cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Determinants of fertilizer adoption among smallholder cocoa farmers in the Western Region of Ghana

Ernest Baba Ali[1], Joseph A. Awuni[1] and Gideon Danso-Abbeam[1*]

Received: 16 June 2018
Accepted: 17 October 2018
First Published: 23 October 2018

*Corresponding author: Gideon Danso-Abbeam, Department of Agricultural and Resource Economics, University for Development Studies, Tamale, Ghana
E-mail: dansoabbeam@uds.edu.gh

Reviewing editor:
Fatih Yildiz, Food Engineering and Biotechnology, Middle East Technical University, Turkey

Additional information is available at the end of the article

Abstract: The enhancement of agrarian productivity through the use of improved technologies such as fertilizer application is a critical avenue for increasing farm income, minimizing poverty, and tackling soil nutrient mining. This study has examined fertilizer adoption decisions using data collected from 226 smallholder cocoa farm households in the Western region of Ghana. The Heckman's two-stage model was employed to estimate the probability and the extent of fertilizer application in the Ghanaian cocoa farms. The result of the study indicated that the likelihood of fertilizer adoption was influenced by factors such as farmers' engagement in off-farm economic activities, extension contacts, farm size, hired and family labour, and the value of productive farm assets. On the other hand, factors including household size, marital status, number of years working as a cocoa farmer (experience), support received from Non-Governmental Organizations (NGOs), farm size, and family labour significantly influence the extent of fertilizer adoption. Therefore, improving extension services to farmers and encouraging the ownership of farm assets could be useful for fertilizer adoption.

ABOUT THE AUTHORS

Ernest Baba Ali, MPhil student at the University for Development Studies, Tamale, Ghana. This current study is a paper from his MPhil thesis.

Joseph A. Awuni (Phd), a senior lecturer at the University for Development Studies, Tamale, Ghana. This current study is developed from the thesis Joseph supervised.

Gideon Danso-Abbeam (Phd), a lecturer at the University for Development Studies, Tamale, Ghana. This current article is developed from the thesis Gideon co-supervised.

PUBLIC INTEREST STATEMENT

Cocoa farming undoubtedly is the main source of livelihood for thousands of Ghanaians and, also a major contributor to Ghana's GDP. The unstable nature of Ghana's cocoa production levels poses a threat to it's economic fortunes. As such, COCOBOD introduced the cocoa HI-TECH programme to encourage among others the use of fertilizer to boost yield. However, adoption levels as reported by many studies have been low. It is, therefore, imperative to identify factors explaining the adoption decisions of farmers. Empirical evidence from the study showed that fertilizer adoption was influenced by farmers' demographic characteristics (e.g., age, sex), productive farm assets (e.g., family labour, farm size, off-farm economic activities), and institutional/policy variables (e.g., extension contacts, FBOs). The study, therefore, recommends that farm-level programmes oriented towards increasing the use of fertilizer should consider improving extension services, as well as, helping farmers to build their asset through engagement in off-farm income activities.

Subjects: Agriculture & Environmental Sciences; Environment & Resources; Environment & Economics

Keywords: fertilizer; adoption; intensity; cocoa farmers; Ghana

1. Introduction

Cocoa has social, economic, and political significance in Ghana and other major producing countries (Aidoo & Fromm, 2015; Anang, 2016). To the Ghanaian smallholder farmer, cocoa production serves as a primary source of direct income and livelihood as it provides jobs for about 794,129 rural farm households (Ghana Statistical Service [GSS], 2014). It is also believed to be a source of social prestige for many rural farm households. Other activities of the cocoa sub-sector such as input delivery and the output market (e.g., licensed cocoa buying companies) also provide a source of livelihood for many people. In 2016, the Ghanaian cocoa industry contributed about 1.8% to Gross Domestic Product (GSS, 2018). Ghana has also made a trademark in the global cocoa economy as the world's second-largest producer generating about USD 2 billion in export revenues (World Trade Organization [WTO], 2014). The cocoa sector also plays a critical role in the development and establishment of several projects in education, health, and other infrastructural projects. For instance, the COCOBOD (the managing body of Ghana's cocoa industry) scholarship is awarded to brilliant but needy children from cocoa growing areas into Senior High Schools (Obuobisa-Darko, 2015). There is also the construction of *"cocoa"* roads and hospitals in cocoa growing areas to facilitate transportation and improving the healthcare of the rural smallholder farmers.

