Journal of Sustainable Development in Africa (Volume 21, No.4, 2019)

ISSN: 1520-5509

Clarion University of Pennsylvania, Clarion, Pennsylvania

PREDICTORS OF EX-ANTE ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES BY COCOA FARMERS IN GHANA

Martin Bosompem

Department of Agricultural Economics and Extension, School of Agriculture, College of Agriculture & Natural Sciences, University of Cape Coast, Cape Coast, Ghana. West Africa.

Abstract

The purpose of the study was to identify the best predictors of cocoa farmers' willingness to adopt future precision agriculture technologies (PATs) in Ghana. The target population was all cocoa farmers who benefited from cocoa high technology programme (an initiative of distributing free fertilizer by the government to selected cocoa farmers) in Ghana. A total of 416 cocoa farmers who are beneficiaries of the programme were interviewed. Majority (83%) of the respondents were willing to adopt future PATs development in Ghana. The binary logistic regression model explained between 37.5% to 60.4% of the variances in cocoa farmers' willingness to adopt any future PATs. The significant predictors of respondents' willingness to adopt future PATs were: i. educational level of cocoa farmers; ii. cocoa farmers who plant in rows; iii. credit from financial institution; iv. relative advantage of PATs and v. farmers' perceived ease of use of PATs. The strongest predictor of farmers' willingness to adopt any future PATs was "row planting" indicating that farmers who had already planted in rows are more likely to adopt future PATs than those who had not yet done so. The study recommended, among others, the need to create awareness among farmers and other major stakeholders in cocoa industry of the potential benefits of PAT development in cocoa industry in Ghana.

Keywords: Predictors, Precision Agriculture, Future Adoption, Cocoa High Technology in Ghana, Small scale Farmers, Sub-Saharan Africa

INTRODUCTION

It is an established fact that agricultural development is the cornerstone to African economic transformation, stability and security (World Bank, 2013; Miller & Shinn, 2012). Agriculture is the most important sector in most African countries because it contributes to an average of 24% to GDP while agribusiness input supply, processing, marketing, and retailing add about 20 percent to GDP (World Bank, 2013).

In Ghana, agriculture used to be the major sector of the economy that contributed about 30-40% of GDP barely a decade ago. Agriculture's contribution to Ghanaian economy has declined to about 22% since 2013 due to the expansion of the oil sector and but currently, agriculture contributes approximately 20% of GDP (ISSER, 2014, GSS,2019). Agriculture still contributes to about 50% of national employment who are mostly smallholder farmers (GSS, 2019).

An important crop that plays an indispensable role in Ghana's economy is cocoa (*Theobroma cacao*, L.). It has been a dominant sub-sector in agriculture sector and has contributed to an average of 26% of Ghana's export earnings between 2007 - 2012 (ISSER, 2013). Therefore, a significant growth in export earnings in Ghana, to some extent, depends on the growth of the cocoa sector. The average national annual yield in Ghana averaged 500 kg/ha even though the potential yield has been estimated to be at least 1000 kg/ha (MoFA, 2017). This average is relatively low compared to 800 kg/ha in Côte d'Ivoire, or 1700 kg/ha in Malaysia (Appiah, 2004; Bosompem, Kwarteng, & Ntifo-Siaw, 2011). Hence, there is a potential for yield and productivity increase in Ghana. However, the concerns of major stakeholders in the cocoa sector have not only been on increasing productivity but also *ensuring environmental sustainability* especially in the face of the growing concern of climate change. Hence, the consensus among many agricultural development practitioners in the world is to increase productivity but also ensure environmental sustainability by engaging in agronomic practices that prevent soil erosion, reduce pesticide and fertilizer contamination, protect biodiversity, preserve natural resources and other relevant climatic indicators (Hamideh, Kurosh & Abdol-Azim, 2011). Mandal and Maity (2013), noted the significant aspects of precision agriculture that can ensure agricultural and environmental sustainability which includes:

(a) enhance productivity in Agriculture,

(b) prevent soil degradation in cultivatable land,

(c) reduce agrochemical use in crop production,

(d) efficient use of water resources, and

(e) disseminate modern farm practices to improve quality and quantity of production.

