γ is a vector of unknown parameters to be estimated; and e_i represents the error term. This is attained in terms of parameterisation of a gamma $\gamma = \frac{\sigma_u^2}{\sigma^2} = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$ and sigma $\sigma^2 = \sigma_u^2 + \sigma_v^2$. γ that is bounded by $0 \le \gamma \le 1$. This indicates the variability in output due to the presence of both stochastic errors and technical inefficiency. Given $\gamma = 1$ indicates that the deviation from the frontier is because of technical inefficiency while $\gamma = 0$ means that the deviation from the frontier is solely because of random noise effects.

Addressing the problem of selectivity bias

The adoption or practice of improved agricultural technologies, innovations, or farming system such as organic vegetable farming has been found to affect farm output and efficiencies (Becerril and Abdulai, 2010; Minten and Barrett, 2008; Moyo et al., 2007). However, scholars often find it difficult to attribute specific effects in an outcome to specific interventions because the counterfactual outcome must first be observed to measure the effect of the change on any target population (Imbens and Wooldridge, 2009; Cameron and Trivedi, 2005). This challenge often leads to selectivity bias, which arises from non-random selection or self-selection. Greene (2010) noted that selectivity bias arises as a consequence of a correlation of the unobservables in the output equation with those in the sample selection equation. Sample selection models are recommended to deal with such problems. In an attempt to overcome this problem, some studies (Sipiläinen and Lansink, 2005; Madau, 2007; Kumbhakar et al., 2009) estimated a single stochastic frontier model for both groups (in this study, organic and conventional farmers) by including a dummy variable that reflects the practice (vegetable farming system in this study). Others (Tzouvelekas et al., 2001; Kumbhakar et al., 2009; Kramol et al., 2013) estimated separate stochastic frontier production models for the groups. But these estimation methods do not permit for adequate correction of selectivity bias because farmers are not randomly assigned to the vegetable farming system adopted. This means that the data on the vegetable farming system and output are subject to sample selectivity bias.

Greene's (2010) SFSSM either simultaneously or jointly estimates the probit model, the propensity scores, and the technical efficiency scores. As such, SFSSM corrects for both observed and unobserved bias (Bravo-Ureta et al., 2011). Procedurally, it estimates and holds a selection equation, using a probit model to find the inverse Mill's ratio (IMR) followed by an estimation of independent variables that include the IMR in the output equation and the evaluation of technical efficiency differences. The technical efficiency scores are further estimated using a Heckman sample selection model to correct for selectivity bias in inefficiencies due to self-selection. Greene (2010) specifies this correlation in the SFM as:

$$A_i^* = W_i'\alpha + \omega_i, [A_i = 1 if A_i^* > 0; A_i = 0 if A_i^* > 0], \omega \sim N[0, 1^2] \quad (4)$$

$$
\begin{gathered}
Y_i = X_i'\beta + \varepsilon_i, \varepsilon_i \sim N\left[0, \sigma_\varepsilon^2\right] \\
\left(Y_i, X_i\right) is observe only when A_i = 1 \\
\varepsilon_i = V_i - U_i \\
U_i = \left|\sigma_u U_i\right| = \left|\sigma_u U_i\right| where U_i \sim N\left[0, 1^2\right] \\
V_i = \sigma_v V_i where U_i \sim N\left[0, 1^2\right] \\
\left(\omega_i, V_i\right) \sim N\left[0, 1^2\right]\left(1, \rho\sigma_v, \sigma_v^2\right)
\end{gathered} \tag{5}
$$

where Y is the value of vegetable output, X_i represents a vector of conventional inputs in the output equation, β is a vector of unknown parameters to be estimated, ε_i is the composite error term, V represents the random noise, and U is the inefficiency effect. A_i^* is the propensity to practice organic vegetable farming, thus, a binary decision representing adoption of organic or conventional vegetable farming; W_i denotes a vector of explanatory variables influencing the decision to go into a particular vegetable farming; α are unknown parameters in the selection equation; and ω_i is the error term.

