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Determinants of the extent of adoption of maize production technologies in Northern Ghana

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In spite of substantial investments in developing and disseminating improved maize production technologies by successive governments and several development partners, technology adoption in Ghana remains low. The purpose of this study was to identify the factors that influence the extent of adoption of improved maize production technologies among farmers in northern Ghana. A Tobit regression model was used to analyse the determinants of the extent of technology adoption. Results of the study revealed that formal education, farming experience, extension contact, access to credit, and membership of a farmer-based organisation are significant determinants of the extent of adoption of all three technologies considered. Moreover, sex of household head did not influence the extent of adoption of improved seeds but was rather significant in the case of fertiliser application and row planting. The study recommends that projects/programmes and policies related to the introduction and dissemination of improved maize production technologies in northern Ghana should draw lessons from studies like this to ensure improved technology uptake.

Key words: Adoption, improved technologies, maize, Tobit regression.

INTRODUCTION

Background

Agriculture has been the backbone of Ghana's economy throughout its post-independence history and the sector remains one of the most competitive in the Ghanaian economy contributing about 19.1% to the country's GDP (GSS, 2017). Though it has been described as the foundation of the country's socio-economic development, the agricultural sector is characterized by low productivity

due to the dominance of the sector by smallholder farmers who heavily depend on rain-fed conditions, limited use of improved seeds, inorganic fertiliser, mechanization, and high post-harvest losses (Chamberlin, 2007). There is the opportunity for farmers to realise high yields and improve farm incomes using the best agricultural practices and technologies. It is evident worldwide that agricultural productivity has been driven by improved farm technologies (Gabre-Madhin and

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Johnston, 2002). Adoption of agricultural technologies has been associated with multiple benefits to farm households, including higher earnings and reducing poverty (Kassie et al., 2011), improved nutritional status and lower food price (Kumar and Quisumbing, 2010). Thus, the adoption of improved agricultural technologies is essential to the attainment of the Sustainable Development Goals (SDGs) one and two of ending poverty and hunger.

Maize is recognised as the most important cereal crop produced in Ghana and an essential part of the food and feed system and of high commercial value (FAO, 2008). In northern Ghana, it facilitates food security and serves as a source of generating income for many households (Wiredu et al., 2010). Owing to this, maize is among the few crops in northern Ghana which have received much attention from the government and other development agencies (ACDI/VOCA, 2012; Ragasa et al., 2013). Also, the importance of maize to the livelihoods of most farming households has made it a target crop for the government's flagship 'Planting for Food and Jobs' policy. However, due to the dependence on traditional farming practices, the use of low yielding varieties, limited use of fertiliser and low plant population, among others, maize production in Ghana has relatively remained stagnant in terms of volumes harvested and area under cultivation (MiDA, 2009). There have been average shortfalls of about 12% in maize supplies since the country is not self-sufficient in the production of this important staple crop (MiDA, 2009). Available estimates indicate an average national yield of 1.9 metric tonnes per hectare. However, with the adoption of appropriate production technologies, yields of 5.0 to 5.5 metric tonnes per hectare have been reported (MoFA, 2016). Growth in the maize sector has mostly been through the expansion of cultivated area rather than productivity increase on existing farms (Fuglie, 2012). However, population growth with its associated competition for land is limiting the land expansion potential of farms in most agro-ecological zones of which northern Ghana is not an exception (Diao, 2010). There is the need to improve the country's production of maize particularly in the three northern regions, with the adoption of improved technologies to ensure adequate supply and improve food security.

This paper specifically ascertains the extent to which farmers have adopted improved varieties, fertiliser application and row planting in maize production and evaluates the key factors that influence the extent of adoption of these improved maize production technologies in northern Ghana.

