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Factors affecting Adoption of Maize Production Technologies: A study in Ghana

Camillus Abawiera Wongnaa[1*], Dadson Awunyo-Vitor[1] and John-Eudes Andivi Bakang[1]

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ABSTRACT

Purpose : *The huge gap between actual and achievable yields in Ghana's maize production threatens Ghana's household food security. Poor adoption of improved maize production technologies is often cited as the major cause of the low yields. This study examined the factors influencing adoption of improved production technologies by maize farmers in order to highlight the constraints and opportunities for improving adoption.*

Research Method : *The data used were obtained through a cross-sectional survey of 576 maize farmers in Ghana using the structured questionnaire. Descriptive statistics and the multinomial logit model were the methods of analysis employed.*

Findings : *The results showed that adoption of production technologies is influenced by age, educational level, initial capital outlay, agricultural extension contact, group membership, availability of ready maize market, access to credit, experience in maize farming, land fragmentation and previous year's price of maize. For adoption of maize production technologies to be improved, technology dissemination programmes should target to literate farmers and farmers should be encouraged to join farmer groups, stakeholders should support maize farmers with credit, maize farmers should be provided with ready market and younger farmers should be encouraged to consider maize production as a business.*

Research Limitations - *The study focused on whether or not in general, maize farmers used production technologies. It presents limited information on specific technologies in different agro-ecological zones.*

Originality/Value : *This study provides insights into why especially some Ghanaian maize farmers adopt or do not adopt certain technological packages promoted by the Council for Scientific and Industrial Research (CSIR) and the Ministry of Food and Agriculture (MOFA) of Ghana.*

Keywords: *fertilizer and row planting, herbicides, maize production technology adoption, improved seed*

INTRODUCTION

Ghana is widely regarded as an African success story due to its impressive achievements in accelerating growth and reducing poverty and hunger in line with the Millennium Development Goals. Strong agricultural output growth (4.6 percent annually from 1991 to 2009) has played an important role in this development (Fuglie, 2012; Ragasa, 2013). However, much of the growth has been through the expansion of cultivated area and not through total-factor-productivity growth, which has averaged only 1.2 percent annually. This is higher than the

[1*]Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Private Mail Bag, University Post Office, Kumasi-Ghana. *wongnaaa@yahoo.com*

African average of 0.5 percent, but well below the global average of 1.8 percent in the 2001-2009 period (Fuglie, 2012). Despite these achievements, major technological challenges and yield gaps persist in Ghana. This is because, for a staple crop like maize, yield is generally less than half of the economically attainable yields (MOFA, 2015). For example, current national average yield of maize stands at 1.73 metric tonnes/hectare (Andam et *al*, 2017). However, data from different on-station and on-farm trials suggest that a yield average of 5.5 metric tonnes/hectare for maize is achievable (MOFA, 2015). This figure shows a huge gap between actual and achievable yield and with maize accounting for over 50% of Ghana's total cereal production and the second most important staple food in Ghana next to cassava, its low yield can threaten Ghana's household food security, if steps are not taken to increase productivity (Angelucci, 2013).

No or low adoption of improved maize production technologies is often cited as the major reason for the above productivity gap of maize (Lobell et *al*, 2009; Horna and Nagarajan, 2010; Ragasa, 2013). Therefore, it is important that key drivers of adoption and non-adoption of maize production technologies be studied to help in making pragmatic recommendations which could lead to policies that will help increase adoption of production technologies by Ghanaian maize farmers. With some recent studies analyzing drivers of adoption of improve maize technologies by Ghanaian maize farmers at the district/municipal and regional levels (Kwadzo et *al*, 2010; Akudugu et *al*, 2012; Aidoo et *al*, 2014; Hussein et *al*, 2015; Alhassan, et *al*, 2016), since 1998, only four nationwide improved input adoption studies including Morris *et al.,* (1999), Doss and Morris (2001), Ragasa *et al.,* (2013) and Chapoto and Ragasa (2013) have been done on maize in Ghana. Of these studies, only Doss and Morris (2001) and Chapoto and Ragasa (2013) have attempted to analyse the drivers of adoption of maize production technologies by maize farmers in Ghana, causing a dearth of knowledge of key factors that influence adoption of improved maize technologies by Ghanaian maize farmers. To determine levels of adoption of improved inputs among Ghanaian maize farmers in general and better understand the constraints and incentives for adoption of maize production technologies as well as devising strategies to help increase Ghana's maize productivity, investigating the factors influencing adoption of maize production technologies by Ghanaian maize farmers is critical.

Several studies in Ghana and other parts of the world have analyzed determinants of farmers' adoption of agricultural technologies using binary probit or logit models (when a single technology was involved) as well as multinomial probit or logit models (when multiple technologies were involved). For instance, Hussein *et al.,* (2015) indicated that age, marital status, education of household head, farmers' experience in maize production and varietal characteristics were the most significant factors that influenced adoption of improved maize varieties. Also, according to Aidoo *et al.,* (2014), whereas educational level, extension contact and credit access had a positive effect on the probability of using certified maize seeds, farmers with larger farm sizes were found to have a higher probability of not using certified seeds to produce maize. Kwadzo *et al.,* (2010) identified the determinants of adoption of maize production technologies to include subsistence requirement of households, extension contact, nature of land tenure arrangement, access to credit, ease of transportation of products to market, storability of the output (grain), costs of inputs and farm size. Akudugu *et al.,* (2012) found that farm size, expected benefits from technology adoption as well as access to credit and extension services determined the adoption of modern agricultural technologies in Ghana. In the adoption study by Aneani *et al.,* (2012), the most pressing determinants of adoption of cocoa production technologies were, access to credit, number of cocoa farms owned by the farmer, gender, age of the cocoa farm, migration, cocoa farm size and cocoa yield. The findings of Owombo and Idumah (2015) revealed that the level of education, extension contact and land ownership significantly influenced farmers' adoption of mulching, cover cropping and tree planting respectively in Nigeria. Jaleta *et al.,* (2013) also found the drivers of adoption of a number of improved maize varieties in Ethiopia to include household characteristics, availability of family labour, wealth status, social networks, access to credit to buy seed and fertilizer, better soil fertility and soil depth and access to market opportunities. In a study in Zambia, Grabowski *et al.,* (2016) reported that adoption of minimum tillage technologies was influenced by female gender, age of household head, labour requirements, farm income, quantity of fertilizer used, value of equipment required as well as capacity training required. Also in Zambia, Manda (2016) concluded that adoptions of improved maize varieties and sustainable agricultural practices were influenced by education level, gender, farm size, access to off-farm income, pest infestation, household size, trust in government support, confidence in skills of extension staff, drought, distance to output markets, soil fertility and awareness of the technology. Finally, in modeling farmers' decisions on tea varieties in Vietnam by Nguyen-Van *et al.,* (2016), the determinants of adoption of tea varieties were tea income, age of household head, use of organic fertilizers, contract farming and membership of the farmer association.