The empirical model for estimating the selection equation for vegetable farming system, vegetable output, and technical inefficiency can be specified by Eqs. 6, 7, and 8 respectively as:

$$
\begin{aligned}
A_i = {} & \alpha_0 + \alpha_1 W_{1,i} + \alpha_2 W_{2,i} + \alpha_3 W_{3,i} \\
& + \alpha_4 W_{4,i} + \alpha_5 W_{5,i} + \alpha_6 W_{6,i} + \alpha_7 W_{7,i} \\
& + \alpha_8 W_{8,i} + \alpha_9 W_{9,i} + \alpha_{10} W_{10,i} + \omega
\end{aligned} \tag{6}
$$

where A_i is the dependent variable representing the decision to engage in organic vegetable farming, W_1 = sex of farmer, W_2 = age of farmer, W_3 = education of farmer, W_4 = household size, W_5 = off-farm income activities, W_6 = ability and resources to cultivate all year (ARCAY), W_7 = ability to make own inputs (AMOI), W_8 = membership of a farmer-based organisation (FBO), W_9 = extension contact, and W_{10} = access to external credit source (AECS).

$$
lnY_i = \beta_0 + \beta_1 lnX_{1,i} + \beta_2 lnX_{2,i} + \beta_3 lnX_{3,i} + \beta_4 lnX_{4,i} + \alpha\lambda + \varepsilon_i \tag{7}
$$

where Y_i = value of vegetable output, X_1 farm size, X_2 = quantity of labour, X_3 = quantity of fertiliser, X_4 = quantity of seed, and λ = IMR generated from the probit model. The value of the output was determined by wQ where Q is the total quantity of vegetable produced and w is the price of a unit (as used by the farmer) vegetable. Also

$$
\begin{aligned}
U_i = {} & \gamma_0 + \gamma_1 Z_{1,i} + \gamma_2 Z_{2,i} + \gamma_3 Z_{3,i} + \gamma_4 Z_{4,i} + \gamma_5 Z_{5,i} \\
& + \gamma_6 Z_{6,i} + \gamma_7 Z_{7,i} + \gamma_8 Z_{8,i} + \gamma_9 Z_{9,i} + \varepsilon_i
\end{aligned} \tag{8}
$$

where U_i represents technical inefficiency in vegetable farming, Z_1 = sex of farmer, Z_2 = age of farmer, Z_3 = education of farmer, Z_4 = off-farm income activities, Z_5 = ability and resources to cultivate all year (ARCAY), Z_6 = ability to make own inputs (AMOI), Z_7 = membership of a farmer-based organisation (FBO), Z_8 = extension contact, Z_9 = access to external credit source (AECS), and λ represents the IMR that accounts for observed and unobserved heterogeneity in the data due to self-selection.

Results and discussion

Socio-economic characteristics of smallholder vegetable farmers

The descriptive statistics of the farmers (Table 1) shows that the average ages of organic and conventional vegetable farmers were 38.2 and 37.8 years, respectively. There is no significant difference between the two mean ages. It can be inferred that most farmers in the study area are within their productive agricultural ages and this can build their experience along vegetable production for a long time. Most of the farmers (81%) were males and the rest 19% were females. Generally, more males than females are farm owners, especially due to resource access and ownership. For instance, Amoah et al. (2014) attributed the low number of females in farming to their low ownership of land. However, it was expected that more females than males would be involved in vegetable production since vegetables are high value crops and require less space for production. It is also plausible that most females engage in other components of the vegetable value chain including processing and marketing other than production. Overall, the mean household size was 9 people and there was no statistically significant difference in the household size among conventional and organic vegetable growers.