In spite of these massive contributions of Ghana's cocoa industry to the economy, there has been evidence of fluctuations in yield. For instance, in the 2010/2011 cocoa production year, the cocoa sector attained a record output level of 1,024,600 tonnes, which decreased by approximately 14% to about 879,000 tonnes in 2011/2012. In the 2012/2013 season, cocoa output declined further by 5% to about 835,000 tonnes (COCOBOD 2016). These fluctuations in cocoa output over the years have been attributed to several challenges such as inadequate extension services, inadequate access to finance, high incidence of pests and diseases, depletion of soil nutrients, among others.

Among these challenges, low soil fertility has been cited as a crucial contributor to the low productivity (Aneani, Anchirinah, Owusu-Ansah, & Asamoah, 2012; Danso-Abbeam & Baiyegunhi, 2017; Wessel & Quist-Wessel, 2015; World Cocoa Foundation [WCF] 2014). To reverse the increasing trend of soil nutrient mining and improve soil quality, fertilizer application must be taken seriously. Fertilizer application had long been proven to have a significant positive impact on cocoa productivity (Danso-Abbeam & Baiyegunhi, 2017). An on-farm experiment conducted in Ghana and Cote d'Ivoire by Ruff and Bini (2012), reported that yields of cocoa were 1890 kg/ha after two years of fertilizer application. However, without fertilizer application, yields were 765 kg/ha. Another study conducted in Cote d'Ivoire by Assiri et al. (2012) found that in the third year of fertilizer application, cocoa yield increased from 600 kg/ha to 1000 kg/ha.

In recognition of the potential benefit of fertilizer application to boost yield, there have been several interventions by the Ghanaian government and other stakeholders to increase the application of fertilizer and other agrochemicals. One of such significant intervention is the introduction of the Cocoa High Technology (Cocoa Hi-tech), which seeks to develop and disseminate cocoa production technologies to accelerate the growth of the industry (COCOBOD, 2012). A critical component of the project among many others was to enhance the intensive use of fertilizer. As a result, the Cocoa Research Institute of Ghana (CRIG) has recommended two main fertilizer formulations to be used by farmers. These include granular fertilizer—*Asaasewura, Cocofeed*, and *Nitrabor* and Foliar fertilizer—*Sildaco, Agricult*, and *Lifert A* (COCOBOD, 2016).

Nevertheless, the adoption of fertilizer over the years by cocoa farmers has been very low. For instance, Aneani et al. (2012) reported the adoption rate of fertilizer to be only 33%. Ruff and Bini (2012) also indicated that the intensity of fertilizer application is low even though about 70% of Ghanaian cocoa farmers purchase fertilizer. They estimated that fertilizer use was approximately 90,000 tonnes while the potential requirement was nearly 350,000 tonnes. These have contributed to the huge gap between the potential and the reported yield of cocoa in the country. Although there is a wide range of studies (Anang, 2016; Aneani et al., 2012; Nunoo, Frimpong, & Frimpong, 2014) that have been conducted to examine the determinants of productivity-enhancing technologies in Ghana, most of these studies focus on the discrete (binary) decision, while farmers' decision on the determinants of intensity of fertilizer application has not been adequately explored. Thus, there is a dearth of empirical evidence about the nature of the economic linkage between farmers' demographic, farm-specific, and policy variables and farmers' attitude towards the intensity of adoption of fertilizer. Moreover, documenting the factors that contribute to the discrete decisions of fertilizer application, as well as the extent of use, is a necessary first step in addressing the constraints of adoption of agricultural technologies as adoption varies in forms, time, and location. The study, therefore, seeks to understand whether a different set of factors influence farmers' discrete decision to adopt and the extent of adoption of fertilizer.

2. Methodology

2.1. Study area, sampling and data collection procedure

The study was conducted in the Western region of Ghana, which is a major cocoa-producing region commanding more than 50% of Ghana's cocoa output (COCOBOD, 2016). The Region has about 75% of its vegetation within the high forest zone of Ghana with temperature ranging from 22°C to 34°C. It is the wettest part of Ghana with an average precipitation of 1,600 mm per annum. The region also has a relatively high humidity, ranging from 70% to 90% annually. The major part of the region has its soil type to be *forest ochrosol* which are suitable for wide range of crops particularly, tree crops such as cocoa, coffee, citrus, and food crops like plantain, cocoyam, yam, maize, among others (Asiamah et al., 2000). However, cocoa is a dominant cash crop and contributes a significant proportion to household incomes.

