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RESEARCH PAPER

Determinants of adoption decision towards GM crops among smallholder farmers in Northern Ghana

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Abstract

This paper presents findings of a study which assessed smallholder farmers in the northern Ghana adoption decision towards GM crops. Through multi – stage sampling techniques 360 smallholder farmers across 10 districts in northern Ghana were surveyed. Descriptive statistics and probit regression were applied in analysing the data. Demographic characteristics such as age, household size and marital status and farm characteristics such as farm seize, experience in crop farming, extension contact, source of information on GM crops and use of certified seeds were identified as significant determinants of farmers' adoption decision towards GM crops. It is recommended that Ministry of Food and Agriculture (MoFA) and National Biosafety Authority (NBA) embark on farmer education aimed at providing information on GM crops to farmers to help them take informed decision.

Keywords: adoption decision, GM crops, agrobiotechnology and Ghana biotechnology agenda

Introduction

Global production of GM crops continue to soar considerably registering nearly 1000% increased from a little under 2 million hectares in 1996 (when it was first commercially released) to about 200 million hectares in 2018 (Brookes & Barfoot, 2019;ISAAA, 2018). In its 23 years period of commercialization (1996 to 2019) global adoption of GM crops have seen a double digit annual growth rates in most of the years, bring economic and environmental benefits to both small and large scale farmers across developed and developing countries (Brookes & Barfoot, 2019).

However, Africa countries are almost missing out in the success stories of GM crops. The continent contributed less than 5% of the 2018 global production of GM crops (ISAAA, 2018). Notwithstanding, experimentation with GM crop technology is widespread in Africa. But the number of countries with significant levels of commercial production is limited (ISAAA, 2016). The leading GM crops producing nations in Africa in 2018 were South Africa, Sudan and Kingdom of eSwatini (formerly Swaziland) (Brookes &

Barfoot, 2019; ISAAA, 2019). The new entrant is Kingdom of eSwatini which planted Bt cotton for the first time in 2018 and thereby bring the number of African countries planting GM crops to three again after the temporal exit of Burkina Faso (ISAAA, 2019).

South Africa is leading the continent in GM crops cultivation growing a total of 2.7 million hectares of GM maize, soybeans and cotton in 2018 (ISAAA, 2019). Both in 2017 and 2018 South Africa placed 9th in the global scale of GM crops cultivation trailing behind USA, Brazil, Argentina, Canada, India, Paraguay, Pakistan and China (ISAAA, 2018 & ISAAA, 2019).

Notwithstanding the delayed adoption of GM crops in Africa which is largely influenced by European policy and the Cartagena Protocol on Biosafety (Biden, Smyth & Hudson 2018), some progress had been made by way of approval and released of biotech crops for cultivation in some Africa countries. For instance, Bt cotton, soybean and canola have been approved and released for commercial production in Egypt, Sudan and Kenya. Also, confined, contained research and of adaptation trials are being conducted in many African countries whilst appropriate institutional, legal and regulatory regimes are being put in place in many other countries in the African continent to ensure safety application of GMOs (ISAAA, 2019; Tarjem, 2017).

Ghana has made steady progress towards application of GMOs technology in commercial agriculture within the last two decades since the country's ratified Cartagena Protocol on Biosafety. The necessary legal and regulatory frameworks have been laid to ensure safety application of GMOs technology in Ghanaian agriculture (Braimah, Atuoye, Vercillo, Warring & Luginaah, 2017; Agorsor, Yafetto, Otwe & Galyuon 2016; Ashitey, 2013; Bennett et al, 2013). Ghana's biosafety act (Act 831) passed in 2011, had layout the necessary institutional and regulatory frameworks required for the smooth commercialization of GM crops. National Biosafety Authority had been established to regulate and oversee safety commercial application GMOs and of GM crops in particular in line with the National Biosafety Act and international standards.

Field trials and contained release pending commercialization of Bt cotton, soybean and cowpea is currently being conducted by Ghana's Savannah Agricultural Research Institute [SARI] (Agorsor *et al*., 2016; Braimah *et al*., 2017). However, the success of Ghana's commercialisation of biotechnology in agriculture depends largely on farmers' adoption decision regarding the cultivation of GM crops. Available studies which examined Ghanaian farmers' views on GMOs often failed to assess their adoption decisions towards GM crops. A study by Ademola, *et al.* (2014) on potential benefits of biotechnology on food security in West Africa, identified challenges such as lack of awareness, inadequate training, low level of education and poor extension services among others as the main challenges facing the introduction of GM technology to resource poor farmers in Ghana and Nigeria. The study call on governments to put in place policy measures to address these challenges. Their study highlighted important policy issues regarding farmers' perceptions about GM crops in Ghana and Nigeria but they did not thoroughly examined farmers' adoption decision.