Even though some studies have analyzed drivers of adoption of improved maize varieties (Doss and Morris, 2001; Chirwa, 2005; Kafle, 2010; Kwadzo et *al*, 2010; Jaleta et *al*, 2013; Aidoo et *al*, 2014; Hussein et *al*, 2015; Manda, 2016) and fertilizer (Doss and Morris, 2001; Kwadzo et *al*, 2010; Chapoto and Ragasa, 2013), from the foregoing and to the best of our knowledge, information on the drivers of adoption of other maize production technologies such as herbicides as well as combinations of available technologies by maize farmers is limited. This study analyses the drivers of adoption of improved maize varieties, fertilizer and row planting combination, herbicide as well as a combination of the aforementioned four technologies using data from smallholder maize farmers in Ghana. The study provides insights into why especially, some Ghanaian maize farmers adopt or do not adopt certain technological packages promoted by the Council for Scientific and Industrial Research (CSIR) and the Ministry of Food and Agriculture (MOFA) of Ghana (improved seeds, fertilizer, row planting and herbicide) in order to highlight the constraints and opportunities for improving adoption of improved maize production technologies.

MATERIALS AND METHODS

Study Area and Data Collection

The study was conducted in the four main agro ecological zones of Ghana, viz. northern savannah, transitional, forest and coastal savannah zones (Figure 01). The Northern Savannah zone is located along the North eastern corridor of the Northern Region with a total land area of about 125,430 square kilometres. The tropical continental climate and Northern Savannah vegetation type are seen in this area. The Transitional zone, which is located around the middle portion of the Brong Ahafo Region and the northern part of Ashanti Region, covers a total land area of about 2300 square kilometres. The zone is characterized by a wet semi-equatorial climate while the vegetation is the savannah woodland and a forest belt. The Forest zone, covering an area of about 135,670 km^2, is floristically divided into a rain forest and semi-deciduous forest and has a population of about 134,354. The climate is a semi equatorial type while the vegetation is a semi-deciduous forest zone with clay, sand and gravel deposits. The Coastal Savannah zone occupies about 20,000 km^2, and comprises the Ho-Keta Plains, the Accra Plains and a narrow strip tapering from Winneba to Cape Coast. The main climatic factor is rainfall, which comes in two peaks. March-July is the main season and September-October is the minor rainy season. August is a dry but cloudy break during which bright sunshine may be less than two to four hours per day.

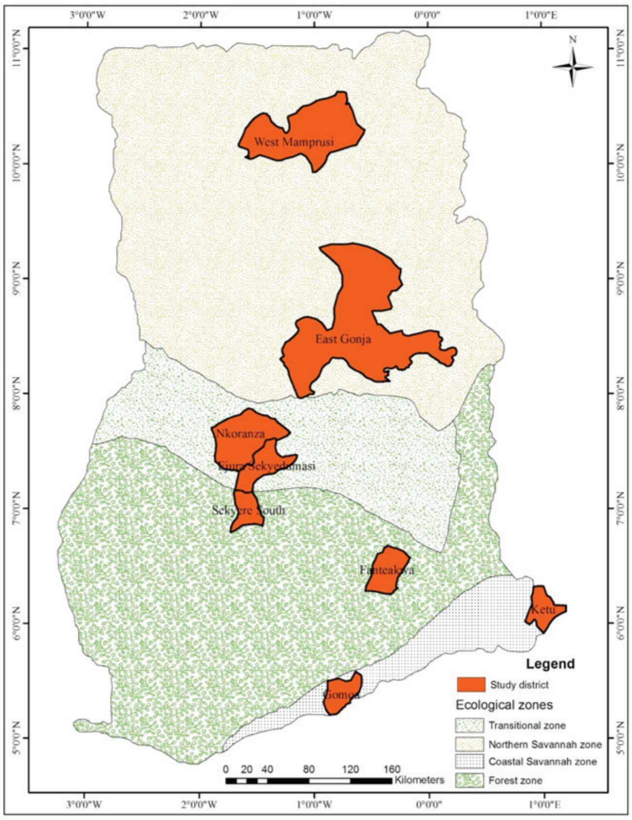

Figure 01: A Map of Various Agro Ecological Zones and District/Municipalities chosen for the study

Source: College of Engineering, Kwame Nkrumah University of Science and Technology, 2015

Farm level primary data on maize production for the 2014 rainy season was collected from 576 maize producers using the structured questionnaire. The study employed multi-stage sampling technique. Two districts/municipalities were purposively selected in the first stage from each agro ecological zone based on the level of maize production. The selected districts/ municipalities were East Gonja and West Mamprusi (Northern Savannah zone), Nkoranza and Ejura Sekyedumase (Transitional zone), Fanteakwa and Sekyere South (Forest zone) and Gomoa and Ketu (Coastal Savannah zone). The second stage comprised a random selection of nine (9) villages or communities from each of the sampled districts/municipalities. Finally, the third stage was made up of a random sample of eight (8) maize farmers from a list of maize farmers in each of the villages or communities with the aid of agricultural extension agents.