Precision agriculture (PA) technologies have been identified to have the potential to address two major problems: 1. increase agricultural productivity to address the anticipated food insecurities and 2. mitigate and adapt to some climate change effects (Najafabadi, Hosseini and Bahramnejad, 2011). A more recent systematic review of the environmental benefits for adoption of precision agriculture technologies also demonstrated that PA has the potential to mitigate some of the environmental impact of climate change (Koutsos & Menexes, 2019).

The International Society of Precision Agriculture (ISPA) defines Precision Agriculture (PA) as "a management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production" ISPA (2019*).* PA also emphasizes the need to ensure environmental sustainability through judicious use of inputs i.e. applying inputs using the right quantity, at the right place and at the right time. To achieve these, PA combines innovations such as geographic information system *(*GIS), global positioning system (GPS), variable rate technology (VRT) and yield monitors in farming. The site-specific application of inputs and monitoring help minimize cost since inputs like fertilizers, pesticides and water are applied only where they are needed. This also reduces environmental loading and excess applications of agrochemicals and other inputs that can affect the soil microbes as well as beneficial insects. The combination of highly mechanized systems and ICT also facilitates large scale and commercial production.

Because of the aforesaid benefits and potentials, farmers in developed countries have been using PATs for over two decades now. However, the use of PATs is limited in sub-Saharan Africa. (Blackmore, Wheeler, Morris, Morris & Jones, 2003). Except for few yield monitors in South Africa and some VRT fertilization in isolated plantation enclaves, adoption of PA technologies was virtually unknown in Africa (Swinton, 2011), even though the use of GPS, which is the conerstone of PA, is readily available in almost all the countries in Africa. It is reported that by the end of 2013, GPS services covered all 54 African countries with maps that are 3D and interactive (African Business, 2014). Even though these services are mainly for the road navigations, they can also serve as a reference point to develop vegetation and soil maps to facilitate the development of PA in Africa. Moreover, the awareness level of cocoa farmers and the potential factors that affect their willingness to adopt these technologies are not known.

Objective of the paper

The main objective of the study was to identify the predictors of cocoa farmers' willingness to adopt future precision agricultural technologies (PATs) in Ghana. The outcome of this study could serve as a basis for initiating PATs development and implementation in Ghana and the sub-region to ensure agricultural and environmental sustainability among small scale farmers in sub-Saharan Africa.

LITERATURE REVIEW/CONCEPTUAL FRAMEWORK

The literature review focuses on three theories of innovations that guided the study. These are : (1) the diffusion of innovation (DOI) theory posited by Rogers (1983) ; (2) The expanded Rogers's attributes of innovation model by Moore & Benbasat (1991) and (3**)** the technology acceptance model (TAM) by Davis (1989) illustrated by Kim and Garrison (2009). Moreover, other factors that affect adoption of innovation such as demographic and farm-related characteristics, attributes of precision agriculture innovations and farmers' awareness level of precision agriculture technologies are reviewed. The relationship between PA and environmental sustainability is also reviewed.

The diffusion of innovation (DOI)

The DOI theory focuses on the five main variables that determine the rate of adoption of innovations in a social system namely (a) perceived attributes of the innovation, (b) the type of innovation-decision, (c) the nature of communication channels diffusing the innovation at various states in the innovation-decision process, (d) the nature of the social system in which the innovation is diffusing, and (e) the extent of change agents' promotion efforts in the innovation diffusions (Rogers, 2003). However, Rogers (2003) noted that because most adoption studies have shown that between 49 to 87 percent variance in the rate of adoption of innovations, has been explained by 'perceived attributes of the innovation alone, the other four variables have not received much attention by most diffusion scholars. Hence, the DOI theory focused on perceived attributes of innovation (namely: relative advantage, compatibility, complexity, trialability, and observability) to explain the impact on adoption. Adoption decision or intention is, therefore, driven by these five attributes of innovation.