This paper therefore presents findings of a study which examined smallholder farmers in the Northern Ghana adoption decision towards GM crops cultivation as Ghana prepares to introduce GMOs in commercial agriculture.

Theoretical background

The paper relied on relevant theories underpinning individual adoption decision and behaviour as a framework in identifying factors influencing farmers' decision regarding the adoption of GM crops. Various theories and models of technology adoption have been propounded and applied to explain adoption behaviour. The theories included but not restricted to the Theory of Reasonable Action (TRA), Theory of Planned Behaviour (TPB), Decomposed Theory of Planned Behaviour, Roger innovation diffusion theory, Random Utility Theory (RUT), the Technology Acceptance Model (TAM) and Unified Technology Acceptance Model (UTAM2) (Lai, 2017). The TPB and RUT were found relevant in modelling smallholder farmers' adoption decision towards GM crops.

Theory of Planned Behaviour

The overall aim of the TPB is to predict deliberative and planned decision undertaken under rational basis and within the context of societal and individual limitations and constraints. The theory posits that behavioural decision is a function of an individual's attitude toward the said behaviour which reflects individual perceptions about the probable outcome of the said behaviour. It further relates individual decision or intention to act on how they view societal perceptions about the said decision. This is referred to as subjective norm, because individual intention is subject to societal approval or otherwise (Ajzen 2005; Fishbein, & Ajzen, 2010). As such individual decision or intention to undertake an action is strongly influence by their social environment such as family, friends/colleagues and the larger community. Finally perceived behavioural control which reflects individual perceptions or beliefs regarding absence or presence of factors that might facilitate or impede the performance of such intention is noted in the TPB as a critical variable in predicting individual intended behaviour (Ajzen, 2005; 2006).

Random Utility Theory

McFadden (1974) RUT follows the utility-maximization condition which assumes that rational farmers will select a technology only if the said technology provides him/her the highest utility subject to certain constraints. Based on this theory, the research attempts to deduce farmers' decision to adopt GM crops cultivation as a choice model in which the farmer aimed at maximizing benefit subject to certain constraints.

RUT is based on the hypothesis that every individual is a rational decision-maker, maximizing utility relative to his or her choice. Specifically, the theory is based on the following assumptions.

a. The generic decision-maker i, in making a choice, consider m_i mutually exclusive alternative that constitutes her choice as I^i. The choice set may differ according to the decision-maker.
b. Decision-maker i assigns to each alternative j in his choice a set of perceived utility or 'attractiveness' U_j^i and selects the alternative that maximizes this utility;
c. The utility assigned to each choice alternative depends on a number of measurable characteristics or attributes, of the alternative itself and of the decision-maker ; $U_j^i = U^i(X_j^i)$, where X_j^i is the vector of attributes relative to alternative j and to the decision-maker i;
d. Because of various factors, the utility assigned by decision-maker i to alternative j is not known with certainty by the external observer (analyst) wishing to model the decision-maker's choice behaviour, thus U_j^i must be represented in general by a random variable.

From the above assumptions, it is not usually possible to predict with certainty the alternative that the generic decision-maker will select. However, it is possible to express the probability that the decision-maker will select alternative j conditional on her choice set I^i; with the probability that the perceived utility of alternative j is greater than that of all the other available alternatives as shown in the equation 1 (Cascetta, 2009).

$$P^i(j/I^i) = \Pr[U_j^i > U_k^i \ \forall k \neq j, k \in I^i] \ldots\ldots\ldots\ldots (1)$$

In general, the utility a farmer derive from a technology can be represented as having two components; a utility function of observed characteristics known as the deterministic component of utility and the unobserved component known as the random component. The deterministic component is exogenous and includes farmers' characteristics and product characteristics and a set of linearly related parameters and the random component may result from missing data/variables (omitted variable), measurement errors and misspecification of the utility function.

This function is specified below:

$$Uj = X\beta + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where,

$$X\beta = v$$

where U_{ij} is the maximum utility attainable when alternative j is chosen by decision-maker i; $X\beta$ is the deterministic component of the utility function, X is a vector of observable socio-demographic and economic characteristics, product-specific factors that influence utility, β is the unknown parameter vector to be estimated and ε is the stochastic term.