Analytical Framework

The study employed descriptive statistics in presenting socioeconomic characteristics of the respondents. Also, the multinomial logit model was employed to analyse the drivers of adoption of maize production technologies in maize production in Ghana. The analysis of adoption of maize production technologies views technology adoption within a conceptual framework that treats potential adopters as agents who make decisions in their own best interest (Ghimire et *al*, 2015). Adoption of maize production technology is the result of optimization by heterogeneous farm agents (Foster and Rosenzweig, 2010; Janvry et *al*, 2010). This optimization happens in the presence of a budget constraint, access to credit, information and the availability of both the technology and other inputs (Ghimire et *al*, 2015). Households are therefore, assumed to maximize their utility function subject to these constraints (Asfaw et *al*, 2012). The difference between the utility from adopting a maize production technology (U_{iA}) and the utility from not adopting the technology (U_{iN}) may be denoted as U_i^*, such, that a utility maximizing maize farmer, i , will choose to adopt a new technology if the utility gained from adopting the technology exceeds the utility from not adopting the technology ($U_i^* = U_{iA} - U_{iN} > 0$). Since these utilities are not observable, they can be expressed as a function of observable elements in the latent variable model. Following Janvry *et al.,* (2010), Asfaw *et al.,* (2012), Aneani *et al.,* (2012), Kohansal and Firoozzare (2013), Owombo and Idumah (2015), Grabowski *et al.,* (2016), Manda (2016) and Nguyen-Van *et al.,* (2016), the adoption decision can be modelled in a random utility framework as follows:

$$U_i^* = X_i'\alpha + u_i$$

With

$$U_i^* = \begin{cases} 1 \text{ } if \text{ } U_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \quad (1)$$

where U_i^* is the latent variable representing the probability of the maize farmer's decision to adopt a maize production technology/combination, and takes the value '1' if the farmer adopts the technology, '0' otherwise, X_i' denotes independent variables that explain the adoption decision, α is a vector of parameters to be estimated, and u_i is the error term which is assumed to be independent and normally distributes as $u_i \sim N(0,1)$. The multinomial logit model of multiple choices concerning modern technologies is stated according to Greene (2005) as: given Y_i to be a random variable which represents the preference of a production technology by famer *i* , then;

$$P_{ij}=E(Y_i=j \mid x_i)=F(\alpha+\beta x_i), \quad j=0,1,\ldots\ldots.6 \quad (2)$$

$$= \frac{1}{1+\sum_{j=1}^{3} e^{-z_i}}, where \ z_i = \alpha + \beta x_i \quad (3)$$

$$= \frac{e^{z_i}}{1+\sum_{j=1}^{3} e^{z_i}} \quad (4)$$

Where $P_{ij}=E(Y_i=j|x_i)$ is the likelihood that maize farmer *i* employs production technology, *j:j = 0* is the based category of not using the production technology, *j = 1* is adoption of only improved seeds, *j = 2* is adoption of only fertilizer and row planting, *j = 3* is adoption of only herbicides and *j = 4* is adoption of a combination of all four technologies (improved seed, fertilizer, row planting and herbicide). The *βs* represent the coefficients of the parameters to be estimated and *α* is the constant term. The decision to choose *j* is influenced by several factors, x_i , which consists of internal factors and external factors. Using equation (4), the probability of not using production technology *j* is given by:

$$1 - P_{ij} = E(Y_i = 0 \mid x_i) = \frac{1}{1+\sum_{j=1}^{3} e^{z_i}} \quad (5)$$

The odds ratio, which is the ratio of the probability of adoption of the production technology to the probability of not using the technology, is given as:

$$\frac{P_{ij}}{1-P_{ij}} = \frac{\frac{e^{z_i}}{1+\sum_{j=0}^{3} e^{z_i}}}{\frac{1}{1+\sum_{j=1}^{3} e^{z_i}}} = e^{z_i} \quad (6)$$

The log-odds after normalizing the probabilities and adding the error term is also given as:

$$\ln\left(\frac{P_{ij}}{1-P_{ij}}\right) = z_i = \alpha + \beta x_i + \varepsilon_i \quad (7)$$

where the dependent variable z_i , is the log of the ratio of the likelihood of adoption of a given technology to the likelihood of not adopting the technology. In this study, it comprises four (4) categories of adoption of improved inputs described as follows; if the farmer had adopted only improved seeds, then *j* = 1,0 otherwise; *j*=2 if the farmer adopted only a combination of fertilizer and row planting technologies, 0 otherwise; *j* = 3 if the farmer adopted only herbicides, 0 otherwise; and *j* = 4 if the farmer adopted a combination of all four technologies. Also, x_i are factors influencing adoption of the various production technologies/combinations, viz. *GENDER* = Gender of maize farmer, measured as a dummy (1 for male and 0 for female), *HOSIZE* = Household size, measured as number of family members living with maize farmer, *AGE* = Age of maize farmer, measured in years, *EDU* = Maize farmer's educational level, measured in the number of years of schooling, *EXP* = Maize farming experience, measured in the number of years in maize farming, *LANDSZ* = Area cultivated with maize, measured in hectares, *NPLOTS*= Land fragmentation, measured as a dummy (1 for owning more than one farm plot and 0 otherwise), *CAPgin* = Capital at the beginning of production (Initial capital outlay), measured in Ghana Cedis, *NOEXTVI* = Extension contact, measured in the number of meetings of maize farmer with agricultural extension agents per season, *MGROUP* = Membership of a farmer association, measured as a dummy (1 for membership of an association and 0 otherwise), *CREDIT* = Access to credit, measured as a dummy (1 for access to credit and 0 otherwise), *SPMAIj12k* = Selling price of maize in the previous season, measured in Ghana Cedis, *REDYMKT* = Access to ready maize market, measured as a dummy (1 for available maize market and 0 otherwise), *NOSAV* = Living in the Northern Savannah zone, measured as a dummy (1 for living in Northern Savannah zone and 0 for living in the Coastal Savannah zone), *TRASIT* = Living in the transitional zone, measured as a dummy (1 for living in transitional zone and 0 for living in the Coastal Savannah zone) and *FOREST* = Living in the Forest zone, measured as a dummy (1 for living in Forest zone and 0 for living in the coastal savannah zone). For a comprehensive interpretation of the coefficients of the multinomial logit model, Gujarati (2004) and Greene (2005) suggested the derivation of the marginal effects of the independent variables. According to Greene (2005), by differentiating equation (3), the marginal effect is obtained as:

$$\delta_j = \frac{\partial P_i}{\partial x_i} = P_j\left[\beta_j - \sum_{k=o}^{J} P_k\beta_k\right] = P_j\left[\beta_j - \bar{\beta}\right] \qquad (8)$$

The multinomial logit model is usually preferred by researchers to the multinomial probit model because computation of its probabilities is simple (Gujarati, 2004; Greene, 2005). Also, multinomial probit model is susceptible to a number of estimation problems, the most serious of which is that the multinomial probit model is often weakly identified in application. Weak identification is difficult to diagnose and may lead to plausible, yet arbitrary or misleading inferences. Notwithstanding the great strengths of the multinomial logit model, it is sometimes criticized because it imposes the independence of irrelevant alternatives (IIA) property on technology/combination choice. For most applications the IIA property is neither relevant nor particularly restrictive (Dow and Endersby, 2004).