Data for the study was collected through a cross-sectional survey using a well-structured questionnaire. The unit of analysis was a cocoa-producing farm household. The study followed a multi-stage random sampling technique to select 226 smallholder cocoa farm households for the study. The regional and the district offices of Ghana COCOBOD assisted in the selection of districts and communities, respectively. In the first stage, the simple random sampling technique was used to select six (6) districts from the list of cocoa-producing districts in the region. From the list of cocoa-producing communities obtained from the district office of COCOBOD, three communities were chosen from each selected district. In the third stage, a stratified sampling technique was used to identified adopters and non-adopters of fertilizer. In the final phase, 10–15 farm households were selected from each community.

2.2. Analytical framework

The study examines the drivers of the probability and the extent of fertilizer use among smallholder cocoa farmers in the Western region of Ghana. The adoption rate was computed as a ratio of the number of sampled farm households who used fertilizer to the total sample size. However, the fertilizer users may have different intensities (extent of application) measured as the quantity of fertilizer applied per hectare. One of the main characteristics of farm technology that explains the rates and intensities of adoption is the degree to which farmers perceive the improved technology as a better alternative to the existing one (Toborn, 2011). Following previous researchers such as Khonje, Manda, Alene, and Kassie (2015) and Becerril and Abdulai (2010), the observed outcome of fertilizer adoption can be modelled under the framework of a random utility function. Consider the i^{th} cocoa farm household facing a decision on whether or not to adopt cocoa fertilizer. Let $P^{\bullet}$ denote the difference between the benefit the farm household derives from adopting the fertilizer (U_{iA}) and the benefit from non-adoption of fertilizer (U_{iO}). Considering the axiom of rationality and profit maximization, the farm household will adopt the fertilizer if $P^{\bullet} = U_{iA} - U_{io} > 0$

The net benefit $P^{\bullet}$ is unobservable and can be expressed as a function of observed characteristics (Z_i) and error term (ε_i) as follows:

$$P_i^* = Z_i\beta + \varepsilon_i;\ P_i = 1 \text{ if } P_i^* > 0 \text{ and } P_i^* = 0, \text{ otherwise}$$

Where P is a dummy variable representing fertilizer adoption decision; $P = 1$, if fertilizer is adopted and $P = 0$, if otherwise. Z_i is a vector denoting household, farm-specific, and other institutional or policy variables, β is a vector of parameters to be estimated, and ε_i is an error term. It is expected that not all cocoa farm households will apply fertilizer on their farms. In such a situation, the fundamental econometric problem that is most likely to arise is the sample selection bias. This is very necessary in the adoption variable but it is not observed for the sample as a whole. By excluding individuals who are non-adopters means the dependent variable is censored and the residuals may not satisfy the condition that the sum of residuals must be equal to zero (Maddala, 1977, 1983). In this study, the problem of sample selection bias was resolved by the use of Heckman two-step estimation procedure (Heckman, 1979). Thus, adoption of fertilizer involves a two-stage process: the first stage has to do with the probability of adoption using the Probit maximum likelihood function. The second stage takes into consideration the extent (intensity) to which a farmer adopts the fertilizer and this is done by means of Ordinary Least Square (OLS) estimator. Because the later decision largely depends on that taken in the former, it is likely that the procedure in the second stage is not random thereby creating selectivity bias. This is because only those who are positively affected by the determinants of adoption will adopt the technology. Hence, the use of the Heckman's two-stage model to correct for the sample selection bias (Heckman, 1979). The first step of the Heckman's model (selection equation) is given by:

$$A_i^* = \beta_0 + \beta_1 X_i + \varepsilon_i \tag{1}$$

Where A^* is an unobserved latent variable representing household adoption decision, X_i is a vector of explanatory variables, β is a vector of parameters to be estimated, and ε_i is an error term distributed with mean 0 and variance 1. The observed binary variable can be expressed as:

$$A = 1 \text{ } if \text{ } A_i^* > 0 \text{ (For adopters)} \tag{2}$$

$$A = 0 \text{ } if \text{ } A_i^* \leq 0 \text{ (For non} - \text{adopters)} \tag{3}$$