About half of the respondents (51%) had no formal education. However, there are more conventional vegetable farmers (33%) with no formal education relative to the only 18% of the organic vegetable farmers with no formal education. Also, the results indicate that organic vegetable farmers had an average of 6 years of formal education while the conventional

Table 1 Socioeconomic characteristics of conventional (200) and organic (200) farmers

Variable	Conventional farmers	Organic farmers	Total	*Statistical test*[(a)]
Age (years)	37.81 (8.44)	38.24 (8.18)	38.02 (8.30)	*− 0.52*
Sex (% of male)	76	87.35	81.75	*− 0.86***
Household size (numbers)	8.76 (3.17)	8.79 (3.87)	8.77 (3.53)	*− 0.71*
Education (years)	5.13 (4.57)	6.12 (5.03)	5.13 (4.90)	*− 5.18****
Vegetable farming experience (years)	16.27 (9.17)	18.67 (7.57)	17.47 (8.48)	− 2.85**
Extension service (numbers of visit)	1.12 (1.64)	2.93 (3.8)	2.04 (3.05)	− 6.08***
AMOI (% of yes)	6.5	100	53.25	− 148.15**
FBO (% of yes)	22.5	35.5	29	− 12.90***
ARCAY (% of farmers cultivating all year around)	28.5	80.5	54.5	− 93.09***
Off-vegetable farm activity (% of yes)	54	53.5	53.8	0.01
AECS (% of yes)	5.5	34.5	20	63.78***
Formal training (% of yes)	7	52	29.5	*− 97.37****
Sole ownership of land (% of yes)	71.5	70	70.75	0.11
Fertiliser (GH¢)	232.15 (93.2)	79.18 (60.4)	155.67 (119.2)	16.73***
Inorganic fertiliser (kg)	211.5 (164.8)	0	232.15 (93.2)	
Organic fertiliser (kg)	561.8 (165.3)	2672.9 (1472.7)	1617.3 (1487.4)	2111.13***
Farm size (hectares)	0.688 (0.38)	0.674 (0.28)	0.681 (0.33)	− 0.44
Seed (GH¢)	8.81 (4.01)	9.10 (5.30)	8.96 (4.70)	*− 0.61*
Labour (GH¢)	232.59 (14.4)	293.27 (104.1)	262.93 (103.2)	− 6.14***
Vegetable outputs (GH¢)[1]	27,144.16	37,091.66	32,316.76	*− 6.44****

Figures in brackets represent standard deviations. [(a)]Statistical test: *t*-test and Pearson chi-square for dummies; ***, **, and *, significant at the 1%, 5%, and 10% levels, respectively.[1]As at the time of data collection, the exchange rate was 1GH¢ to about $4.3

farmers had an average of 5 years. The mean difference in the educational level for the two groups of vegetable farmers was statistically significant at 1% level. The mean distribution of the farm size for organic vegetable farmers was 0.67 hectares and 0.69 hectares for conventional farmers. Conventional farmers who received extension contact were visited for only one time on the average while the organic farmers had about 3 times contact. The major source of extension information is the extension staffs of MoFA and other NGOs. The study found that the years of experience in vegetable production was relatively high for organic vegetable producers (18.7 years) compared to conventional vegetable producers (16.3 years). Although generally low, membership in FBOs is more pronounced among organic vegetable farmers (17.8%) than conventional vegetable farmers (11.3%). It was also observed that organic vegetable farmers engaged in off-farm activities more than conventional farmers.

The average annual vegetable revenue of the organic vegetable farmers was GH¢37,091.66 per hectare while that of conventional farmers was GH¢27,144.16 per hectare. This gives a statistically significant mean difference of GH¢9,947.50 per hectare.

The data shows that some of the interviewed conventional farmers also used organic fertilisers in the cultivation of vegetables. These farmers remained classified as ‘conventional’ farmers because they used chemicals such as herbicides and inorganic fertilisers for vegetable production. On the other hand, the organic vegetable producers used either compost, crop rotation, farmyard manure (FYM) or a combination of these for vegetable cultivation. FYM was the commonest type of organic fertiliser used by nearly all organic farmers, and this was obtained from cattle, poultry, sheep, and goat dungs as well as poultry pens. Only few of them bought the FYM from colleague farmers in the communities or from major cities such as Sunyani. Aside FYM, most other organic vegetable producers used compost.