LITERATURE REVIEW

As highlighted by Roger's adoption and diffusion of innovations theory, the adoption of agricultural technologies is influenced by individual characteristics,

perceived characteristics of the technology, and the institutional environment within which the adoption process occurs (Rogers, 2003). Traditionally, an array of personal characteristics, information flow, risk, institutional and input constraints have been considered as the prevailing factors influencing the adoption of agricultural technologies. For instance, some personal and household characteristics such as sex of household head, number of years in school, farming experience, household size, farm size and ownership of farm plots have been recognised as factors that influence technology adoption. Male-headed households are believed to have improved access to education, productive resources (such as land) and information on new technologies than female-headed households who are faced with social, cultural and religious constraints (Mignouna et al., 2011). This is a likely constraint to the adoption of improved technologies by female-headed households. Household size of farmers represents the pool of labour available to farm households, and this is believed to have a positive relationship with technology adoption, especially technologies that are labour-intensive. Bonabana-Wabbi (2002) asserts that families with large size are less limited by labour constraints in adopting some labour-intensive technologies. Failure of the labour market to provide on-farm labour for the adoption of labour-intensive technologies might deny smaller households the incentive to extensively adopt an improved technology. In such cases, households with larger sizes resort to the family for labour, hence speeding up the adoption of the technology.

It is often believed that land ownership has a positive influence on technology adoption. Doss (2005) argues that landowners are more likely to adopt innovations than tenants as tenants are faced with the insecurity of tenure that deprives them of adopting fixed input technologies such as irrigation system, mulching among others. Similarly, it is believed that farmers with larger farm sizes are more likely to adopt improved technologies as they can dedicate part of their lands to test the technology unlike those with smaller land sizes (Uaiene et al., 2009). On the contrary, Mwangi and Kariuki (2015) asserts that small land size will encourage technology adoption as an incentive for increased productivity. Education has been identified to positively and significantly influence technology adoption (Mignouna et al., 2011). Farmers with relatively high education are assumed to better comprehend and interpret new technologies much faster than farmers without formal education. Also, several studies have found a positive relation between farming experience and adoption. It is believed that due to their long stay in farming, they might have retrieved all their capital investments and are financially well off and can bear the cost of innovation unlike a starter in the industry (Uaiene et al., 2009). However, the converse has also been reported (Mwangi and Kariuki, 2015).

In addition, some institutional variables such as

extension visits and training, access to credit, membership of a farmer-based organisation and the distance to input market have been identified as significant factors that influence the adoption decision and extent of adoption of improved technologies. For instance, Doss (2005) cites access to extension service as one of the critical avenues to acquire information about new technology. Regular contacts with extension agents help in the transmission of message about the existence of new technology, its usage and benefits from the producers to the adopters (Mwangi and Kariuki, 2015). Similarly, participation in extension training programmes has been identified to influence technology adoption positively (Monfared, 2011). Access to credit facilities offers a greater chance of adopting new technology. Farmers with access to credit facilities, either in cash or kind (inputs) are more likely to adopt improved technologies than those with limited access. Mwangi and Kariuki (2015) asserts that lack of credit opportunities relax the adoption decision of farmers and this is likely to influence the extent to which farmers can adopt improved technologies on their farms. Assurance of financial stability would imply that the farmer would be able to bear the cost of adopting the technology. According to Doss (2005), access to the input market makes farmers less restrained in purchasing inputs. Distance as a measure of technology adoption increases the cost of adoption and the time of adoption. When cost increase with limited financial reliability, farmers are less willing to and less capable of investing in the technology. Uaiene et al. (2009) notes that there exists a negative relationship between distance and adoption of improved technology. Social networks gained from social groups among farmers help in agricultural technology adoption as farmers can share information and learn from one another. According to Salifu et al. (2012), farmers with membership in a farmer-based organisation can get easy access to extension services, credit facilities as well as information on new technologies unlike those outside such farmer-based organisations. Contrary to this assertion, Doss (2005) argued that acquiring information about new technology through farmer groups and extension services are not necessarily a guarantee for technology adoption.

The effects of the factors identified as possible determinants of adoption were tested in this study.