The substantive equation (the second step) which is usually estimated by an Ordinary Least Square (OLS) estimator is given as:

$$Y_i = \alpha_0 + \alpha_1 Z_i + \mu_i \tag{4}$$

It should be noted that Equation (4) is a sub-sample of Equation (1) and is only estimated for fertilizer adopters. To correct for self-selection biases in the substantive equation (Equation (4)), we add an Inverse Mills Ratio (IMR) denoted by the symbol λ as an additional explanatory variable. The computed IMR provides OLS selection corrected estimates (Greene, 2003). The IMR is estimated as the ratio of the ordinate of a standard normal to the tail area of the distribution (Greene, 2003). Refusing to add the IMR will render the results from the Equation (4) bias (Heckman, 1979). Adding IMR translates Equation (4) into Equation (5) as:

$$Y_i = \alpha_0 + \alpha_i X_i + \delta_i \lambda_i + \mu_i \tag{5}$$

Where δ_i is the coefficient of the IMR (λ_i). If lambda (λ) is statistically significant, sample selection bias is a problem and, therefore, Heckman's two-stage model is appropriate for the estimation (Marchenko & Genton, 2012). The formulation process of IMR is given by:

$$\lambda_i = \frac{\varphi(X_i\alpha)}{\Phi(X_i\alpha)} \quad (6)$$

Where φ and Φ are normal probability density function and cumulative density function, respectively of the standard normal distribution, and $\Phi \equiv (\omega_i \chi)$. μ_i is a two-sided error term with $N(0, \sigma_v^2)$. The rest are as defined earlier. Equation (6) is obtained by an extrapolation process of Equation (1) with the substantive equation defined by Equation (4) and then integrate it into the equation defined by Equation (5).

3. Results and discussion

3.1. Descriptive statistics of socioeconomic variables

Descriptive statistics for all the independent variables are summarized in Table 1. Of the 226 respondents interviewed, about 149 farm households representing 66% applied fertilizer to their cocoa farms. This is similar to the 68% rate reported by Danso-Abbeam and Baiyegunhi (2017). However, it is lower than figures reported by Nunoo et al. (2014).

Many studies (Akudugu, Guo, & Dadzie, 2012; Asfaw, Kassie, Simtowe, & Leslie, 2012; Nmadu, Sallawu, & Omojeso, 2015) have used farmer-specific characteristics such as age, sex, household size, marital status, among others to explain adoption decisions of agricultural technologies. The

Table 1. Descriptive statistics of socioeconomic variables

	Adopters		Non-adopters		
Variable definition	***Mean***	***SD***	***Mean***	***SD***	***t-test***
Household Characteristics					
Sex of the Household head (male = 1, 0 otherwise)	0.73		0.71		0.72
Age of the household head (years)	46.51	13.06	46.39	15.15	0.06
Marital status (married = 1, 0 otherwise)	0.81		0.80		0.85
Number of years in cocoa farming (years)	18.57	9.54	20.12	9.88	1.13
Household asset					
Active family labour (count)	6.22	3.06	6.43	3.13	0.49
Farm size (hectares)	6.95	4.99	8.28	6.06	1.77
Value of farm asset (GH¢)	547.37	606.40	482.51	749.40	−0.70
Off-farm income (GH¢)	503.87	530.45	4.29E+02	2.58E+02	1.29
Farm-specific characteristics					
Age of the cocoa farm (years)	15.61	8.39	16.51	7.71	0.78
Institutional factors					
Contact with extension services (yes = 1, 0 otherwise)	0.67		0.5		0.01
Received other agricultural related training (yes = 1, 0 otherwise)	0.29		0.24	0.42	0.37
Membership of FBO (yes = 1, 0 otherwise)	0.25		0.13		4.06
Received incentives from NGOs (yes = 1, 0 otherwise)	0.22		0.21		0.03
Other factors					
Distance to farm plot (kilometres)	1.02	2.01	2.01	5.87	1.87

Source: Field survey (December, 2016).

present study draws its model specification from these studies. Considering the difficult nature of cocoa production coupled with the fact that Ghanaian women are resource-constrained regarding access to land and other assets, Matata, Ajay, Oduol, and Agumya (2010) reported that sex is a significant factor explaining the adoption decision of many agricultural technologies. The study, therefore, hypothesized that male farmers would have a higher probability of adopting fertilizer than their female counterparts. Age of household head has been used extensively in many adoption studies, but its effect in many instances has been indeterminate. For instance, Simtowe, Asfaw, and Abate (2016) reported that older farmers were more likely to adopt innovation because of the wealth of experience accumulated over years of farming. However, Tiamiyu, Akintola, and Rahji (2009) asserted that older farmers were more conservative and this negatively impacts on adoption while young farmers tend to be more innovative. The study, therefore, hypothesized age of farmer to be indeterminate. As indicated in Table 1, adopters are marginally older than non-adopters. Marital status is one of the variables postulated to influence fertilizer adoption decisions of farm households positively. This variable is measured as a dummy. Thus, 1 if a cocoa farmer is married and 0 if otherwise. It is expected that cocoa farmers who are married should be better placed to have relatively larger family sizes and hence be labour sufficient than their unmarried counterparts. The mean cocoa farming experience of fertilizer adopters are lower (18.56 years) than that of the non-adopters (20.12 years). However, the study expects a positive correlation between fertilizer adoption and cocoa farming experience.