The analyses reveal significant difference in the quantity and cost of organic and chemical fertilisers between farmers who engaged in organic vegetable farming and those who produced vegetables by conventional methods. Expectedly, the organic vegetable producers used significantly higher quantities of organic manure than was used by conventional vegetable farmers. For instance, on average, organic farmers used 2,672.9 kg per hectare of organic manure in 2014/2015 production year. For the conventional farmers who also used organic manure, an average quantity of 561.8 kg/hectare was applied. The disparity between the quantity of inorganic and organic fertilisers is simply based on availability and cost. Also, the compound fertiliser NPK 15–15-15 used by conventional farmers contains 15% nitrogen whereas most organic fertilisers such as compost and poultry manure have only 1–4% nitrogen. This means that higher amounts of the organic fertilisers are required to meet the nutrient demands of the vegetables (Amanullah et al., 2010; Gao et al., 2010). The results also suggest that any policy intervention that would encourage further research into the improvement in the mineral composition and availability of organic manure will encourage organic farming. Although organic farmers use large quantities of organic fertiliser, the average cost associated with its use was lower than for the conventional fertilisers. This is because most of the organic manures are obtained from the farmers own pens and hence were unable to associate cost to them.

The average cost of seeds per hectare for organic farmers was higher than that of conventional farmers. About 81% of organic farmers had the capacity and resources to grow vegetables throughout the year, and as such incur more annual average cost on seeds (Table 1). However, the difference in the cost of seed for the two groups was statistically insignificant. Labour costs (family and hired labour) of organic farmers was higher as compared to conventional farmers (Table 1). This means that organic vegetable farmers require more labour than conventional vegetable farmers. The analysis indicates that all the organic vegetable farmers had the capacity and resource to prepare almost all their inputs as compared to only 6.5% of conventional vegetable farmers.

Almost all the farmers financed their farm operations from their personal savings. However, approximately 20% of the sampled farmers had received agricultural credit for production. Majority of the organic vegetable farmers (80.5%) in the study area had the ability and resources to cultivate vegetables throughout the year as compared to 28.5% of the conventional farmers. The organic farmers attributed their ability to farm throughout the year to the high presence of organic matter in their farmlands. This is because the organic matter in the soil retains moisture and requires little external water supply to support plant growth in the dry season. This allowed them to invest in simple and less costly irrigation systems for all year vegetable production.

While 26% of the organic farmers received formal training on farming businesses, only 3.5% of conventional vegetable growers had received such trainings. Similarly, 71.5% and 70% of the organic and conventional farmers respectively used their own lands for vegetable production. This implies that access to farmland is not a major limitation to many vegetable producers in the region.

Determinants of organic vegetable production

To explain the factors that influence farmers' decision into organic vegetable production, a probit model was estimated. The maximum likelihood estimation result in Table 2 shows a significant Wald chi-square statistic (277.92; *p*-value < 0.01), and this indicates that the variables in the model together are significant in explaining the probability of farmers going into organic vegetable farming. The results indicate that education, ARCAY, AMOI, FBO membership, and AECS are significant in explaining farmers' decisions, and the estimated marginal effects of these variables were positive. Indicatively, vegetable farmers with formal education were more likely to go into organic vegetable production than those with no formal education. This could mean that organic farming is relatively knowledge-intensive, and requires good managerial skills provided by formal education. Also, organic products are cited to be healthier or less health risky; hence, highly educated farmers with adequate information on organic products are more likely to go into its production. This finding is consistent with the studies of Beshir et al. (2012), Demiryurek (2010), Mignouna et al. (2011), and Uaiene et al. (2009) which indicates that education increases