METHODOLOGY

Study area

The study was conducted in the northern part of Ghana, covering Upper East, Upper West and Northern Regions. The area has a single rainy season which mostly begins in April/May and ends in September/October. This is followed by a continuous dry season from early November to the end of March. The maximum temperature within this season occurs towards the end of March whereas minimum temperature occurs in December and January (GSS, 2013). The population of Northern Ghana is predominantly

rural (72%) with agriculture as the main economic activity (GSS, 2010). It is the most significant contributor to the local economy and employs more than 70% of the economically active population in the three regions (MoFA/SRID, 2011). Northern Ghana plays an essential role in agriculture in Ghana; accounts for about 40% of the country's agricultural land and is commonly referred to as the grain basket of the country (MoFA, 2010). Major staple crops cultivated in the area include maize, rice, sorghum, millet, groundnut and cowpea grown on a subsistence basis. The choice of the study area was based on the importance of maize in the farming system in northern Ghana and the availability of many interventions in the area disseminating and promoting the adoption of improved maize production technologies. However, the study area is considered among the poorest in the country in spite of the existence of enormous potential to achieve food security due to the area's comparative advantage in tubers (yam), grains and legume production (SRID-MoFA, 2012). In the Comprehensive Food Security and Vulnerability Analysis by the World Food Programme (WFP) in Ghana, the three regions were ranked as the most food insecure in the country (WFP, 2012). The underlying factors of food insecurity in the study area have been generally attributed to low yields of produce which are due to unfavourable weather, limited use of improved technologies, lack of agricultural inputs, storage and processing facilities, poor market linkages and poor road networks (WFP, 2012).

Sampling, data collection and data analysis

The study population included maize producing households in the three northern regions. A multi-stage sampling approach was utilised in selecting districts, communities and ultimately farmers for the survey. At the first stage, each region was considered as a cluster within which districts were purposively selected to include beneficiary districts of the USAID's Agriculture Development and Value Chain Enhancement (ADVANCE) project. A comprehensive list of maize producing communities in each district was obtained, and this served as the basis for the next stage of sampling. Communities were selected from each district through a simple random sample approach based on the list of communities obtained. In each community, farming households were listed with the help of ADVANCE field officers and households were randomly selected to reflect the number of households in the community. A total of 1,302 households were selected for the survey. Table 1 presents the distribution of sampled respondents across the study regions. The study employed a structured questionnaire to collect data from maize producing households in the study area in a cross-sectional survey. Trained enumerators conducted the household survey through a face-to-face interview.

Descriptive tools such as frequency tables, proportions and arithmetic mean were employed to summarise and describe the characteristics of respondents. For the continuous variables, student's t-test was used to ascertain statistical differences between adopter and non-adopter categories. The study adopted the Multivariate Tobit regression model in identifying factors that influence the extent of technology adoption.

At best, adoption studies based on dichotomous regression models such as the probit and logit models only explain the probability of adoption and non-adoption and not the extent to which farmers apply the improved technologies on their fields. A farmer adopting an improved technology may be doing so in part or all of his/her field. Therefore, a dichotomous definition of adoption will not be adequate in explaining the extent of technology adoption (Feder et al., 1985). The Tobit model, which is an extension of the probit and logit model, is one of the models that have discrete and continuous parts and mostly used in dealing with the problem of censored data (Johnston and Dinardo, 1997). Indeed, a number of studies have employed the Tobit model in estimating the extent of

Table 1. Sample size.

Region	Number Districts	Households	
		N	%
Northern	20	646	49.60
Upper East	9	228	17.50
Upper West	9	428	32.90
Total	38	1302	100.00

Table 2. Description of variables used in the model and their *a priori* expectations.