Farm household assets such as family labour, farm size, the value of productive farm assets, and off-farm income are all postulated to have a direct relationship with adoption as documented by previous studies (e.g., Diiro, 2013; Helder, Edward, & Ralph, 2005). On the average, the number of persons who are actively involved in cocoa farming operations is approximately six per household for both adopters and non-adopters. Regarding the farmland allocated to cocoa production, the mean farm size of the adopters is significantly lower than the non-adopters. However, the value of productive farm assets of adopters is higher than that of the non-adopters. Moreover, the amount of Ghana Cedis (GH¢) generated from adopters' engagement in off-farm income (alternative off-farm sources of employment such as salaried employment) is higher than that of the non-adopters.

Similar to other studies such as Djokoto, Owusu, and Awunyo-Vitor (2016) and Kassie, Jaleta, Shiferaw, Mmbando, and Mekuria (2013), institutional factors such as contact with extension services, agricultural-related training (e.g., farm financial management, farm as a business, etc.), FBO membership and incentives from NGOs (e.g., input or cash credit, free cocoa seeds, etc.) are critical in explaining adoption and adoption intensities. Table 1 shows that about 67% of fertilizer adopters received extension services while about half (50%) of the non-adopters had received extension services. Also, 29% of the adopters had received other agricultural-related training while 24% of the non-adopters did benefit from the training. Though only few farmers (25% of adopters and 13% of non-adopters) belonged to a farmer-based organization, there is a large disparity between the two sample groups as indicated in Table 1. However, there is no much difference between the two sample groups regarding the variable of whether or not respondents received incentives from NGOs. About 22% and 21% of the adopters and non-adopters benefited from NGOs, respectively. Distance to farm plots is hypothesized to have a negative effect on adoption of fertilizer. This is because farmers whose farms are far away from their communities usually face financial difficulties transporting the inputs to the farms, hence, likely to negatively influence agricultural technology adoption. The mean distance from farmers' homes to their farms for adopters is significantly different from the non-adopters. Adopters recorded about 1 km while non-adopters recorded about 2 km.

3.2. Determinants of adoption and intensity of adoption of fertilizer

Empirical results obtained from the Heckman two-stage model is presented in Table 2. *The Wald chi-square* is highly significant at 1% (*Prob >Chi^2 = 0.0000*) indicating that the explanatory variables jointly contribute in explaining the variations in cocoa farmers' decision to adopt fertilizer. Lambda

Table 2. Results from the Heckman two-stage model

	Heckman: Stage one		Heckman: Stage two	
Variable	**Coeff.**	**SE**	**Coeff.**	**SE**
Household Characteristics				
Sex of the household head	−0.3220	0.2339	−0.0011	0.0007
Age of the household head	0.0045	0.0102	−0.0018	0.0014
Marital status			0.0021	0.0008***
Number of years in cocoa farming	0.0014	0.0189	0.0002	3.80E-05***
Household asset				
Active family labour	0.0014	0.0008***	−0.0023	0.0006***
Farm size	−0.0718	0.0228***	−0.0005	8.60E-05***
Value of farm asset	0.2214	0.0812***	0.0004	0.0003
Off-farm income	0.0004	0.0002**	1.90E-07	1.50E-07
Farm-specific characteristics				
Age of the cocoa farm	−0.0222	0.0169		
Institutional factors				
Contact with extension services	0.4441	0.2215**	−0.0001	0.0007
Received other agric. Related training	−0.3546	0.2789		
Membership of FBO	0.4107	0.2982	0.5405	0.2240**
Received incentives from NGOs			0.0019	0.0006***
Other factors				
Distance to farm plot	−0.031	0.0262	0.0178	0.0056
Constant				
Wald chi^2 (12)	161.88			
Prob>chi^2	0.000			
Lambda	−0.0365	0.0017		
Number of observations	226			

***, **, * respectively indicate significance level at 1%, 5%, and 10%.
Source: Field survey (December, 2016).

(λ) is significant at 5% suggesting that the intensity of fertilizer adoption depends on the discrete decision to adopt. From the study, the set of factors that affect households' discrete decision to adopt fertilizer may differ from the factors influencing the intensity of adoption. In some cases, same factors may have different effects on the probability and the intensity of adoption.