Wittink (2011) observed that in probabilistic choice theory, it is argued that human behaviour cannot be approximated by deterministic parameters. It seems plausible to state that human behaviour has a probabilistic nature. Furthermore, it can be argued that whilst the decision-maker has knowledge of his or her utility function, the researcher or analyst does not know the exact form. As such probit regression model, as a probability model was applied in assessing factors influencing smallholder farmers' adoption decision towards GM crops.

Methodology

Descriptive survey design was employed in carrying out this study with mixed (both quantitative and qualitative) methodological approaches used in guiding data collection and analysis. The target population of the study was smallholder crop farmers belonging to Famer Based Organizations (FBOs) across the 50 districts in northern Ghana. With the application of Cochran (1977) sample size determination formula 360 smallholder crop farmers belonging to FBOs were sampled. From this sample both qualitative and quantitative data were collected through the use of questionnaires, personal and key informant interviews and focus group discussion.

Farmers' adoption decision towards the cultivation of GM crops or otherwise, when the country eventually allows commercial production of GM crops, was modelled guided by Ajzen (2005) Theory of Planned Behaviour (TPB) and Random Utility Theory (RUT). Respondents were asked a direct question, 'do you intend to adopt the cultivation of GM crops when the technology is finally commercialised in Ghana? As such their responses were binary as 'Yes' or 'No'.

Probit Regression Analysis

In identifying determinants of farmers' adoption decision, probit regression analysis was used. Probit regression analysis being probability cumulative normal distribution function (Gujarati, 2004) was considered appropriate for modeling a binary choice situation. The dependent variable in this study is farmers' adoption intention towards GM crops cultivation, which was measured as binary (1 = 'yes intending to adopt'; 0 = 'no, do not intend to adopt).

The choice of employing the probit model for the analysis was based on its realistic standard normal distribution of errors (Gujarati, 2004). The Probit model assumes that there is a latent continuous variable that determines the value of the observed dependent variable specified as;

$$y^* = \beta_0 + \sum_{i=1}^{n} xi\beta i + u_i \quad \text{..........................} \quad (3)$$

Where y* is the latent continuous variable, X_i is a set of explanatory variables assume to influence adoption, β_i is a vector of unknown parameter to be estimated and u_i is the statistical error assumed to be normally and independently distributed with a zero mean and a constant variance. The method of estimation of the Probit model was by maximum likelihood and interpretation of Probit results were based on marginal effects treated as probabilities, which explains the slope of the probability curve relating one explanatory variable to prob(y=1|x), holding all other variables constant. The observable dependent variable is defined by:

$$y = \begin{cases} 1 \; Yes \;\; if \;\; y^* > 0 \\ 0 \;\; No \;\;\; if \;\;\; y^* \leq 0 \end{cases} \quad \text{................................} \quad (4)$$

The probit model Y follows the Bernoulli distribution with probability

$$\pi_i = prob(y = 1) = \Phi(X\beta) \quad \text{..........................} \quad (5)$$

where π_i is the probability that individual intend to adopt the cultivation of GM crops, $X_i^{'}$ is the explanatory variables, β is the regression parameters to be estimated.

In the Probit model functional distribution of error is very important to constrain the values of the latent variable into desirable property of probability values of 0 and 1. The Probit model assumes a cumulative distribution function of standard normal distribution represented by Φ .

$$\begin{aligned} prob(y = 1) &= prob(y_i^* > 0) = prob(\beta X + e > 0) \\ &= prob(e > -\beta X) \\ &= prob(e < \beta X) \\ &= \Phi(\beta X) \end{aligned}$$

……………………………………………………………..*(6)*

In the case of normal distribution function, the model to estimate the probability of observing a farmer intending to adopt the cultivation of GM crops can be stated as:

$$Pr\,ob(y_i = 1/X) = \Phi(\beta X) = \int_{-\infty}^{\beta X} \frac{1}{\sqrt{2\Pi}} exp\left[\frac{-z^2}{2}\right] \partial z$$

………………………………………………………………. (7)

where

Prob is the probability of the farmer intending to adopt the cultivation of GM crops, X is a vector of the explanatory Variables, Z is the Standard Normal Variable (Z ~N (0, δ^2) and β is a k by 1 vector of the Coefficients estimated.

Empirical model

In modeling determinants of smallholder famers' decision toward adoption of GM crop cultivation, TPB and RUT were applied. These theories guided the selection of explanatory variables used in the probit models applied in assessing the determinants of adoption decision. This was supported by information gathered from literature (Gogitidze and Phutkaradze, 2017; Paredes and Martin (2007). The explanatory variables selected consist of farmers' socioeconomic characteristics; knowledge and information on GM crops, perceptions and attitudes towards GM crops and farm characteristics. Equation 8 represents the empirical probit model used in estimating the determinants of smallholder farmers' adoption decision.