Table 2 Probit model showing the determinants of organic farming adoption

Variable	Coef.	Std. Err.	Marginal effect
Sex	0.100	0.229	0.039
Age	0.016	0.011	0.006
Education	0.043**	0.019	0.017**
Household size	−0.017	0.025	−0.007
Off-farm work	0.101	0.178	0.040
ARCAY	1.080***	0.180	0.401***
AMOI	2.545***	0.354	0.684***
FBO membership	0.566***	0.204	0.223***
Extension contacts	0.378**	0.175	0.148**
AECS	1.586***	0.367	0.544***
Constant	−4.024	0.643	

Statistics: No. of obs. = 400; LR chi^2 (11) = 277.92; Prob > chi^2 = 0.0000; pseudo R^2 = 0.5012. Note: *** and ** indicate significance at 1% and 5% respectively.

the ability of farmers to obtain and use information to enhance their adoption of an agricultural technology.

Vegetable farmers with ARCAY exhibited a greater probability to engage in organic vegetable production than their resource-constrained counterparts. Demand for organic vegetables is increasing and may call for an all-year production. As such, farmers with enough resources can better invest in this all-year production than their counterparts with less resources. Similarly, AMOI showed a positive significant marginal effect on organic vegetable farming. Organic materials in the soil allow the soil to retain enough moisture to support plant growth, even in the dry season (Carter, 2002; Pimentel et al., 2005). This suggests that farmers who have the ability and resource to make their inputs (homemade input) tend to reduce costs associated with organic vegetable production. This result concurs with that of Hattam and Holloway (2006).

AECS was significant and positively linked to the probability of organic vegetable farming. This means that vegetable farmers who had access to credit were more likely to produce vegetables through organic farming system as compared to farmers without access to credit. Credit, as an input, enables farmers to invest in technology and undertake farm investment decisions such as organic farming. In Nigeria and Ethiopia, Awotide et al. (2016) and Abayneh and Tefera (2013) respectively established similar results. However, Ogada et al. (2014) and Afolami et al. (2015) estimated a negative relationship between access to credit and dissemination of improved agricultural technologies. Vegetable producers who had access to agricultural extension were more likely to participate in organic farming. Farmers obtain information on organic farming, sustainable agricultural production processes, and potential markets through extended communication and are often driven or supported by improved inputs and other organic vegetable husbandry practices which are critical for the promotion of organic vegetable farming (Langyintuo and Mekuria, 2005). Extension access, in general, can counterbalance the negative effect of lack of formal education in the overall decision to adopt new technologies. The positive link between extension contact and adoption corroborates with Asfaw et al. (2012), Mariano et al. (2012), and Yaron et al. (1992) who contend that access to extension services is critical in promoting the adoption of modern agricultural production technologies.

The results also indicate that vegetable farmers who are members of FBOs were more likely to engage in organic farming than non-FBO members. This is probably because FBO membership serves as a platform where farmers learn, improve their understandings, and share knowledge among themselves on various agricultural innovations such as organic farming. This finding is consistent with studies such as Bayard et al. (2007), Hattam and Holloway (2006), and Uaiene et al. (2009).

Tests for stochastic frontier model specification and the determinants of vegetable output

The study tested three hypotheses using the generalised likelihood ratio (LR) test technique and the results presented in Table 3. The null hypotheses tested include the following: (1) the Cobb–Douglas model specification appropriately explained the production of vegetables over translog model; (2) an average response model can best explain vegetable production than SFA; and (3) there are no explanatory factors that significantly explain the efficiency of vegetable farmers. The first test conducted to determine the choice between Cobb–Douglas and transcendental (translog) functional forms shows that the Cobb–Douglas production is a more appropriate