Variable	Description/Definition	Expected sign
HHsex	Sex of household head (1=Male; 0=female)	+
Farmexp	Number of years in maize production (Years)	+/-
HHsize	Number of family members in a household (Number)	+/-
Educ	Number of years in school (Years)	+
Ownland	Ownership of maize plots (1=owner; 0=otherwise)	+
Extcontact	Farmer's access to extension visits (1=Yes; 0=otherwise)	+
Accredit	Access to credit for farming (1=yes; 0=otherwise)	+
Dist	Distance from house to the nearest input market (Kilometers)	-
Acctrain	Participation in extension training programmes (1=yes; 0=otherwise)	+
FBO	Belonging to a farmer-based organisation (1=yes; 0=otherwise)	+

technology adoption (Nkonya et al., 1997; Mafuru et al., 1999; Wiredu et al., 2012; Rahman and Chima, 2016).

A Tobit regression model was employed to investigate the factors that influence the proportion of maize field farmers allocate to improved technologies. For each of the three technologies considered in this study (improved seeds, row planting and fertiliser application), the dependent variable takes the value of the percentage of maize field allocated to that improved technology. The Tobit model is most suitable in dealing with this kind of data because it makes use of both observations at the limit, usually zero (those who did not adopt an improved technology) and those with positive values. Considering the multiple technologies under consideration, three Tobit equations are required. Since a number of farmers may be adopting different combinations of the three technologies, a multivariate Tobit model was developed to capture the joint outcome. According to Belderbos et al. (2004), the multivariate model estimates the influence of the explanatory variables on each of the technologies and the correlation between the adoption of the different technologies.

Let the outcome function for adopting a particular technology be represented by:

$$i^* = X_i + u_i \quad (1)$$

Where, X_i represents the vector of regressands/explanatory variables; γ represents the vector of parameters to be estimated, and u_i represents the error term.

Unlike the probit model which only provides information on the decision to adopt, the Tobit model captures the decision and the outcome. The three equations in this case are specified as:

$$Y_{1i}^* = \gamma_1 X_{1i} + u_{1i} Y_{1i}^* = \text{maximum}(Y_{1i}^*, 0) \quad (2)$$

$$Y_{2i}^* = \gamma_2 X_{2i} + u_{2i} Y_{2i}^* = \text{maximum}(Y_{2i}^*, 0) \quad (3)$$

$$Y_{3i}^* = \gamma_3 X_{3i} + u_{3i} Y_{3i}^* = \text{maximum}(Y_{3i}^*, 0) \quad (4)$$

Where, Y_{1i}^* = extent of adoption of the i^{th} farmer who adopted improved seed; Y_{2i}^* = extent of adoption of the i^{th} farmer who adopted row planting and Y_{3i}^* = extent of adoption of the i^{th} farmer who adopted fertiliser application.

The empirical model used was specified as:

$$\text{EXT_Adopt} = \beta_0 + \beta_1 \text{SEX_HHH} + \beta_2 \text{FARMEXP} + \beta_3 \text{HHSIZE} + \beta_4 \text{EDUC} + \beta_5 \text{LANDDOWN} + \beta_6 \text{EXT} + \beta_7 \text{ACCREDIT} + \beta_8 \text{DIST} + \beta_9 \text{ACCTRAIN} + \beta_{10} \text{MFBO} + u_i$$

Where, EXT_Adopt represents the extent of adoption of improved seed, row planting and fertiliser and μ is independent normally distributed error term. The meaning of the covariates, their definitions, and expected *a priori* signs are presented in Table 2.

RESULTS AND DISCUSSION

Descriptive results

Table 3 presents characteristics of the surveyed farmers by their adoption status of the selected improved technologies. As shown by the t-test for all the technologies, there is no significant difference between adopters and non-adopters in terms of age and land ownership. However, there was a statistically significant difference between adopters and non-adopters of the technologies in terms of education, farming experience, extension contact, credit access, distance to input market, access to training, and membership in farmer-

Table 3. Characteristics of adopters and non-adopters of different maize production technologies.