$Y_i = \beta_0 + \beta_1 X_1 i + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 i + \beta_6 X_{6i} + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10i} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14} X_{14} + \beta_{15} X_{15i} + \beta_{16} X_{16} + \beta_{17} X_{17} + \mu$
……………………………………………………………(8)

The definition, description and a priori expectations of variables used in the model above is presented in the Table 1.

Table 1: Definition of Variables used in the Probit Model

Variable	Description	A priori Expectation
	Dependent Variable	
Y_j	adoption decision (dummied as i = 1; if intend to adopt; 0 = otherwise)	
	Independent Variable	
X1i	Sex (Dummied as i = 1 if male; otherwise = 0)	+/-
X2	Age (in years)	+
X3	Household size (number of persons)	+
X4	Education (number of years of formal schooling)	+
X5i	Religion (Dummied as i = 1: if traditional; i =0; if otherwise)	-
X6i	Marital Status (Dummied i= 1 if married; i= 0 if otherwise)	+
X7	Farm Size (acres)	+
X8	Ratio of crop revenue to Household income	+
X9	Experience in crop Farming (years)	+
X10i	Source of Information on GM crops (Dummied as i= 1; if mass media; i=0; otherwise)	-
X11	Favourably attitude (score on a scale of 1 – 5 as less favourable to more favourable view on GMOs)	+
X12	Negative attitude (Score on a scale of 1 -5 as less negative to strong negative view on GMOs)	-
X13	Sceptic attitude (Score on a scale 1 -5 as less sceptical to very sceptical view on GM crops)	-
X14	Neutral attitude (Score on a scale of 1 -5 as less neutral to very neutral views on GMOs)	-
X15i	Used of certified seed (Dummied as i= 1; if yes; i= 0; if otherwise)	+
X16	Experience in FBO (in years)	+
X17	Extension contact (number of extension contact/visit in a season)	+

Source: Author, 2015

Results and Discussion

Respondents' Adoption decision

Two out of every five farmers interviewed intends to adopt GM crops cultivation. Out of the 360 farmers interviewed, 149 of them (representing 41%) intent adopting the cultivation of GM crops when commercialization commences in Ghana.

Determinants of Farmers' Adoption decision

Table 2 1 presents description statistics and definition while table 3 presents the coefficients of the variables used in the probit regression model. As shown in table 2 farmers' adoption decision (Y_j) (dummied as j = 1 if a farmer decision is to adopt GM crop cultivation and j = 0 if otherwise) had a mean score of 0.4 (SD = 0.5). Thus 40% of the 360 farmers surveyed have intention of adoption GM crops cultivation when commercialization commence in the country.

Also explanatory variables sex (X_{1i}), age (X_2) and household size (X_3) respectively have mean scores of 0.6, 42.8years and 9.1. Similarly, the variable education (X_4), religion (X_{5i}) and marital status (X_{6i}) had a mean score of 8.8, 0.3 and 0.8 respectively. Also Farm size (X_7), 'crop revenue as a ratio of household income'(X_8) and experience in crop farming (X_9) had mean score of 6.0, 0.8 and 20.8 years respectively. Furthermore, as shown in the table 2, ratio of crop revenue to Household income (X_9), Source of Information on GM crops (X_{10}) and favourably attitude towards GM crops (X_{11}) respectively had average score of 0.6, 0.4 and 3.7.

Also variables such as negative attitude towards GM crops (X_{12}), Sceptic attitude towards GM crops (X_{13}), neutral attitude towards GM crops (X_{14}), used of certified seeds (X_{15}), experience in FBOs (X_{16}) and extension contact (X_{17}) respectively had a mean score of 3.4, 3.8, 3.9, 0.3 and 8.3.