Even though DOI research originally focused on the innovation attributes to determine its rates of adoption, further studies have showed that the adopter characteristics are also very important to the decision to adopt (Rogers, 2013).

The expanded Rogers's attributes of innovation model

Moore and Benbasat (1991) expanded the five attributes of innovations of Rogers to include two (2) main additional attributes namely (1) voluntariness and (2) image. Voluntariness is defined as, "the degree to which use of an innovation is perceived as being voluntary, or of free will" whereas (2) image, is "the degree to which use of an innovation is perceived to enhance one's image or status in one's social system" (Moore & Benbasat 1991, p.195).

The technology acceptance model (TAM)

The TAM posits that individual's acceptance and usage of a technology (especially information technology) are determined by two key perceptions: (1) perceived ease of use (PEOU) and (2) perceived usefulness (PU) of the technology (Davis, 1989). Accordingly, Davis (1989, p.310) defined PU as "the degree to which a person believes that using a particular system would enhance his or her job performance." and PEOU as "the degree to which a person believes that using a particular system would be free of effort" or free from pressure from organizations especially relevant governmental agencies, non-governmental agencies and civil society organizations. It should be noted that TAM is rooted in two (2) of the five (5) attributes of innovation posited by Rogers (1983) i.e. a. relative advantage and b. complexity for which TAM referred to them as 'perceived usefulness' and 'perceived ease of use' respectively.

Cocoa farmers' perceived attributes of precision agriculture innovations in cocoa production.

Applying these three theories to this study, Rogers' (1985) five (5) characteristics or attributes of innovations that affect the likelihoods of its adoption namely (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability were adapted. Also, even though Moore & Benbasat (1991) expanded the five (5) attributes of innovations of Rogers to include two (2) more additional attributes namely (1*)* voluntariness and (*2)* image, only the attribute of 'voluntariness' was considered since 'image' has been found to be embedded in Rogers' attribute of 'relative advantage'(Rogers, 2003). Moreover, since TAM by Davis (1989), is rooted in two (2) of the five (5) attributes of innovation by Rogers (2003) (i.e. 1. relative advantage and 2. complexity for which TAM called it 'perceived usefulness' and 'perceived ease of use' respectively), 'relative advantage' and "perceived usefulness' were considered to mean the same and 'complexity' and 'perceived ease of use' were also used interchangeable. Therefore, the six main constructs of cocoa farmers' perceived technology characteristics or attributes of PA innovation that were conceptualized in this study were:

- *Relative advantage (perceived usefulness*): the degree to which PA innovations are perceived as being better than the existing cocoa technologies.
- *Compatibility:* The degree to which PA innovations are perceived as consistent with the existing values, past experiences, and needs of cocoa farmers
- *Complexity* (ease of use): the degree to which PA innovations are perceived by cocoa farmers as relatively difficult or simple to understand and use compared to the existing ones.
- *Trialability:* is the degree to which cocoa farmers perceive that PA innovations can be experimented with on a limited or small-scale basis.

- *Observability:* the degree to which the results of PA innovation are visible to cocoa farmers.
- *Voluntariness***:** the degree to which the use of the PA innovations is perceived as being voluntary, or of free will by cocoa farmers.

Five of these attributes of innovation (i.e relative advantage, compatibility, ease of use, trialability and observability) are expected to have positive impacts on cocoa farmers' intentions to adopt PATs, where as *voluntariness* is expected to have negative impacts on farmers intentions to adopt PATs (Moore & Benbasat,1991; Agarwal & Prasad, 1997; Aubert et al., 2012; Rogers 2003,Walton et al. ,2008).

The demographic and farm-related characteristics of cocoa farmers.