Variable	Improved seed			Row planting			Fertiliser			All farmers (N=1302)
	Adopters (N=295)	Non-adopters (N=1007)	t-value	Adopters (N=535)	Non adopters (N=767)	t-value	Adopters (N=415)	Non dopters (N=887)	t-value	
Sex of household head (1=Male)	0.67 (0.47)	0.71 (0.45)	1.56	0.65 (0.48)	0.74 (0.44)	3.41***	0.67 (0.47)	0.72 (0.45)	1.60	0.70 (0.46)
Age (Years)	42.18 (11.97)	42.78 (12.29)	0.75	42.10 (12.41)	43.03 (12.07)	1.36	41.86 (12.18)	43.02 (12.22)	1.60	42.65 (12.22)
Education (Years)	5.42 (4.86)	3.06 (4.23)	8.14***	5.37 (4.84)	2.37 (3.77)	12.56***	5.18 (4.91)	2.86 (4.08)	8.95***	3.60 (4.49)
Household size (Number)	9.28 (4.11)	9.85 (4.12)	2.10**	9.68 (4.09)	9.74 (4.14)	0.24	9.67 (4.20)	9.74 (4.09)	0.30	9.72 (4.12)
Farming experience (Years)	19.28 (8.01)	16.41 (8.38)	5.23***	19.22 (8.67)	15.55 (7.83)	7.94***	19.17 (8.72)	16.07 (8.03)	6.31***	17.06 (8.38)
Farm size (Hectares)	1.88 (1.81)	1.82 (1.54)	0.62	1.94 (1.89)	1.76 (1.37)	1.98*	1.98 (1.93)	1.76 (1.43)	2.29**	1.83 (1.61)
Land ownership 1=Yes)	0.94 (0.23)	0.94 (0.24)	0.01	0.94 (0.24)	0.94 (0.23)	0.29	0.93 (0.25)	0.95 (0.22)	1.05	0.94 (0.23)
Extension contact (1=Yes)	0.51 (0.50)	0.23 (0.42)	9.48***	0.52 (0.50)	0.14 (0.35)	16.12***	0.55 (0.50)	0.17 (0.38)	14.86***	0.29 (0.46)
Access to credit (1=Yes)	0.53 (0.54)	0.30 (0.46)	7.70***	0.58 (0.49)	0.19 (0.39)	15.95***	0.58 (0.49)	0.24 (0.23)	12.48***	0.35 (0.48)
Distance to market km)	8.61 (10.52)	10.10 (11.78)	1.97**	8.3 (10.23)	10.78 (10.78)	3.85***	8.98 (11.37)	10.13 (11.58)	1.68*	9.76 (11.52)
Training (1=Yes)	0.57 (0.50)	0.34 (0.48)	7.12***	0.58 (0.49)	0.27 (0.44)	12.14***	0.55	0.32	8.03***	0.4 (0.49)
FBO member-ship (1=Yes)	0.66 (0.47)	0.39 (0.49)	8.50***	0.66 (0.48)	0.31 (0.46)	13.17***	0.64	0.36	9.85***	0.45 (0.50)

*, **, *** Indicates significance at 10%, 5% and 1% respectively. Values in parenthesis are standard deviations.

based organisations. There was a significant difference in the household sizes of adopters and non-adopters of improved seeds only. Also, there was a significant difference in the percentage of adopters and non-adopters of row planting in terms of the sex of household head. The results also show a significant difference in the average maize farm size of adopters and non-adopters of row planting and fertiliser.

Extent of adoption

Following Feder et al. (1985), the study measured the extent of adoption as the proportion of farmers' maize farm allocated to the adoption of improved technology. Table 4 presents the difference between adopters and non-adopters of the selected maize production technologies across the three regions in terms of maize farm sizes.