RESULTS AND DISCUSSION

Descriptive Analysis of Maize Farmers' Socioeconomic Characteristics

The results show that 77.4% of the sampled maize farmers were males while 22.6% were females (Table 01), an indication of active male involvement in maize production than females in the study area. This result is consistent with those of Sadiq *et al.,* (2013) and Oladejo and Adetunji (2012) that also reported the dominance of males in maize production in Nigeria. Also, there was no significant difference in male gender among adopters and non-adopters of maize production technologies in the study area (Table 02). This finding is consistent with those of recent similar studies (Challa and Tilahun**,** 2014; Ghimire et *al*, 2015).

Even though the majority of maize farmers (56.9%%) were aged from 18 to 45 years (Table 01), the average ages of adopters and non-adopters (41.8-50.2) show that in general, the sampled farmers were old (Table 02). Similar findings were reported by Akpan (2010) as well as Ojiako and Ogbukwa (2012). With a significant difference between the mean ages of adopters and non-adopters of maize production technologies (Table 02) and the mean age of adopters indicating a younger adopter age, old age could negatively affect maize farmers' adoption of maize production technologies.

The results of educational level of the sampled farmers show that 35.9% of maize farmers had received no formal education suggesting that majority of them (64.1%) were formally educated. Oladejo and Adetunji (2012) also obtained similar results for maize farmers in Nigeria. Generally, the educational levels of adopters were significantly higher vis-à-vis non-adopters, indicating that adopters of production technologies are more educated than non-adopters (Table 02).

The implication is that, giving maize farmers formal education could have a positive influence on their adoption of desired technologies. Recent similar studies also reported similar findings (Bernard et *al*, 2010; Challa and Tilahun, 2014; Ghimire et *al*, 2015).

Table 01: Characteristics of maize farmers interviewed

Variables	Sub level	Freq	%
Gender	Male	446	77.4
	Female	130	22.6
	Total	576	100
Age in years	18-45	328	56.9
	46-60	180	31.2
	Greater than 60	68	11.8
	Total	576	100
Educational level of farmer	No formal education	207	35.9
	Primary school	84	14.6
	Middle school/JSS/JHS	200	34.7
	SSS/SHS	69	12
	Training college/Tertiary	16	2.8
	Total	576	100
Number of plots	One plot	454	78.8
	More than one plot	122	21.2
	Total	576	100
Association membership	No	436	75.7
	Yes	140	24.3
	Total	576	100
Ready market last year	No	70	12.2
	Yes	506	87.8
	Total	576	100
Access to extension	No	331	57.5
	Yes	245	42.5
	Total	576	100
Access to credit	No	475	82.5
	Yes	101	17.5
	Total	576	100
Source of credit	ADB	4	4
	GCB	4	4
	Rural bank	22	15.8
	Savings and Loans	13	12.3
	Credit unions	16	10.8
	Informal sources(friends, etc)	42	53.1

Source: Survey, 2015

Note: ADB = Agricultural Development Bank, GCB = GCB Bank Limited

Table 02 shows that on average, even though both adopters and non-adopters of production technologies have appreciable high levels of maize farming experience (at least 11 years), and the results show that adopters of especially all technologies have significantly higher levels of experience than non-adopters, depicting a positive correlation between farming experience and adoption of production technologies. This corroborates the findings of Bernard *et al.,* (2010) even though it disagrees with the findings of Kwadzo *et al.,* (2010) and Ghimire *et al.,* (2015) that reported insignificance of the mean experience difference between adopters and non-adopters of recommended agricultural technologies.

The mean household size for both adopters and non-adopters of the technologies ranged from 4 to 7 with those of adopters being significantly higher than those of non-adopters (Table 02). With maize production being a labour intensive activity, the results showed that adopters had some family labour which encouraged adoption of especially, labour intensive technologies. This finding, which agrees with Bernard *et al.,* (2010) as well as Challa and Tilahun (2014), also disagrees with other previous similar studies (Kwadzo et *al*, 2010; Ghimire et *al*, 2015).

The number of farm plots owned or operated by the sampled maize farmers was also significantly higher for non-adopters than adopters of the various technologies. Generally, the sampled maize farmers cultivated small farms of sizes ranging from 1.37 to 4.38 hectares (ha) for both adopters and non-adopters of the production technologies with adopters cultivating relatively higher farm sizes (Table 02). The results also show that there was a significant difference between the mean farm sizes of adopters and non-adopters of production technologies and this confirms similar findings reported by Challa and Tilahun (2014) as well as Ghimire *et al.,* (2015). The study however, disagrees with the findings of Bernard *et al.,* (2010) and Kwadzo *et al.,* (2010) that reported insignificant differences between the mean farm sizes of adopters and non-adopters of agricultural technologies.

The results in Table 01 show that a greater proportion of the respondents (57.5%) had no contact with the extension agents. Table 02 also shows that the number of visits by agricultural extension officers to adopters of maize production technologies was significantly more than visits to non-adopters, indicating a poor provision of extension service triggering low adoption of production technologies.

Table 02: Characteristics of adopters and non-adopters of maize production technologies (Test of Equality of Means)