Table 3 Results of hypotheses tests in the stochastic frontier model

	Conventional farms	Organic farms	Pooled sample	
Null hypothesis	LR-statistic (*p*-value)	LR-statistic (*p*-value)	LR-statistic (*p*-value)	Decision
$H_0 = \beta_{jk} = 0$	12.42 ($p > 0.10$)	11.37 ($p > 0.10$)	4.92 ($p > 0.10$)	Accept H_0
$H0 = \Omega = \delta_0 = \delta_1, \ldots \delta_k = 0$	33.18 ($p < 0.05$)	65.33 ($p < 0.01$)	125.06 ($p < 0.01$)	Reject H_0
$H_0 = \gamma = 0$	14.48($p < 0.01$)	12.33 ($p < 0.01$)	27.44 ($p < 0.01$)	Reject H_0

Table 4 Determinants of vegetable output

Variable	Coef	Std. Err
ln farm size	0.375**	0.177
ln labour	– 0.094	0.060
ln inorganic fertiliser	– 0.209***	0.069
ln seed	0.097	0.141
Constant	13.018	0.478
Returns –to-scale	0.169	
Log-likelihood function	– 824.927	
σ_u^2	3.387***	
σ_v^2	0.574***	
γ	0.844***	
λ	2.431***	
Selectivity bias ($\rho_{(w,v)}$)	0.373**	0.171

*** and ** indicate significant levels at 1% and 5%, respectively.

specification of the production frontier than the transcendental production function. Therefore, the study failed to reject the first hypothesis.

From the LR test (33.18; $p < 0.01$), the second hypothesis is rejected, justifying the use of the stochastic frontier framework over an average response model. The significance of the coefficient of gamma in Table 4 also supports the presence of technical inefficiency. The gamma (γ) estimate which measures the overall technical inefficiency in the conventional production model was 0.844 and significant at 1% probability level. This implies that about 16% of the variation in vegetable output is largely due to inefficiency among farmers and not random errors.

Table 4 displays the elasticities of vegetable output with respect to the production inputs. The correlation coefficient between the errors of the factors influencing organic farming equation and that of the vegetable output equation was negative and statistically significant. This indicates that unobserved factors that lead to a decline in the decision to produce organic vegetables also lead to a decline in vegetable output. Hence, the specification of the stochastic frontier model with sample selection is better than simply estimating independent equations for organic vegetable producers and conventional vegetable producers. Overall, the elasticity of vegetable production depicts decreasing returns to scale (0.169). This means that output changes less proportionally than simultaneous change in all inputs.

The results in Table 4 shows that two (farm size and fertiliser) of the four variables included in the Cobb–Douglas model exhibited statistically significant effects on output at 5% and 1% significance levels, respectively. This suggests that vegetable output increases with farm size but decreases with inorganic fertiliser. For instance, doubling the current farm size increases vegetable output by 37.5% while doubling the quantity of inorganic fertiliser reduces vegetable output by 20.9%. The positive relationship between farm size and output is consistent with Ngango and Kim (2019) and Rajendran et al. (2015) while the negative relationship between fertiliser usage and output corroborates that of Abdulai and Huffman (2000) and Asante et al. (2014). This call for further understanding on the fertilizer use efficiency of the farmers.

Technical efficiency level among vegetable farmers

Overall, Table 5 shows that vegetable farmers have a mean technical efficiency of 0.325, which means that the farmers were only 32.5% technically efficient in their vegetable farming. Hence, 67.5% of potential vegetable output was unattained due to technical inefficiency of its production. The organic vegetable farmers had a slightly higher mean technical efficiency (34.2%) with maximum and minimum efficiency of 80.8% and 1.2% respectively as compared to conventional farmers' mean of 30.7%, and maximum and minimum efficiencies of 75.8% and 0.9%, respectively. These results also show that vegetable farmers are producing farther from the frontier due to poor farming practices and other institutional and socio-economic limitations that needs to be corrected.