Table 2: Descriptive Statistics of Variables in the Probit Model

Variable	Description	Mean	Std. Dev.	Min.	Max.
	Dependent Variable				
Y_j	adoption decision (dummied as i = 1 if farmer will be adopting; 0 = otherwise)	0.4	0.5	0.0	1.0
	Independent Variable				
X_{1i}	Sex (Dummied as i = 1 if male; otherwise = 0)	0.6	0.5	0.0	1.0
X_2	Age (in years)	42.8	10.5	24.0	75.0
X_3	Household size (number of persons)	9.1	3.8	3.0	24.0
X_4	Education (number of years of formal schooling)	8.8	6.0	0.0	16.0
X_{5i}	Religion (Dummied as i = 1 if traditional; i =0; if otherwise)	0.3	0.7	0.0	1.0
X_{6i}	Marital Status (Dummied i= 1 if married; i= 0 if otherwise)	0.8	0.4	0.0	1.0
X_7	Farm Size (acres)	6.0	5.5	1.0	70.0
X_8	Ratio of crop revenue to HH income	0.6	0.2	0.1`	1.0
X_9	Experience in crop Farming	20.8	10.5	2	53.0
X_{10i}	Source of Information on GM crops (Dummied as i= 1 if mass media; i=0; otherwise)	0.4	0.5	0.0	1.0
X_{11}	Favourably attitude (score on a scale of 1 – 5 as less favourable to more favourable view on GMOs)	3.7	1.6	1.0	5.0
X_{12}	Negative attitude (Score on a scale of 1 -5 as less negative to strong negative view on GMOs)	3.4	1.5	1.0	5.0
X_{13}	Sceptic attitude (Score on a scale 1 -5 as less sceptical to very sceptical view on GM crops)	3.8	1.3	1.0	5.0
X_{14}	Neutral attitude (Score on a scale of 1 -5 as less neutral to very neutral views on GMOs)	3.9	1.1	1.0	5.0
X_{15i}	Used of certified seed (Dummied as i= 1; if yes; i= 0; if otherwise)	0.3	0.5	0.0	1.0
X_{16}	Experience in FBO (in years)	8.3	3.3	2.0	21.0
X_{17}	Extension contact (number of extension contact/visit in a season)	4.1	2.4	0.0	20.0

Source: Analysis of field survey Data, 2016

Coefficients of the Probit Regression Equation

With LR Chi – Square (17) = 299.51; Prob > Chi2 = 0.0000 the model was found to be statistically significant in prediction farmers adoption decision. Also, with pseudo R – square of 0.86, it indicates that 86% of the variation in farmers' adoption decision towards GM crops is jointly explained by the independent variables used model. In the case of the continuous explanatory variables, the marginal effect relates to a one-unit change in the variable. For the binary explanatory variables, the marginal effect is the difference in probabilities between setting the explanatory variable to 1 and setting it to 0, given that all other explanatory variables are set at their sample means.

Out of the seventeen (17) independent variables in the model, eleven (11) were found to be significant determinants of farmers' adoption decision. The significant variables were 'age', 'household size', 'marital status', 'farm size', 'ratio of crop revenue to household income' and 'experience in crop farming'. The others were 'source of information on GM crops', 'score on positive views on GM crops', and 'use of certified seeds'.

Age of Farmers: The variable age of respondent (X_2) was found to be significant at less than1% and negatively related to adoption decision. This implies that farmers' age significantly predicts their adoption decision. As shown in the Table 3 the marginal effect of the variable 'age' was -0.0195, which illustrates that a unit change in respondents' age reduce the probability of farmers' adoption decision by 0.02 (or 2%). Also the negative relationship between age and adoption decision, indicates that younger farmers are more likely to adopt GM crop cultivation compared with the elderly. GMOs technology being a novel innovation appears to be more appealing to younger generation because they are more likely to have some level of education and as such can better understand the technology. A study on 'Attitudes of European farmers towards GM crop adoption' by Areal, Riesgo and Rodrıguez-Cerezo (2011) also concluded that age of farmers is a significant determinant of GM crops adoption among European farmers. Similarly, Gogitidze and Phutkaradze (2017) found age of farmers to be a significant determinant of GM crops adoption.

However, Paredes and Martin (2007) in studying the adoption of transgenic crops by smallholder farmers in Entre Rios, found age of smallholder farmers insignificant in influencing their adoption of transgenic crops. Their study established that young farmers as well as elderly ones were equally likely to adopt Bt Corn and/or Roundup Ready Soybeans cultivation. Thus their finding do not agreed with the finding in this study which established significant and negative relationship between age of famers and their adoption decision.

Since adoption of new technology involves risks and uncertainties, younger farmers are more likely to take risk compared to the older ones. Although their asset base may be more limited, they have more years to recover from any potential loss, should anything happen. Also, because adoption of new and unfamiliar technologies may increase production and/or income risk, older and more traditional farmers may be less likely to entertain such risks. A similar assertion was made by Gogitidze and Phutkaradze (2017) in explaining the negative effect of age on adoption of GM crops.

Household Size: The study also found significant and negative (at 5% level) relationship between household size of respondents and their adoption decision towards GM crops cultivation. The marginal effect of the variable 'household size' (X_2), as shown in the Table 3 is -0.0202. This signifies that one unit increase in respondents' household size will decrease the likelihood of adoption by 0.02.