The study considered the following demographic and farm related characteristics**:** sex**,** age, educational background, years of experience in cocoa farming, household dependents, size of farm, agrochemical use, source of finance and labour, quantity of fertilizer used, yield of farmers etc. (Akudugu et al., 2012; Rogers, 2003; Maheswari, Ashok, & Prahadeeswaran ;2008). These individual variables (see Table 1) are expected to have either positive or negative impacts on cocoa farmers' willingness to adopt PATs. For example, sex, educational level, years of farming experience, size of land under cultivation, row planting, land ownership and right, access to credit, access road to cocoa farm, quantity of fertilizer applied, yield of farmers, frequency of extension agents' visits and use of mobile phone are expected to have positive impacts on the cocoa farmers willingness to adopt PATs (Tey & Brindal, 2012; Aubert et al.,2012; Larson et al., 2008; Antolini et al, 2015; Swinton & Lowenberg-Deboer, 2001; Asare, 2011; Degu, Mwangi, Verkuijl, & Abdishekur, 2000). Age, marital status and number of households dependents, on the other hand, are expected to have negative impacts on cocoa farmers' willingness to adopt PATs (Batte, Jones, & Schnitkey, 1990 ; Gloy & Akridge, 2000 ; Batte & Arnholt, 2003; Robert at al. 2004).

Awareness level of cocoa farmers in PATs.

The awareness level of cocoa farmers in PATs were assessed based on how they perceived the three main components of PA namely (a) information or data base, (b) technology or tools, and (c) management of PA information. The specific items used to measure each of these 3 constructs are shown in Appendix A. Generally, cocoa farmers' perceived awareness of these three main components are expected to have direct impact on their willingness to adopt the PATs (Watkins, Lu, & Huang, 2008; Morgan & Ess, 2003; Forouzanmehr & Loghavi, 2012).

Hence, this paper posits that the behavioral intention of cocoa farmers (willingness to adopt PATs) would be significantly affected by three (3) main set of factors: (i. demographic and farm-related characteristics of cocoa farmers; ii. their perceived attributes (technology characteristics) of PA innovation; and iii. their awareness level of PATs (Table 1).

Precision Agriculture and environmental Sustainability

Bongiovanni & Lowenberg-DeBoer (2014) and Koutsos & Menexes, (2019) observed **various benefits of PA** as a result of managing field spatial variability and ensuring site-specific application of input to ensure long-term sustainability of agricultural production. Hence, the targeted use of fertilizers and precise use of pesticides and other agrochemicals do not only reduce cost of production but also reduce the environmental impact of the agrochemicals by using them only when and where they are needed. Moreover, adoption of PA technologies has been found to reduce environmental impact of the agronomical practices since PA technologies help allocate and minimize inputs use and reduce tractor laps and gas emissions from mechanized operations in the farm (Koutsos & Menexes, 2019). Targeted use of agrochemicals (such as inorganic fertilizers and pesticides) also has the potential to protect biodiversity by minimizing the impacts of such agrochemicals on soil fauna and flora as well as beneficial insects that aid pollination.

METHODOLOGY

Correlational research design was used. The target population was all cocoa farmers under the cocoa high technology programme (CHTP) in seven cocoa regions in Ghana. The new CHTP was established by the government of Ghana in 2014. Under the programme, free fertilizers were distributed to selected cocoa farmers in Ghana. Because PA emphasizes site-specific application of inputs especially fertilizer, cocoa farmers under the CHTP were identified as ideal target population since these farmers have been taught and exposed to various technologies including the use of some PA tools such as the use of GPS receivers. Approximately 140,000 cocoa farmers benefited from the programme. Multistage sampling technique was used to select 425 cocoa farmers in the six out of the seven cocoa growing regions in Ghana (the remaining one cocoa region was used for pilot study to pretest the interview schedule used for the data collection).