Table 5 Technical efficiency scores of vegetable farmers

TE levels (%)	Organic producers (%)	Conventional producers (%)	Pooled (%)
0–10	13.00	14.00	13.50
11–20	17.00	17.50	17.25
21–30	9.50	19.00	14.25
31–40	15.50	16.00	15.50
41–50	21.50	19.00	20.25
51–60	17.00	10.00	13.25
61–70	6.00	3.50	14.00
71–80	0.50	1.00	4.75
81–90	0.50	0.00	0.75
Mean TE	0.342	0.307	0.325
Max TE	0.808	0.758	0.009
Min TE	0.012	0.009	0.808

Table 6 Effects of organic vegetable production on technical inefficiency of farmers

Variable	Coef	Std. Err
Organic vegetable production	−0.020***	0.004
Education	0.012	0.008
AECS	0.276***	0.101
Extension contacts	0.127	0.080
FBO membership	−0.181**	0.082
AMOI	0.167*	0.095
ARCAY	−0.135	0.081
Off-farm work	0.273***	0.078
Age	0.015***	0.005
Sex	0.759***	0.121
Constant	−2.255	0.231

***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

Although vegetable production is mostly a secondary activity to the production of most staple crops such as maize, the estimated low technical efficiency requires attention from stakeholders in the agricultural sector, particularly, the Ministry of Food and Agriculture.

Effects of organic vegetable production and other factors on technical efficiency

Table 5 shows a wide distribution of technical efficiency among the farmers. Therefore, it is important to understand the factors responsible for such estimated efficiency differences. This is provided in Table 6, and the discussion of the significant factors including vegetable production decision is provided in this section. From the results, AECS, AMOI, off-farm income work, age, and sex had positive significant effects on technical efficiency of vegetable farmers. This means that an increase in these factors leads to a decrease in the technical efficiency of vegetable production, or an increase in these factors leads to an increase in technical inefficiency. On the other hand, FBO membership, ARCAY, and organic vegetable production lead to an increase in technical efficiency of vegetable farmers.

The positive significant effect of sex implies that female vegetable farmers are more technically efficient than the male vegetable producers. This is because a positive estimate is interpreted with the definition of the sex group that is defined as '1', in this case, male farmers. Therefore, an increase in inefficiency is associated with male farmers. This could be that women devote more of their time and resources on vegetable production, thereby making them more efficient in vegetable farming than men. Considering that vegetables are high value crops and require less land, this provides an opportunity to improve the livelihood of female farmers. On the contrary to this result, Amoah et al. (2014) and Binam et al. (2008) studied other crops in Ghana and concluded that female farmers are less efficient.

The results show that an increase in age reduces the efficiency of vegetable production and, thus, younger farmers are more technically efficient as compared to older farmers. This is because the estimated coefficient is positive, implying that, as age increases, the level of technical inefficiency increases. Younger farmers are generally physically strong and can labour for longer hours than older farmers, and this may increase their ability to utilise inputs for vegetable production more efficiently. The high innovativeness of younger farmers can also contribute to their high technical efficiencies.

The coefficient estimate of AECS is significant and positive. This suggests that organic vegetable farmers who received credit support for farming were less efficient in vegetable production. This result did not meet our a priori expectation and also contradicts the findings of Ahmad et al. (2006), Kuwornu et al. (2013), and Waqar et al. (2008) who reported that farmers with access to in-kind inputs and institutional credit support in the form of seed and irrigation are more productive. Also, farmers involved in off-farm income activities were less technically efficient than those who did not engage in off-farm activities. This could be that farmers who do off-farm economic activities give less time to vegetable farming or may divert income from off-farm work away from their vegetable farms, thereby reducing investment in vegetable production. Contrary to this study is the result of Chirwa (2007).