The inverse relationship between adoption decision and household size is ample demonstration of the fact that respondents from smaller households are more likely to have intention of adopting GM crop cultivation than large households. Information gathered at most of the focus group discussions clearly shows that Roundup Ready (RR) GM crop traits are widely known among participants. Their understanding of the technology is that it reduces cost, time and labour requirement in weed control, which is one of the most labour intensive agricultural activities in this part of the country. According to Chikoye *et al*. (2007) smallholder farmers in Africa spend 50-70% of their total labour time weeding. It is normally expected that bigger households will have enough labour and as such less likely to adopt labour saving technology. Therefore any technology which seeks to reduce cost and labour intensity of weed control will be more appealing to smaller farm households with fewer farmhands compared with large households. Areal *et a*l. (2011) shows in their study that economic issues such as the guarantee of a higher income and the reduction of weed control costs are the most encouraging reasons for potential adopters and rejecters of Genetically Modified Herbicide Tolerant (GMHT) crops.

Education: The Probit regression results reveal positive significant (5%) relationship between respondents' education (X_4) and their adoption decision. The marginal effect of education, measured as number of years of formal schooling completed, was 0.0086 as shown in the Table 3. This indicates that one-unit increase in number of years of formal schooling completed is likely to increase the probability of GM crops adoption decision by 0.0086, holding other variables constant. Education and for that matter literacy has been largely established to have effect on farmers' understanding and adoption of agricultural technologies. Education also plays critical role in farmers' access to agricultural information in planning and making production decisions. Paredes and Martin (2007) also found positive and significant effect of farmers' education on adoption of Bt corn. Also Gogitidze and Phutkaradze (2017) found positive impact of farmers' education on their awareness and adoption of GM crops. Similar conclusion of the effects of education on GM technology by smallholder farmers was made in Zakaria (2014).

Marital Status: The variable marital status (X_6) dummied as '1' if married and '0' otherwise, was found to be a significant predictor (at 10%) of respondents' adoption decision towards GM crop. The negative sign of the coefficient of marital status (Table 3) indicates that respondents who are married are less likely to intend adopting GM crops cultivation. In other words there is high probability of single respondents intending to adopt GM crops technology than married respondents. The marginal effect of marital status (-0.0802), illustrate that the difference in probabilities between varying the variable X_6 to 1 and setting it to 0, given that all other explanatory variables are set at their sample means, reduce the likelihood of prospective adoption behaviour by 0.0802. Marital status provides proxy to farm labour availability, because smallholder farmers depend on family labour for their agricultural activities. Marriage being the foundation of family and basis for laying claim to family labour is expected to have influence on farmers' decision towards adopting a technology they perceived to be labour saving. This explains the negative relationship between marital status and the prospects of farmers' adoption behaviour because both Herbicide Tolerant (RR) and insecticide tolerant (Bt) GM crops varietal traits are energy, labour, time and cost saving technologies as proven in Brookes & Barfoot (2018), Brookes & Barfoot (2017), Brookes (2017) and Biden et al. (2018).

Farm Size: The variable farm size (X_7) has a positive and significant effect on adoption behaviour of farmers, suggesting that farmers with large farm size are more likely to intend adopting GM crop cultivation than those with smaller farm size (see Table 3). The marginal effect illustrates that a unit increase in farm size increases the probability of GM technology adoption by 0.0129 as shown in the Table 3. As expected, farmers with large farm holdings are more likely to take risk and are more likely to adopt new technologies. Keelan et al (2009) in their study 'Predicted Willingness of Irish Farmers to Adopt GM Technology' found farm size as a significant predictor of Irish farmers' willingness to adopt GM technology. Also, Paredes and Martin (2007) also found positive and significant effect of farm size on adoption of Bt corn.

Ratio of crop revenue to household income: The probit analysis (both stepwise and marginal effect models) confirms ratio of crop revenue to household income as negative and significant determinant of farmers' adoption behaviour at 1% level of significance. Thus farmers' crop revenue relative to their household annual income significantly influences the likelihood of farmers' prospective adoption behaviour towards GM crops. A marginal effect of -0.4227 (see Table 3), implies that a unit increase in the proportion of respondents' crop revenue relative to annual household income induces 0.4227 decrease in the probability of respondent decision to adopt GM crops cultivation, holding all other variable constant at their mean values.

However, the negative sign of the coefficient of the variable X_8, indicates that respondents whose main source of income is from crop production are less likely to adopt GM crops cultivation compared with others who sourced significant proportion of their annual household income from other sources. It is understandable that farmers whose household income security depends largely on crop revenue will be more hesitant in taking the risk of adopting new and unfamiliar technologies. Those farmers with diverse sources of income will have more resilient income security and as such will not be that hesitant in taking the risk of adopting GM technology.