Variable	Improved Seed			Fertilizer/Row Planting			Herbicide			All Technologies		
	Adopter	Non-Adopter	t-value	Adopter	Non-Adopter	t-value	Adopter	Non-Adopter	t-value	Adopter	Non-Adopter	t-value
Age (Years)	43.30	50.20	-3.34***	45.20	49.11	-2.15**	41.78	47.12	-1.31**	42.55	45.28	-1.78*
Male Gender	72.3	69.2	0.37	63.4	58.9	2.19	71.5	68.8	1.94	58.9	52.4	3.56
Education(Years)	6.92	4.94	2.15*	5.91	4.93	1.01	6.12	4.07	3.44**	7.47	4.81	1.41**
Experience(Years)	14.03	13.31	1.15	15.22	11.34	1.24	16.44	13.83	0.45	17.42	13.46	0.06**
Farm size (ha)	4.38	2.41	0.03**	2.81	2.28	1.37*	3.54	2.15	1.81*	2.26	1.37	0.29*
No. of farm plots	5.28	2.21	1.49***	3.14	1.58	0.07**	4.21	3.11	1.78	3.51	1.67	0.16**
Extension visits	2.74	1.12	0.07**	2.82	1.55	1.84*	3.31	1.94	2.11***	2.27	1.13	1.46***
Credit (Gh¢/ha)	221	127	1.21***	184	125	2.78*	334	134	1.81***	198	135	0.08*
Size of household	7.12	5.61	0.44*	6.89	4.59	1.43**	7.48	6.41	2.11	5.98	3.78	2.44**
Price(Gh¢/Kg)	1.10	0.81	0.09	0.89	0.74	0.04	0.78	0.62	1.41	0.94	0.78	0.45*
Capital (Gh¢)	542	289	1.45***	581	512	0.21*	615	432	2.41***	494	312	1.47**

Source: Survey, 2015

Note: *** is significant at 1%, ** is significant at 5% and * is significant at 10%.

This finding corroborates those of Kwadzo *et al.,* (2010) and Ghimire *et al.,* (2015). Also, with most maize farmers not receiving an agricultural extension service, it will not be surprising if adoption rates are low since farmers will likely be unaware of recommended technologies. This is because those who are supposed to disseminate the technologies to them (i.e, extension agents) are far from them. Also, the majority of sampled farmers (75.7%) did not belong to any farmer association (Table 01). This could prevent most of the farmers from becoming aware of recommended maize production technologies, thereby causing low adoption. This is because, extension agents are used to disseminating technologies through farmer based organizations. In fact, most of the respondents (82.5%) had no maize production credit from any financial source be it formal or informal (Table 01).

Also, most of those who received credit (53.1%) had it from informal financial sources. Few maize farmers in Ghana received production credit probably because of the reluctance of most financial institutions to support agricultural production with credit facilities probably due to the perceived risky nature of agricultural production. The result is in line with Awunyo-Vitor (2012) that only Agricultural Development Bank (ADB) offered production credit to maize farmers. Also, according to Awunyo-Vitor (2012), only 18% of the sampled universal banks offered credit for agricultural production in general but this time, it was only for registered agricultural businesses that could present a well-structured financial statement and appropriate records on their operations. Obviously, smallholder maize farmers will find it difficult meeting the loan requirements of most universal banks if the aforementioned criterion is anything to go by, hence the low credit access received by farmers in the country. Table 02 also shows that the mean amounts of credit received by adopters of maize production technologies were significantly higher than amounts received by non-adopters of technologies. This is not surprising since credit enhances the purchasing power of farmers, thereby making them able to procure and meet the demands of adopting production technologies**.** This result agrees with the findings of Challa and Tilahun **(**2014) that there is a significant difference between the credit received by adopters and non-adopters of agricultural production technologies. Finally, there appeared to be a significant difference in the previous season's price of maize and initial capital outlay of the sampled maize farmers between adopters and non-adopters. The prices and capital outlays were significantly higher for adopters vis-à-vis non-adopters. This is expected since higher prices encouraged investments in recommended technologies and appreciable levels of initial capital outlay made it possible for farmers to be able to purchase and meet application requirements of production technologies.

Adoption of Maize Production Technologies by Sampled Farmers

Figure 02 shows that few of the maize farmers in all agro ecological zones adopted all technologies, indicating that most farmers adopted either a single technology, a combination of some of them or none. Moreover, 16.7%, 18.1%, 11.8% and 11.8% of maize farmers in the Northern Savannah, Transitional, Forest and Coastal Savannah zones respectively did not adopt any of the technologies (i.e, improved seed, fertilizer, row planting and herbicides). Generally, the sampled maize farmers adopted different categories of maize production technologies in maize production. Adoption of a combination of fertilizer and row planting was practiced by the majority of respondents in almost all agro ecological zones, indicating that farmers appreciate the importance of fertilizer and row planting in maize production. That is, with the exception of the Forest zone where herbicide was most adopted, a combination of fertilizer and row planting was most adopted in the rest of the agro ecological zones, as 48.8% of maize farmers in the pooled sample, 63.9% of maize farmers in the Northern Savannah zone, 43.8% of maize farmers in the Transitional zone and 54.2% of maize farmers in the Coastal Savannah zone adopted only fertilizer and row planting technologies combination.

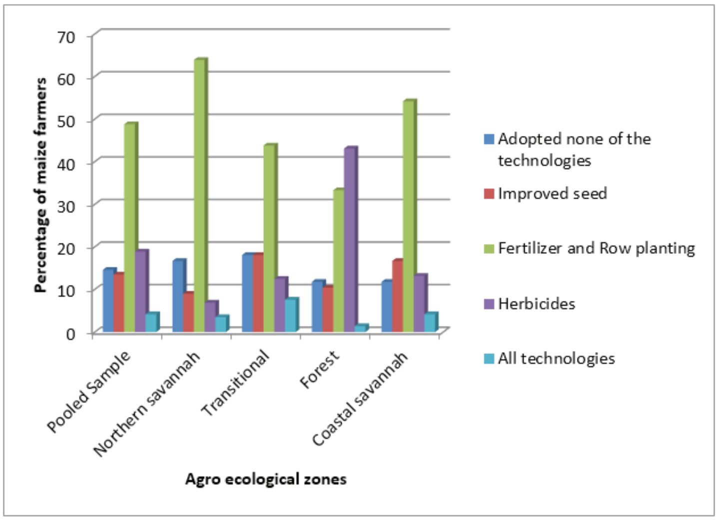

Figure 02: Maize farmers' adoption of production technologies

Source: Survey, 2015

This finding is consistent with Ragasa *et al.,* (2013) in Ghana and very recently, Saliu *et al.,* (2016) in Nigeria. Herbicide technology was most adopted in the Forest zone because the lands there were not good for ploughing because of the presence of many trees. Therefore, the maize farmers in this zone preferred chemical control of weeds instead of mechanical ploughing. Farmers in the Forest zone, to plough, have to spend so much on felling trees and removing stumps and this is uneconomical, hence the resultant in popularity of herbicide adoption in this agro ecological zone. This is in line with the findings of Ragasa *et al.,* (2013) which also reported the prevalence of herbicide adoption in the forest belt of Ghana.