The technical efficiency of vegetable farmers also reduces with AMOI. Thus, farmers who make their own inputs were less technically efficient in vegetable farming. Perhaps, these farmers have less time for working on their vegetable farms, thereby, reducing their efficiencies. Since ARCAY had a negative coefficient, it implies that there is a positive and statistically significant effect of ARCAY on vegetable farmers' technical efficiency. Thus, farmers who can cultivate vegetable for the entire year were technically efficient in their farming processes. Farmers who participate in all-year production are more likely to engage in vegetable farming as their major crops, thereby, giving vegetable production their maximum attention. The results also show that vegetable farmers who belong to FBOs were more technically efficient than non-FBO members. Farmers in FBOs have more access to information and training on improved agronomic practices such as the application of fertiliser (both organic and inorganic) and crop protection inputs, which increases their knowledge and skills of producing efficiently.

One of the objectives of this study is to examine the effect of organic vegetable production on the technical efficiency of vegetable farmers. From the result, the coefficient on organic vegetable production was statistically significant and negative, indicating that vegetable farmers who engaged in organic farming were more technically efficient than conventional vegetable producers. This suggests that organic vegetable farmers are able to use their production inputs appropriately. On the other hand, the conventional farmers may be complacent that the use of chemical fertilisers would increase their productivity, hence neglects the implementation of good agronomic practices. The implication is that if organic vegetable farmers are provided with the needed technical support, organic vegetable production can increase in the region. Overall, the high technical efficiency of organic vegetable production justifies the need for technical support, considering the increasing demand for organic vegetables across the globe. This also supports the conclusion by Jouzi et al. (2017) conclusion that organic farming is suitable for environmental protection, has higher resilience to environmental changes, increases farmers' income and reduces external input cost, enhances social capacity, and increases employment opportunities.

Conclusions and policy recommendations

The demand for organic vegetables continues to increase as consumers cite some irregularities such as fast deterioration and low taste of vegetables produced using chemicals. This makes it important to understand the efficiency implications of organic vegetable production as a step to improve its production. This study evaluated the factors that influence the decision to produce organic vegetables and the technical efficiency of vegetable farmers, using a selectivity bias correction SFM approach. This involved 400 vegetable farmers in the Northern region of Ghana. The results indicate that the estimated elasticities for farm size and seed were positive while those of fertiliser and labour were negative for both conventional and organic vegetable farms. The computed returns to scale of vegetable production exhibited a decreasing trend. Similarly, the technical efficiency scores of the farmers were low, although slightly higher for organic vegetable producers. The effect of organic vegetable production on technical efficiency shows that organic vegetable production improves the technical efficiency of vegetable production. The results of this study also defeat the argument that there is low yield under organic vegetable production. Since organic vegetable farmers tend to be more productive than conventional farmers, the gap should be interpreted as an absolute advantage for organic vegetable farmers over the conventional farmers in the study area. Factors such as FBO membership and farmers' ability and resources to farm throughout the year led to increased technical efficiency while sex, age, off-farm work, access to external support and farmers' ability to produce their own inputs negatively influenced technical efficiency.

Other socioeconomic characteristics such as education, farmers' ability and access to resources to farm throughout the year, farmers' ability to produce their inputs, FBO membership, extension contacts, and external credit support had significant influence on the decision of farmers to go into organic vegetable production. Therefore, while measures to increase production efficiency of vegetable farmers should be promoted, these socioeconomic factors should also be considered to increase organic vegetable production. It is also concluded that MoFA should sensitise farmers on the importance of sustainable agricultural production practices such as organic farming technologies to enhance their practice. There is also the need for government (through MoFA) to network with agricultural research institutions across the country for capacity building and technology development in order to enhance extension service delivery. This would increase and consolidate gains from extension services in organic vegetable production and the overall technical efficiency of vegetable production. One major limitation of the research is that it failed to provide information on whether or not the organic or conventional vegetable farmers were into those types of vegetable production continuously over the years or there is a change only in the year of the data collection. Therefore, a future study must understand the organic vegetable production dynamics in the region.

Author contribution VFB designed the research protocol and led the data analysis, SAD led the design of the research methodology, and WA wrote the background. All authors reviewed the manuscript and accepted its current form.

Data availability Data would be made available upon request.

Declarations

Conflict of interest The authors declare no competing interests.

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