Across the study area, the average maize farm size under cultivation was estimated at 1.83 hectares. Among the regions, the northern region recorded the highest average maize farm size (1.90 ha), followed by Upper East (1.83 ha), and the lowest was recorded in the Upper West region (1.73 ha). An ANOVA test (F-value = 1.384, p=0.251) showed that the difference between the regions was not significant. Among all farmers, the difference in maize farm size for adopters and non-adopters was significant only for row planting and fertiliser (Table 4). Further analysis of the proportion of farmers' field allocated to the adoption of improved technologies revealed that, adopters of improved seeds allocated about 54% of total maize farm to that technology. Similarly, farmers who planted in rows and those who applied fertiliser did so about 59 and 56% of total maize farm respectively (Table 5). It can be observed from Table 5 that technologies which

required relatively higher level of investments recorded a comparatively lower extent of adoption. Thus, the relatively low extent of adoption of fertiliser and improved seeds may be attributed to the financial requirement in the adoption of these purchased inputs. Indeed, capital-intensive technologies are only affordable to farmers who are well-to-do and thus their adoption and extent of application are usually limited to farmers who have the means to meet the capital requirements it comes with (Khanna, 2001).

Determinants of the extent of technology adoption

Table 6 shows the results of the estimated Tobit regression model. Results of the Tobit regression model show that the log likelihood is -18849.818

Table 4. Average maize farm size under cultivation.

Region	Improved seeds			Row planting			Fertiliser			All farmers
	Adopters	Non-adopters	t-value	Adopters	Non-adopters	t-value	Adopters	Non-adopters	t-value	
Northern	2.06(1.56)	1.87 (1.51)	1.14	2.02 (1.82)	1.84 (1.35)	1.47	2.12 (1.94)	1.82 (1.34)	2.19 **	1.90(1.52)
Upper East	1.91 (1.74)	1.8 (1.51)	0.45	1.9(1.65)	1.77 (1.50)	0.60	1.95 (1.78)	1.76 (1.44)	0.83	1.83(1.57)
Upper West	1.74 (1.99)	1.73 (1.62)	0.09	1.87 (2.08)	1.59 (1.32)	1.63	1.86 (1.98)	1.65 (1.56)	1.24	1.73(1.75)
All farmers	1.88 (1.81)	1.82 (1.54)	0.62	1.94 (1.89)	1.76 (1.37)	1.98 **	1.98 (1.93)	1.76 (1.43)	2.29 **	1.83(1.61)

Values in parenthesis are standard deviations

Table 5. Extent of adoption/proportion of land allocated to improved technologies.

Technology	Northern (%)	Upper East (%)	Upper West (%)	All farmers (%)
Improved seed	56	52	52	54
Row planting	59	56	60	59
Fertiliser	60	51	53	56

and is significant at 1% level. This indicates that the model adequately represents the data. There were positive relationships between the extent of adoption of all the three selected improved technologies and education, farming experience, extension contact, access to credit, participation in training programmes, and membership in a farmer-based organisation. Meanwhile, sex of household head had a significant positive relationship with the extent of adoption of row planting and fertiliser only. On the other hand, there was a negative relationship between household size and the extent of adoption of improved seeds and fertiliser. Land ownership and distance to the nearest input shop were however not significant determinants of the extent of adoption of all the selected technologies.

In this study, years of formal education was hypothesised to have a positive association with the extent of adoption of improved maize

technologies. As expected, the coefficient of formal education was positively significant for all three technologies. Farmers with some level of formal education are more likely to better understand and interpret the consequence of adopting a new technology much faster than farmers without formal education. It is therefore not surprising that years of formal education has a positive influence on land allocated to the adoption of improved maize technologies. This finding is comparable to that of Mafuru et al. (1999) who reported education as a significant factor affecting the proportion of land allocated to improved maize technologies in Tanzania. This implies that the relevance of human capital development cannot be underestimated. A similar finding on the effect of education on the allocation of land to improved wheat variety has been reported by Gebresilassie and Bekele (2015) in Ethiopia. Sex of household is significant and

positively influences the extent of adoption of improved seed, row planting, and fertiliser. This implies that holding all other variables in the model constant, male-headed households are more likely to allocate a greater part of their maize plots to improved technologies than their female-headed counterparts. This finding conforms to our *a priori* expectation and is consistent with earlier results of Omonona et al. (2006) and Asante et al. (2011). Farmers experience was measured as the number of years engaged in maize farming, and this was hypothesised to have a positive effect on the extent of adoption. As expected, farming experience has a significantly positive effect on the extent of adoption of improved seeds, row planting and fertiliser at 1% level.