Among the set of household characteristic variables, marital status exhibited a significant positive effect on the intensity of fertilizer adoption. Thus, an intensity of fertilizer used is increased by households with spouses than those with no spouses. A plausible explanation for such a result is that farming in Ghana depends largely on human capital (labour) which is very expensive to employ. As such, farmers with spouses are more likely to have larger family sizes which may translate into more access to family labour. When this happens, these households can reduce labour cost and hence spend more on fertilizer application. Farming experience plays a vital role in the adoption of agricultural technology practices. Previous adoption studies have documented the effect of experience (measured as the number of years in cocoa farming) on the adoption of farm technologies (Hattam & Holloway, 2005). Farmers with longer years in farming had acquired more knowledge about the success and failure of a particular technology, hence, may either stick to their old practices or try new techniques. The positive and statistically significant coefficient of experience variable suggests that longer experience in cocoa farming leads to higher intensity of fertilizer adoption. Contrary to the results of this study, Djokoto et al. (2016) reported a negative correlation between farming experience and agricultural technology adoption. They argued that farmers with longer experience tend to learn multiple ways of overcoming challenges, hence, they tend to stick to old technologies rather than move to other technologies which they have little or no idea about. However, the experience of repeated failures in the past may also motivate farmers to try modern improved technologies.

The coefficient of active family labour is significant and positive indicating that cocoa farmers who rely more on family labour for their farming activities are more likely to adopt and intensify the use of fertilizer. Previous studies such as Beshir (2014) and Danso-Abbeam and Baiyegunhi (2017) have reported similar findings. In the Ghanaian rural economy, ownership of farmland is considered as a great asset. The results indicate that farmers with large cocoa farms have a higher probability of adoption and intensification of fertilizer application. Similar results have been reported elsewhere (Danso-Abbeam, Edinam, & Ansah, 2014). Similarly, the value of productive farm asset had a significant and direct influence on the probability of fertilizer adoption but did not affect the intensity of adoption. Extant literature such as Nasir (2014), Danso-Abbeam and Baiyegunhi (2017) have documented the positive effects of off-farm employment on agricultural technology adoption. These studies argue that engagement in off-farm economic activities helped farmers to overcome financial constraints regarding the purchase of inputs.

Consistent with other agricultural adoption studies (Diiro & Sam, 2015; Mmbando & Baiyegunhi, 2016; Sisay, Jema, Degye, & Abdi-Khalil, 2015), institutional factors positively and significantly explain adoption decisions of cocoa farmers. Estimates from the first stage of the Heckman model (Table 2) indicates that farmers who had contact with cocoa extension agents are more likely to adopt fertilizer than their counterparts who did not. Similarly, membership of farmer-based organizations (FBOs) increases the intensity of fertilizer application. A study by Simtowe et al. (2016) concluded that social capital and network variables such as FBO membership are significant in explaining farmers' adoption decisions. This is because membership of farmers' group increases access to information on productivity-enhancing technologies, and serve as a driving force for positive adoption decisions. The results of the present study further indicate that farmers who had some incentives from cocoa-related NGOs had greater adoption intensities than those who did not. This could partly be attributed to the fact that farmers associated with these NGOs gain access to credit, vital information on production technologies, and market information which may significantly influence their decision on the quantities of fertilizer to apply per unit area.

4. Conclusions and recommendations

The use of fertilizer in Ghana's cocoa industry is very important for increasing output. Consequently, the Cocoa High Technology (Cocoa Hi-tech) programme was established to promote the use of cocoa technologies such as fertilizer. The present study, therefore, sought to identify the determinants of adoption and the extent of adoption of fertilizer among cocoa farm households in the Western region of Ghana. Using Heckman's two-step estimation procedure, it was found that the quantity of fertilizer applied per area is conditioned on the discrete decision to adopt fertilizer. The results further indicated that household characteristics such as marital status and experience in cocoa farming do not significantly affect the discrete decision to adopt fertilizer. However, it significantly influenced the extent of adoption. Value of productive farm assets and off-farm income affect fertilizer adoption positively. Thus, it is recommended that farmers should be supported through training programmes on off-farm income generating activities which could help build their asset base. Farmers' contact with extension agents and membership of FBOs influenced farmers' decision to adopt fertilizer. Thus, the government of Ghana and other stakeholders should make effort to improve the farmer-extension agents' contact by improving the farmer-extension agent ratio as well as the provision of logistics.

Funding
The authors received no direct funding for this research.

Competing interests
The authors declare no competing interests.