Income and other economic factors have always played critical roles in technology adoption among farmers. Many studies have established significant effects of income and other economic factors on farmers' adoption decision towards GM technology (see Gogitidze and Phutkaradze, 2017; Keelan *et al*, 2009 and Paredes and Martin, 2007). Similarly, Areal *et al* (2011) showed in their study that economic issues such as the guarantee of a higher income and the reduction of weed control costs are the most encouraging reasons for potential adopters and rejecters of Genetically Modified Herbicide Tolerant (GMHT) crops.

Experience in crop farming: The variable X_9 – 'experience in crop farming' being one of the proxies for human capital of farmers was also found to be a significant determinant of farmers' adoption decision at 1% level of significance (Table3). The positive signs of the coefficient illustrates that more experienced farmers are more likely to adopt GM crop technology compared with less experienced ones. This relationship was anticipated because more experienced farmers can understand crop improvement technology better as they have engaged in the enterprise for many years and have encountered and experienced the benefit of improved technology on yield, income and better crop management. Through many years of practicing crop farming, the experienced farmers are expected to accumulate a wide range of crop production knowledge and skills, which are critical in taking decisions regarding adoption of innovations.

As illustrated in the Table 3 the marginal effect of the variable 'experience in crop farming' is 0.0172, implying that, for every unit increase in years of practicing crop farming, the probability of a respondent intending to adopt GM crops cultivation increase by 0.0172. Thus, holding all other explanatory variables constant at their mean value, a unit variation in farmer's experience in crop farming induces about 2% corresponding change in the probability of the farmer adopting GM crop technology.

Source of information on GM crops: The variable X_{10} – 'source of information on GM crops' dummied as 1 if sourced from mass media and '0' if otherwise was found to have significant and negative effect on prospects of adoption behaviour towards GM crops at 10% (Table 3). This demonstrates that farmers who heard or read about GM technology from the mass media are less likely to adopt the technology compared with those who heard about it from other sources (colleagues, input dealers, extension officers, scientists and researchers). The marginal effect in Table 3 indicates that a unit change in the source of information means that farmers who heard or read about GM crops from the mass media are 7.4% less likely to grow GM crops than those who heard about it from other sources.

Considering the fact that most information on GM technology churned out from the mass media, particularly radio and television, are typically not validated by scientists and are mostly driven by anti- GM activists, there is a high tendency of creating misconceptions and negative attitude towards GM technology. As such, farmers who source their information from these sources are more likely to disapprove of GM crop cultivation. Therefore, this finding was to be expected. The arguments put forward by opponents of GM crops and their food derivatives which have received wide media coverage have a high potential effect on consumers and general public attitude towards the consumption of GM food and its consequential effects on farmers' adoption decisions.

It has also been observed that societal anxiety over GM food hinges on several reasons, including consumer unfamiliarity, lack of reliable information, a steady stream of negative opinion in the media and vigorous campaigns by anti–GM activist groups (Biden, *et al*., 2018; Raman, 2017). Until the scientific community provide accurate information regarding safety of GM food and address the health and environmental concerns associated with GM technology using the media, societal anxiety and negative public opinion about GM food will continue to linger.

Favourably attitude towards GM crops: The variable X_{11} – 'favourably attitude towards GM crops' was found to be significant at 1% level of significance in predicting farmers' adoption decision. The positive sign of the coefficient (see Table 3) indicates a positive effect of farmers' favourable attitude towards GM crops on their intention to adoption GM crop cultivation. In other words, respondents with positive attitude towards GM crops are more likely to incline towards adopting GM crops than those with negative attitudes. The marginal effect of the variable (X_{11}) as shown in Table 3 is 0.0993, meaning that a unit increase in farmers score on positive attitude towards GM crops will induce 0.099 or 9.9% increase in probability of farmers' adoption decision towards.

Use of certified seed: As shown in Table 3, the used of certified seed (X_{15}) measured as a dummy; was found to be a significant determinant of farmers' adoption decision at 1% level of significance. The positive sign of the coefficient of the variable indicates that farmers who mostly use certified seed are more likely to adopt GM crop cultivation than those who mostly relied on traditional sources such as seeds stored from previous harvest, seed exchange with colleague farmers and seed purchased from the open market. The marginal effect of the variable as shown in Table 3 is 0.9035 and this implies that one-unit change in use of certified seed means that farmers who mostly use certified seeds are 90% more likely to grow GM crops than those who do not use certified seed. This finding was expected, because farmers who mostly use certified seeds in their crop production enterprise will better appreciate the effect of improved crop varieties and seeds and as such will be more willing to adopt improved crop technologies.