With adequate experience, farmers are expected to improve their skills in production and be able to evaluate the advantages of improved technologies (Mignouna et al., 2011). Contrary to this finding,

Table 6. Tobit regression estimates of factors influencing the extent of adoption.

Independent variables	Seed		Row Planting		Fertiliser	
	Coefficient (Standard Error)	Z-score	Coefficient (Standard Error)	Z-score	Coefficient (Standard Error)	Z-score
Sex of household head	2.3845 (1.9134)	1.25	8.4257 (2.0390)	4.13***	4.3828 (2.0498)	2.14**
Years of Education	0.8214 (0.2020)	4.07***	1.6727 (0.2152)	7.77***	0.7876 (0.2164)	3.64***
Household Size	-0.5095 (0.2126)	-2.40**	0.0860 (0.2265)	0.38	-0.3110 (0.2277)	-1.87*
Farming Experience	0.3547 (0.1044)	3.40***	0.6276 (0.1112)	5.64***	0.3448 (0.1118)	3.08***
Land ownership	-0.3212 (3.7142)	-0.09	-0.9725 (3.9581)	-0.25	-1.1193 (3.9789)	-0.28
Extension contact	11.6444 (1.9686)	5.92***	20.7032 (2.0978)	9.87***	23.2090(2.1089)	11.01***
Access to credit	9.2711 (1.8753)	4.94***	19.5832 (1.9984)	9.80***	15.9091 (2.0089)	7.92***
Distance to market	-0.1214 (0.0749)	-1.62	-0.1907 (0.0799)	-1.39	-0.0210 (0.0803)	-0.26
Training	6.7996 (1.8379)	3.70***	12.9052 (1.9586)	6.59***	5.8565 (1.9689)	2.97***
FBO Membership	7.5861 (1.8102)	4.19***	14.3877 (1.9291)	7.46***	8.2615 (1.9392)	4.26***
Constant	8.7961 (4.6203)	1.90*	6.1743 (4.9236)	1.25	10.0566 (4.9495)	2.03**
σ^2	30.9301 (0.6061)	51.03***	32.9608 (0.6459)	51.03***	33.1342 (0.6493)	51.03***
Wald chi2 (33) = 700.38***						
Log Likelihood = -18849.818						
No. Obs = 1302						

Dependent variable = percentage of maize farm allocated to improved technology adoption.

Values in parentheses are standard errors. *, **, *** indicates significance at 10%, 5% and 1% respectively.

Gebresilassie and Bekele (2015) observed no significant effect of farming experience on the extent to which smallholder farmers adopted improved wheat varieties on their farms. Results from Table 6 also show that household size is significant and negatively affects the extent to which farmers adopt improved maize seeds and fertiliser. The implication is that increasing household size reduces the area allocated to improved maize seeds and inorganic fertiliser. A plausible explanation to this finding may be the fact that households with larger household members may be burdened with additional cost in meeting other household needs and as such may be reluctant in allocating financial resources to improved technologies, particularly those that are

cost intensive. Consistent with this finding, Simtowe and Manfred (2006), observed that while larger households may have abundant labour required for maize production, the extent of adoption will depend on the household's financial ability to purchase the improved seed and fertiliser. Similarly, Samuel and Wondaferahu (2015), identified a negative relationship between household size and the area allocated to planting improved soybean seed. On the contrary, other studies (Danso-Abbeam et al., 2017; Mignouna et al., 2011) have reported a significant positive effect of household size on technology adoption. This study hypothesized extension contact to have a positive influence on the extent of adoption. As expected, results in Table 6 show