Author details
Ernest Baba Ali[1]
E-mail: ernestali2014@gmail.com
Joseph A. Awuni[1]
E-mail: aawuni@uds.edu.gh

Gideon Danso-Abbeam[1]
E-mail: dansoabbeam@uds.edu.gh
ORCID ID: http://orcid.org/0000-0002-7971-4676
[1] Department of Agricultural and Resource Economics, University for Development Studies, Tamale, Ghana.

Citation information
Cite this article as: Determinants of fertilizer adoption among smallholder cocoa farmers in the Western Region of Ghana, Ernest Baba Ali, Joseph A. Awuni & Gideon Danso-Abbeam, *Cogent Food & Agriculture* (2018), 4: 1538589.

References

Aidoo, R., & Fromm, I. (2015). Willingness to adopt certifications and sustainable production methods among small-scale cocoa farmers in the Ashanti Region of Ghana. *Journal of Sustainable Development*, *8*(1), 33–43. doi:10.5539/jsd.v8n1p33

Akudugu, M. A., Guo, E., & Dadzie, S. K. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions. *Journal of Biology, Agriculture and Healthcare*, *2*(3), 1–13.

Anang, B. T. (2016). A probit analysis of the determinants of fertilizer adoption by cocoa farmers in Ghana. *Asian Journal of Agricultural Extension, Economics and Sociology*, *8*(1), 1–8.

Aneani, F., Anchirinah, V. M., Owusu-Ansah, F., & Asamoah, M. (2012). Adoption of some cocoa production technologies by cocoa farmers in Ghana. *Sustainable Agriculture Research*, *1*(1), 103–117. doi:10.5539/sar.v1n1p103

Asfaw, S., Kassie, M., Simtowe, F., & Leslie, L. (2012). Poverty reduction effects of agricultural technology adoption: A micro-evidence from rural Tanzania. *Journal of Development Studies*, *48*(9), 1288–1305. doi:10.1080/00220388.2012.671475

Asiamah, R. D., Adjei-Gyapong, T., Yeboah, E., Fening, J. O., Ampontuah, E. O., & Gaisie, E. (2000). *Soil characterization and evaluation of four primary cassava multiplication sites (Mampong, Wenchi, Asuansi and Kpeve) in Ghana*.Soil Research Institute (SRI), Kumasi

Assiri, A. A., Kacou, E. A., Assi, F. A., Ekra, K. S., Dji, K. F., Couloud, J. Y., & Yapo, A. R. (2012). Rentablite economique des techniques de rehabilitation et replantation desvieux vergers de cacaoyers (*Theobroma cacao L.*) en Cote d'Ivoire. *Journal of Animal & Plant Science*, *14*, 939–951.

Becerril, J., & Abdulai, A. (2010). The impact of improved maize varieties on poverty in Mexico: A propensity score-matching approach. *World Development*, *38*(7), 1024–1035. doi:10.1016/j.worlddev.2009.11.017

Beshir, H. (2014). Factors affecting the adoption and intensity of use of improved forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*, 4(1), 12–27. doi:10.9734/AJEA

COCOBOD (Ghana Cocoa Board). (2012). The mass cocoa spraying exercise –Ministry of Food and Agriculture. Retrieved December 12, 2016, from http://mofa.gov.gh/site/?p=11249

COCOBOD (Ghana Cocoa Board). (2016). Retrieved from https://cocobod.gh/weakly_purchase.php

Danso-Abbeam, G., & Baiyegunhi, L. J. S. (2017). Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. *African Journal of Science, Technology, Innovation and Development*, *9*(6), 717–728. doi:10.1080/20421338.2017.1380358

Danso-Abbeam, G., Edinam, D. S., & Ansah, I. G. K. (2014). Modelling farmers investment in agrochemicals: The experience of smallholder cocoa farmers in Ghana. *Research in Applied Economics*, *6*(4), 12–27. doi:10.5296/rae.v6i4.5977

Diiro, G. (2013). Impact of off-farm income on agricultural technology adoption intensity and productivity: Evidence from rural maize farmers in Uganda.

Diiro, G. M., & Sam, A. G. (2015). Agricultural technology adoption and nonfarm earnings in Uganda: Asemiparametric analysis. *Journal of Developing Areas*, *49*(2), 145–162. doi:10.1353/jda.2015.0013

Djokoto, J. G., Owusu, V., & Awunyo-Vitor, D. (2016). Adoption of organic agriculture: Evidence from cocoa farming in Ghana. *Cogent Food & Agriculture*, *2* (1242181), 1–15. doi:10.1080/23311932.2016.1242181

Ghana Statistical Service (2014). *Ghana living standard survey*(Report of the sixth round). Accra, Ghana: Author.