Extension contact: The variable X_{17} – 'extension contact' measured as the number of extension contacts/visits within a production season, was found to be significant at 5% in predicting farmers' adoption decision towards GM crops. Thus the study established positive relationship between extension contact and farmers' adoption decision as shown by the positive sign of the coefficient of the extension contact variable (see Table 3). Also, the marginal effect of extension contact was 0.0217, which indicates that one-unit increase in extension visit received by a farmer will increase the probability of their adoption decision by 2.2%.

Extension contact – a proxy for farmers' access to agricultural information, has been shown in many studies to have positive effect on technology adoption. Indeed, the agricultural education and information level of farmers make them more receptive to new ideas and more willing to investigate alternative farming systems, such as the adoption of GM crops as observed by Keelan *et al*, (2009). Gogitidze *et al* (2017) also found significant and positive effect of extension access and agricultural education on Georgian Farmers' Attitudes and adoption decision towards GM crops.

However, variables such as X_1 – 'sex', X_5 – 'religion', X_{12} – 'negative attitude towards GM crops', X_{13} – 'sceptic attitude towards GM crops', X_{14} – 'neutral attitude towards GM crops' and X_{16} – 'experience in FBO' were not significant determinants of farmers' adoption decision. Both male and female farmers were found equally likely to intend adopting GM crops cultivation. Contrary to expectation, religion of respondents was found not significant in predicting farmers' adoption decision. During many of the focus group discussions, participants expressed religious and spiritual sentiments in their argument against genetic engineering. It was therefore expected that one's religious belief will had a significant effects on their prospective adoption behaviour towards GM technology and hence GM crops. These findings were least expected, because farmers' negative and sceptic views on GM technology were anticipated to have significant effect on their decision regarding growing GM crops. These were obviously contrary to the findings of Gogitidze *et al.* (2017) and Zakaria (2014) who found significant relationship between negative attitudes towards GM crops and farmers' adoption decision.

Table 3: Results of probit model on prospects of GM crop adoption

Variable	Coefficient.	Std. Err.	dF/dx	Z
Sex (X_1)	0.6693	0.5530	0.0753	1.21
Age (X_2)	-0.2091****	0.0586	-0.0195	-3.57
Household size (X_3)	-0.2162**	0.0846	-0.0202	-2.56
Education (X_4)	0.0915**	0.0467	0.0086	1.96
Religious background (X_5)	-0.7624*	0.5811	-0.0564	-1.31
Marital status (X_6)	-1.3678*	0.7658	-0.0802	-1.79
Farm Size (X_7)	0.1385*	0.0774	0.0129	1.79
Ratio of crop revenue to HH income (X_8)	-4.5216 ***	1.3887	-0.4227	-3.26
Experience in crop Farming (X_9)	0.1838***	0.0664	0.0172	2.77
Source of Information on GM crops (X_{10})	-0.6029*	0.3426	-0.0738	-1.76
Favourably attitude (X_{11})	1.0624***	0.3592	0.0993	2.96
Negative attitude (X_{12})	-0.1054	0.1939	-0.0099	-0.54
Sceptic attitude (X_{13})	-0.0665	0.3153	-0.0062	-0.21
Neutral attitude (X_{14})	0.2208	0.2099	0.0206	1.05
Used of certified seed X_{15})	4.5385 ***	0.9627	0.9035	4.71
Experience in FBO (X_{16})	-0.0762	0.0779	-0.0071	-0.98
Extension contact (X_{17})	0.2316**	0.1225	0.0217	1.89
_const.	7.2361***	2.6403		2.74
Log likelihood	-23.4590			
LR $Chi^2(17)$	299.51***			
Pseudo R^2	0.8646			

Note; ***, **, * denotes significant at 1%, 5% and 10% respectively
Source: Analysis of field survey, 2016

Conclusions and recommendations

The determinants or predictors of farmers' adoption decision towards the cultivation of GM crops among smallholder farmers in northern Ghana are age, household size, marital status, farm seize, ratio of crop revenue to Household income, experience in crop farming, source of information on GM crops, favourably views on GM crops, extension contact and used of certified seeds. It is recommended that educational and information programmes aimed at providing accurate information on GM crops and Ghana's agrobiotechnology policy to farmers be embarked upon by the extension service department of the Ministry of Food and Agriculture (MOFA).

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