that the coefficient of extension contact is significant and associated positively with the extent of adoption of all three technologies. This implies that regular contact with extension agents is necessary to enhance the extent of adoption of improved maize technologies. Other studies (such as Mafuru et al., 1999; Namwata et al., 2010; Ayinde et al., 2010) have reported comparable results. For instance, Mafuru et al., (1999) identified extension access as a significant factor that influences the proportion of land allocated to the adoption of improved maize varieties. Contrary to this finding, Salifu et al. (2015) reported that having access to extension services did not show a significant influence on the adoption of improved maize varieties. Similarly,

the results also show that attending a training programme has a significant effect on the extent of adoption of improved seeds, row planting, and fertiliser. Farmers' participation in training programmes exposes them to information about new technologies, and thus training participants (farmers) are more likely to allocate a greater proportion of their farms to improved technologies than non-training participants. This finding is in agreement with that of Hall and Khan (2002). The authors reported that training programmes in Ethiopia produced a positive influence on the adoption of improved seeds, fertiliser and herbicides. Similar findings have been reported by other adoption studies on different technologies and crops (Baffoe-Asare et al., 2013; Namwata et al., 2010). Access to credit for agricultural purposes had a positive and significant effect on the extent of adoption of all the three selected improved technologies. This suggests that improved technologies are more likely to be adopted extensively on farmers' field if there is adequate access to credit. Farmers with access to credit will have the purchasing power to purchase agricultural inputs such as improved seeds and fertiliser, and also to pay for extra labour for labour-intensive activities like row planting on the farm. With the rising production cost resulting from the rising input price, credit access becomes important in promoting extensive adoption of improved technology adoption. Similar to this finding, Wiredu et al. (2012) identified lack of credit access as a constraint to the adoption of the mini-sett technology by yam producing farmers in northern Ghana. The results also show a significant positive effect of having membership in a farmer-based organisation on the extent of adoption of all the three selected technologies. Membership in a farmer-based organisation facilitates farmers' access to credit, land, and labour resources. Such farmers are more likely to have information regarding new technologies, improved seeds and inputs. In northern Ghana, information on new technologies and agronomic practices are mostly disseminated through farmer groups. These social ties increase the awareness of farmers on the importance of adopting improved production technologies. It is therefore not surprising that having membership in a farmer-based organisation has a positive and significant effect on the proportion of farmers' field allocated to the adoption of improved technologies. The result of this study is comparable to other adoption studies (Baffoe-Asare et al., 2013; Godtland et al., 2004). This finding is however at variance with Wiredu et al. (2012) who observed no significant effect of group membership on the extent of adoption of the yam mini-sett technology in northern Ghana.

CONCLUSIONS AND RECOMMENDATIONS

This study sought to identify the factors that influence the extent of adoption of improved maize seeds, row planting and fertilizer in northern Ghana. The empirical results

showed that among the socio-economic and institutional variables considered, years of formal education, household size, farming experience, access to credit, extension contact, membership in a farmer-based organisation, and participation in training programmes are variables that significantly influence the extent of adoption of all the three selected technologies. Having a male-headed household only influenced the extent of adoption of row planting and fertiliser.

The study recommends that projects/programmes, as well as policies related to maize technology introduction and dissemination, should consider giving much prominence to these identified socio-economic variables. This will enhance the extensive adoption of improved maize production technologies which will help to increase productivity, enhance households' income and improve food security, particularly in northern Ghana. The importance of farmers' access to credit for farming cannot be overemphasized. Government and development partners should explore innovative avenues that will ensure sustainable credit access by farmers to fill the current demand and supply gap. This could include group credit and a nucleus farmer out-grower model. Farmers should be encouraged to have better savings culture to improve their credit access. Also, there is the need to increase the frequency of extension visits to farmers by increasing the number of extension agents in various agricultural districts as they have the potential to influence adoption. Finally, extension programmes should include periodic training through field demonstrations to enhance farmer learning.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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