Ghana Statistical Service. (2018). *Provisional 2017 annual gross domestic product, April 2018 edition*. Accra, Ghana: Author.

Greene, W. H. (2003). *Econometric analysis*. Prentice Hall

Hattam, C. E., & Holloway, G. J. (2005, September 21–23). Adoption of certified organic production: Evidence from Mexico. In *Paper at: researching sustainable systems - international scientific conference on organic agriculture*. Adelaide, Australia. [Unpublished].

Heckman, J. J. (1979). The common structure of statistical models of truncated, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement*, *5*(4), 475–495.

Helder, Z., Edward, M., & Ralph, C. (2005). *Adoption of improved seed by smallholder farmers in Mozambique*. Cornell: Department of Applied Economics and Management, Cornell University.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, *80*(3), 525–540. doi:10.1016/j.techfore.2012.08.007

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of adoption and impact of improved maize variety in Eastern Zambia. *World Development*, *66*, 695–706. doi:10.1016/j.worlddev.2014.09.008

Maddala, G. S. (1977). *Econometrics, economic handbook series*. New York: McGraw-Hill.

Maddala, G. S. (1983). *Limited dependent and qualitative variables in econometrics*. Cambridge University Press

Marchenko, Y. V., & Genton, M. G. (2012). A Heckman selection model. *Journal of the American Statistical Association*, *107*(497), 304–317. doi:10.1080/01621459.2012.656011

Matata, P. Z., Ajay, O. C., Oduol, P. A., & Agumya, A. (2010). Socio-economic factors influencing adoption of improved fallow practices among smallholder farmers in western Tanzania. *African Journal of Agricultural Research*, *5*(9), 818–823.

Mmbando, F. E., & Baiyegunhi, L. J. S. (2016). Socio-economic and institutional factors influencing adoption of improved maize varieties in Hai District, Tanzania. *Journal of Human Ecology*, *53*(1), 49–56. doi:10.1080/09709274.2016.11906955

Nasir, M. (2014). Determinants of off farm employment: Case of Abeshge Woreda, Guraga Zone, SNNPRS, Ethiopia. *Developing Country Studies*, 4(7), 39–51.

Nmadu, J. N., Sallawu, H., & Omojeso, B. V. (2015). Socio-economic factors affecting adoption of innovations by cocoa farmers in Ondo State, Nigeria. *European Journal of Business, Economics and Accountancy*, *3*(2), 58–66.

Nunoo, I., Frimpong, B. N., & Frimpong, F. K. (2014). Fertilizer use among cocoa farmers in Ghana: The case of Sefwi Wiawso District. *International Journal of Environment*, *1*(3), 22–31.
Obuobisa-Darko, E. (2015). Socio-economic determinants of intensity of adoption of cocoa research innovations in Ghana. *International Journal of African and Asian Studies*, *12*, 29–40.
Ruff, F., & Bini, S. (2012). Cocoa and fertilzers in West Africa. In *CIRAD, UMR Inovation*.
Simtowe, F., Asfaw, S., & Abate, T. (2016). Determinants of agricultural technology adoption under partial population awareness: The case of pigeonpea in Malawi. *Agricultural and Food Economics*, 4(7). doi:10.1186/s40100-016-0051-z
Sisay, D., Jema, H., Degye, G., & Abdi-Khalil, E. (2015). Speed of improved maize seed adoption by smallholder farmers in Southwestern Ethiopia: Analysis using the count data models. *Journal of Agricultural Economics, Extension and Rural Development*, *3*(5), 276–282.
Tiamiyu, S. A., Akintola, J. O., & Rahji, M. (2009). Technology adoption and productivity difference among growers of new rice for Africa in savanna zone of Nigeria. *Tropicultura*, *27*(4), 193–197.
Toborn, J. (2011). *Adoption of agricultural innovations, converging narratives and the role of Swedish Agricultural Research for Development*
Wessel, M., & Quist-Wessel, P. M. F. (2015). Cocoa production in West Africa, a review and analysis of recent developments. *Wageningen Journal of Life Sciences*, *74–75*, 1–7. doi:10.1016/j.njas.2015.09.001
World Cocoa Foundation (WCF). 2014. World cocoa foundation market update report. Retrieved from www.worldcocoafoundation.org/wp-content/uploads/Cocoa-Market-Updatepdf
World Trade Organization (WTO). 2014. Trade policy review body, Ghana [Policy document number: WT/TPR/S/298]. Retrieved from http://www.wto.org/english/tratop_e/tpr_e/s298_e.pdf