Factors Influencing Adoption of Maize Production Technologies

The estimated coefficients of the multinomial logit models, along with the levels of significance and marginal effects are presented in Table 03. The likelihood ratio statistic is significant at the 1% level of significance for each model, suggesting the robustness of the models. The coefficients and the marginal effect of age are negative and significant for adoption of improve seed ($p<0.05$) as well as fertilizer and row planting ($p<0.1$) but insignificant for the adoption of herbicides and all technologies. The marginal effects reveal that a unit increase in the age of a maize farmer would result in a 0.4% and 0.2% decrease in the probability of adopting improved seed as well as fertilizer and row planting technologies respectively. This is in line with the results presented in Table 02 that there is a significant difference in the mean ages of adopters and non-adopters of maize production technologies. The reasons for the inverse relationship between age and adoption of fertilizer and row planting were the conservative nature of older farmers and the risk taking behavior of younger farmers. This finding is consistent with many agricultural technology adoption studies (Bernard et *al*, 2010; Akudugu et *al*, 2012; Ogada et *al*, 2014; Letaa et *al*, 2015; Owombo and Idumah, 2015; Hussein et *al*, 2015). It however, disagrees with the findings of Aneani *et al.,* (2012) and Grabowski *et al.,* (2016).

Also, farming experience is positive and statistically significant for adoption of all technologies at the 5% significance level but is insignificant for adoption of improved seed, fertilizer and row planting as well as herbicide. That is, a year increase in maize farming experience will increase the probability of adoption of all technologies by 0.2%. This is consistent with the results in Table 02 as well as Bernard et *al*, 2010 and Letaa *et al.,* (2015) but disagrees with the findings of Aneani *et al.,* (2012), Aidoo *et al.,* (2014) and Saliu *et al.,* (2016).

Table 03: Parameter estimates and marginal effects of the multinomial logit model for determinants of adoption of maize technologies for maize farmers in Ghana

Independent	Improved	Seed	Fertilizer/Row Planting		Herbicides		All technologies	
Variable	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx	Coeff/SE	dy/dx
Constant	-4.162		-0.284		-0.097		-5.483	
	(1.482)		(0.913)		(1.039)		(2.170)	
HOSIZE	1.015	0.046*	0.435	0.007***	0.061	0.003**	0.733	0.004
	(0.607)		(0.380)		(0.424)		(0.795)	
SEX	0.366	0.006	0.330	0.017	0.634	0.002	0.438	0.002
	(0.503)		(0.351)		(0.403)		(0.645)	
AGE	-0.026**	-0.004	-0.024	-0.002*	-0.025	-0.015	0.020	0.007
	(0.021)		(0.014)		(0.017)		(0.026)	
EDU	0.081	0.002*	0.059	0.002**	0.058	0.009**	0.072	0.003**
	(0.047)		(0.036)		(0.042)		(0.063)	
EXP	0.028	0.003	0.010	0.005	0.017	0.001	0.086	0.002**
	(0.026)		(0.016)		(0.020)		(0.039)	
LANDSZ	-0.163	-0.015**	0.008	0.014**	0.049	0.049*	0.004	0.008***
	(0.119)		(0.018)		(0.020)		(0.151)	
NPLOTS	0.606	0.012**	0.492	0.004***	0.071	0.003	2.0006	0.026**
	(0.299)		(0.161)		(0.102)		(0.797)	
CAPgin	0.007	0.002**	0.006	0.039**	-0.005	0.006	0.003	0.025
	(0.003)		(0.003)		(0.003)		(0.005)	
NOEXTVI	0.697	0.028***	0.415	0.002***	0.148	-0.001	0.662	0.004***
	(0.132)		(0.125)		(0.143)		(0.139)	
MGROUP	0.279	0.009*	0.368	0.143*	0.938	0.139**	0.131	0.072
	(0.663)		(0.556)		(0.018)		(0.803)	
CREDIT	2.896	0.117***	1.965	0.031**	1.273	0.003	2.558	0.011***
	(0.853)		(0.788)		(0.908)		(0.968)	
SPMAIj12k	0.986	0.049	0.422	-0.049	0.351	-0.007	2.806	0.039**
	(0.785)		(0.513)		(0.549)		(1.279)	
REDYMKT	1.675	0.030**	1.554	0.171***	0.542	-0.005	0.657	-0.014
	(0.668)		(0.384)		(0.458)		(0.731)	
NOSAV	2.697	0.247***	0.679	0.272**	0.457	0.005*	3.558	0.094***
	(0.830)		(0.476)		(0.611)		(1.174)	
TRASIT	2.395	0.310***	-0.015	-0.348	-0.285	-0.003	2.749	0.074***
	(0.729)		(0.451)		(0.531)		(0.985)	
FOREST	1.841	0.208**	0.164	-0.184	0.971	0.621***	0.467	0.009
	(0.801)		(0.483)		(0.528)		(1.231)	
Number of Observations				571				
LRchi2 (64)				429.51				
Prob> chi2				0.000				
Pseudo R2				0.2792				
Log likelihood				-554.423				

Source: Survey, 2015

Note: Coeff = Coefficient, SE=Standard errors are in parentheses. *** is significant at 1%, ** is significant at 5% and * is significant at 10%. dy/dx represents marginal effects.

The coefficients and marginal effects of the variable representing farm size are positive for adoption of all technologies, herbicides as well as fertilizer and row planting and these are significant at 1%, 10% and 5% levels respectively (Table 03). The marginal effects show that an increase in land under maize cultivation by one hectare would increase the probability of a maize farmer adopting all technologies, herbicides as well as fertilizer and row planting by 0.8%, 4.9% and 1.4% respectively. This result reflects the significant mean difference between the farm sizes of adopters and non-adopters reported in Table 02. The positive effect of farm size on the aforementioned technologies is on the premise that maize farmers with large farm sizes have already assumed some risk and therefore, will do the best they can, to maximize yield. Therefore, once a technology has proven to be effective in improving yield, they will do their best to adopt it. Similar findings of positive effects of farm size on adoption of agricultural technologies have also been reported by previous similar studies (Kwadzo et *al*, 2010; Challa and Tilahun**,** 2014; Owombo and Idumah, 2015; Manda, 2016; Saliu et *al*, 2016). The coefficient and marginal effect of farm size are however, negative for adoption of improved seeds and this is significant at 5%. The marginal effect showed that an increase in farm size by one hectare would increase the probability of maize farmers' adoption of improved seeds by 1.5%. The negative relationships observed could be the result of inadequate funds to meet the demands of large farms so even though farmers may have the desire to adopt these technologies their low purchasing power would prevent them from adopting the technologies. This finding agrees with the findings of Jaleta *et al.,* (2013) and Aidoo *et al.,* (2014) in which negative correlations between farm size and adoption of maize production technologies were reported**.** Land fragmentation variable is positive and significant for adoption of improved seeds ($p<0.05$), fertilizer and row planting ($p<0.01$) as well as adoption of all technologies ($p<0.05$) but insignificant for adoption of herbicide (Table 03). This is consistent with the significant difference observed between number of farm plots owned by adopters and non-adopters of improved seeds, fertilizer and row planting as well as all technologies (Table 02). The marginal effects imply that an increase in the number of farm plots owned or operated by a maize farmer will increase his/her probability of adopting improved seed, fertilizer and row planting as well as all technologies by 1.2%, 0.4% and 2.6% respectively. Land fragmentation is positively correlated with adoption because owning many farm plots will create avenues for farmers to be able to adopt the new technologies in some of their plots while maintaining some of the old technologies on other plots in order to reduce the risk associated with the new technology. The result is in consonance with the findings of Tedla (2011) and Aneani *et al.,* (2012).

The results show that the number of extension visits variable is statistically significant at the 1% significance level for adoption of improved seeds, all technologies as well as fertilizer and row planting. The marginal effects imply that an increase in extension contact by one visit would increase the likelihood of a maize farmer adopting improved seeds, all technologies as well as fertilizer and row planting by 2.8%, 0.4% and 0.2% respectively (Table 02). This might be due to the negative effect of lack of years of formal education in the overall decision to adopt some agricultural technologies. A number of previous studies have also reported a positive influence of extension contact on adoption of agricultural technologies (Kwadzo et *al*, 2010; Bernard et *al*, 2010; Ghimire, 2015; Owombo and Idumah, 2015; Yirga et *al*, 2015; Manda, 2016) even though recently, Nguyen-Van *et al.,* (2016) reported negative effects for tea farmers in Vietnam. The positive effect of education variable is statistically significant at 10% for adoption of improved seed and 5% for the other technology categories (Table 03). Consistent with the results presented in Table 2, the marginal effects reveal that an increase in the level of education by one more year will increase the probability of a maize farmer's adoption of improved seeds, a combination of fertilizer and row planting, herbicides and a combination of all four technologies by 0.2%, 0.2%, 0.9% and 0.3% respectively (Table 03). The implication is that formally educated farmers easily adopt recommended technologies vis-à-vis farmers with no formal education. This is because higher education influences farmers' attitudes and thoughts making them more open, rational and they are able to analyze the benefits of the new technology. Formal education also increases farmers' ability to obtain, process and use information relevant to adoption of a new technology. This finding confirms the results of similar studies conducted in Ghana and other parts of the world including Jaleta *et al.,* (2013), Ogada *et al.,* (2014), Aidoo *et al.,* (2014), Yirga *et al.,* (2015), Challa and Tilahun (2014), Owombo and Idumah (2015), Ghimire *et al.,* (2015) and Grabowski *et al.,* (2016).

The marginal effects in Table 03 also show that an increase in the household size of a maize farmer by one person would increase the probability that the farmer will adopt improved seeds ($p<0.1$), fertilizer and row planting ($p<0.01$) as well as herbicides ($p<0.05$) by 4.6%, 0.7% and 0.3% respectively. The implication is that maize farmers with large family sizes are more likely to adopt maize production technologies than those with small families. This is because a large household size working on the farm reduces the farms' external labour requirements, making farmers being able to meet the labour requirements of adopting recommended production technologies. This finding corroborates those of Bernard *et al.,* (2010), Jaleta *et al.,* (2013), Owombo and Idumah (2015), Yirga *et al.,* (2015), Letaa *et al.,* (2015) and Nguyen-Van *et al.,* (2016) even though it disagrees with Challa and Tilahun (2014) which reported a significant negative effect of household size on adoption of agricultural technologies. Membership of a farmer association was found to be significant and positively related to adoption of improved seeds ($p<0.1$), fertilizer and row planting ($p<0.1$) as well as herbicides ($p<0.05$). The marginal effects imply that farmers who belong to farmer associations will more likely have their probabilities of adopting improved seeds, fertilizer and row planting as well as herbicides increased by 0.90%, 14.3% and 13.9% respectively. This is because agricultural technologies are normally disseminated through farmer associations and therefore, farmers who belong to such associations will more likely have access to knowledge of suggested technologies than those who are not members of such associations. Belonging to a farmer group also enhances social capital allowing trust, idea and information exchange as well as learning the benefits and usage of a new technology from each other. Consistent with this finding are the results of the works of Bernard *et al.,* (2010), Kwadzo *et al.,* (2010), Jaleta *et al.,* (2013), Owombo and Idumah (2015), Manda (2016), Saliu *et al.,* (2016) and Nguyen-Van *et al.,* (2016) that found a positive influence of group or association membership on adoption of agricultural technologies.

The coefficient of the variable representing access to credit has a positive and significant effect on adoption of improved seeds ($p<0.1$), fertilizer and row planting ($p<0.05$) as well as a combination of all four technologies ($p<0.1$). With a significant difference between the average credit received by adopters and non-adopters of maize production technologies (Table 02), the marginal effects reveal that access to credit would increase the probability of a maize farmer adopting improved seeds, fertilizer and row planting as well as a combination of all four technologies by 11.7%, 3.1% and 1.1% respectively (Table 03). The implication is that access to credit is crucial to adoption of maize production technologies. This is because access to credit reduces the liquidity constraints that maize farmers normally face in trying to purchase and use new technologies. This is in line with the results of previous similar studies (Kwadzo et *al*, 2010; Jaleta et *al*, 2013; Challa and Tilahun, 2014; Aidoo et *al*, 2014; Ogada et *al*, 2014) but contradicts the findings of Aneani *et al.,* (2012). Similarly, the coefficient of the variable representing initial capital outlay is positive and significant for adoption of improved seed ($p<0.05$) as well as fertilizer and row planting ($p<0.05$) (Table 03). The marginal effects imply that enough money for the farmer at the beginning of production will increase his/her probability of adopting improved seed as well as fertilizer and row planting by 0.2% and 3.9% respectively (Table 03). This, together with the results in Table 02 is expected since money is needed to purchase the technologies. The effect of the variable for access to ready market was found to be significant and positively related to adoption of improved seeds ($p<0.05$) as well as fertilizer and row planting ($p<0.01$) but insignificant for adoption of herbicide and all technologies (Table 03). The marginal effects imply that access to ready market by a maize farmer will increase his/her probability of adopting improved seeds as well as fertilizer and row planting by 3.0% and 17.1% respectively (Table 03). This is because, the presence of ready market encourages farmers to put in their best to map out resources for purchasing appropriate production technologies as they are assured of ready market for their produce. This is consistent with the findings of Kwadzo *et al.,* (2010), Ogada *et al.,* (2014) and Manda (2016). The variable representing the previous year's price of maize has a positive significant relationship with adoption of a combination of all four technologies ($p<0.05$) but was not significant with adoption of improved seed, fertilizer and row planting as well as herbicide. Consistent with the results in Table 02, the marginal effects reveal that an increase in the previous year's price of maize by one Ghana Cedi will increase the likelihood of a maize farmer adopting a combination of all four technologies by 3.9%. This is because an increase in the previous year's price will let maize farmers have confidence in maize production as a profitable venture, thereby allowing them to strive to employ all possible production technologies in their production as they are assured of a favourable produce price. This result is consistent with earlier similar studies (Jack, 2013; Sanga and Mahonge, 2014; Letaa et *al*, 2015).

Finally, the coefficients of the variable representing maize farmers living in the Northern Savannah zone of Ghana are significant, and positively related to adoption of improved seeds ($p<0.01$), fertilizer and row planting ($p<0.05$), herbicides ($p<0.05$) and all technologies ($p<0.01$) (Table 3). The marginal effects reveal that living in the Northern Savannah zone will increase the probability of adoption of improved seeds, fertilizer and row planting, herbicides as well as a combination of all four technologies by 24.7%, 27.2%, 0.5% and 9.4% respectively (Table 03). Adoption of all technologies in the Northern Savannah zone could be one of the positive impacts of the Savannah Accelerated Development Authority (SADA) project that supplied production inputs to farmers in the northern part of the country. The variable for living in the Transitional zone was also found to be positive and statistically significant for adoption of improved seeds ($p<0.01$) and a combination of all four technologies ($p<0.01$) but was not significant for adoption of fertilizer and row planting as well as herbicides (Table 03). The marginal effects imply that living in the Transitional zone will increase maize farmer's probability of adopting improved seeds and all technologies by 31.0% and 7.4% respectively (Table 03). Adoption in the Transitional zone is due to the availability of improved inputs and a well-developed road transport system which facilitate the flow of inputs and outputs (Morris et *al*, 1999). The variable for farmers living in the Forest zone was also positive and statistically significant for adoption of improved seeds ($p<0.05$) and herbicides ($p<0.01$). We infer from the marginal effect that living in the Forest zone has the effect of increasing the likelihood of adoption of improved seeds and herbicides by 20.8% and 62.1% respectively (Table 03). The astronomical increase in the use of herbicides in the Forest zone is probably due to the fact that lands in this zone have many trees which make ploughing very expensive, making maize farmers resort to using herbicides as an alternative to mechanical ploughing (Figure 02). This corroborates the findings of Ragasa *et al.,* (2013).

CONCLUSIONS

There is a huge gap between actual and achievable yield in Ghana's maize production and with maize accounting for over 50% of the country's total cereal, its low yield could threaten Ghana's household food security. This study examined the drivers of adoption of maize production technologies by Ghanaian maize farmers using data from four agro ecological zones of Ghana. The results showed that adoption of maize production technologies is influenced by a number of factors. Firstly, the higher the educational level, the higher the likelihood of adoption of production technologies. This is because farmers with higher education can think and act rationally. Secondly, higher levels of initial capital outlay and access to credit will increase adoption because they reduce the liquidity constraints that a normal maize farmer faces in trying to purchase and use new technologies. Thirdly, an increase in contact with agricultural extension agents and membership of farmer associations will likely increase adoption of modern technologies. With access to agricultural extension service, maize farmers become aware of new technologies and their applications. Membership of farmer associations is necessary because most of the agricultural technologies and new methods of farming are usually being disseminated through farmer based organizations. Farmers' access to ready market and the previous year's price of maize have a positive impact on technology adoption. This is because, the presence of a ready market and an increase in the previous year's price of maize do motivate the farmers allowing them to apply required methods and technologies. In addition, land fragmentation will increase adoption because owning many farm plots will create avenues for farmers to be able to adopt the new technologies in some of their plots while maintaining some of the old technologies on other plots in order to reduce the risk associated with the new technology. Moreover, younger farmers were found to be better adopters because older farmers are risk averters. Furthermore, farmers with large farm sizes have already assumed some risk and therefore, will do the best they can to maximize yield, thereby making such farmers adopt improved production technologies. Finally, farmers with many members as well as more experience were found to be good adopters. The study also found that in general, the adoption of new technologies was independent of where the farmer was residing.

With adoption of technologies increasing with formal education, technology dissemination programmes will be effective if literate farmers are targeted. Also, extension officers should encourage maize farmers to join Farmer Based Organizations by making farmers aware of the benefits of joining such organizations. In places where such organizations do not exist, extension officers should assist maize farmers to form teams. In addition, key stakeholders in the maize industry comprising the government and non-governmental organizations could assist farmers to increase their adoption of new technologies by supporting them with production capital in the form of credit. Moreover, policy makers through the Ministry of Food and Agriculture should analyse the problems faced by the extension officers and take the necessary actions to solve them. This will pave the way for the provision of appropriate incentives to extension officers. Furthermore, government and other stakeholders should join hands to devise strategies aimed at providing maize farmers with readily available markets and a guaranteed favourable price for their produce. Finally, younger farmers should be encouraged to consider maize production as a business since they are better adopters of production technologies. Policy makers can do this by incorporating agricultural production and entrepreneurship as a core course in the curricula of all levels of education in the country and by creating a favourable environment for youths to adopt improved agricultural production technologies.

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