A content-validated structured interview schedule was used to collect primary data from respondent cocoa farmers. The instrument consisted of four main parts: i. demographic and farm related characteristics of cocoa farmers, ii. cocoa farmers' perceived technology-related characteristics (attributes) of PA innovations; iii. awareness level of cocoa farmers in PATs and; iv. cocoa farmers' willingness to adopt PATs. Items in the part ii were measured using a six-point Likert-type scale ranging from 0 to 5 i.e. no agreement (0) to strong agreement (5). These items in part ii focused on the level of agreement of farmers on statements related to the 6 attributes of innovation (*relative advantage/perceived usefulness; compatibility*; c*omplexity*/*ease of use*; *trialability; observability; and voluntariness*) conceptualized and used in this study (Appendix A). Items in Part iii were the level of awareness of cocoa farmers in PATs in the three main components of PA: information/data base, technologies/tools and management of PA innovations. These were also measured using six-point Likert-type scale ranging from not aware (0) to very much aware (5). A pilot study was done using 25 cocoa farmers to pretest the structured interview schedule to check its reliability. Cronbach's alpha reliability and Kuder-Richardson (20) coefficients were used to determine the internal consistency of the items of all Likert-type scales and dichotomous scales respectively. The reliability coefficients ranged from 0.75 to 0.96 indicating higher internal consistency of the structured interview scheduled used in this study (Nunnelly, 1998). Out of the 425 targeted interviews, 416 were successful indicating about 98% response rate.

Descriptive statistics and binary logistic regression were used to identify the best predictors of cocoa farmers' likelihood or willingness to adopt (i.e. dependent variable) future PATs from the independent variables (i. demographic and farm-related characteristics of cocoa farmers (19 predictors); ii. cocoa farmers perceived technology-related characteristics or attributes of PA innovation (6 predictors); and iii. awareness level of cocoa farmers in PATs (3 predictors).

Model specification of the binary logistic regression

The odds of an event occurring (i.e. a cocoa farmer willingness to adopt PATs measured as 1 =adoption) is the probability that the event will occur divided by the probability that the event will not occur (Acquah, 2013). Following Greene (2008), the probability $y = 1$ occurring varies according to the values of the explanatory variables and specified the relationship as shown in equation 1:

$$log\left[\frac{P(y=1)}{1-P(y=1)}\right] = logit[P(y=1)] = \beta_0 + \beta_j X \qquad (1)$$

From equation 1, P(Y=1) is given by $P(Y=1) = \frac{e^{\beta_0+\beta_j X}}{1+e^{\beta_0+\beta_j X}}$

where ln $\left(\frac{\text{p}}{1-\text{p}}\right)$ is the logit transformation. This value is the log of the odds of the outcome (since odds=P/(1-P)). β_0 and β_j are parameters to be estimated and X_j is a vector of explanatory variables with index *j*.

Furthermore, $\frac{P}{1-P} = e^{(\beta_0+\Sigma\beta_j X_j)}$where P is the probability that Y=1 and 1-P is the probability that Y=0 and e is the exponential constant.

In the following empirical model specified equation, Y = 1 defines a cocoa farmer would be willing to adopt PATs measured as 1 = adoption; Y = 0 define otherwise. The X's define independent variables that explain the probability that a cocoa farmer would be willing to adopt PATs measured as 1 = adoption and ε_i is error term (equation 2):

$$logit[P(Y_i = 1)] = \beta_{0i} + \beta_{i1}X_{i1} + \beta_{i2}X_{i2} + \beta_{i3}X_{i3} + \beta_{i4}X_{i4} + \beta_{i5}X_{i5} + \beta_{i6}X_{i6} + \beta_{i7}X_{i7} + \beta_{i8}X_{i8} + \beta_{i9}X_{i9} + \beta_{i10}X_{i10} + \beta_{i11}X_{i11} + \beta_{i12}X_{i12} + \beta_{i13}X_{i13} + \beta_{i14}X_{i15} + \beta_{i16}X_{i16} + \beta_{i17}X_{17} + \beta_{i18}X_{i18} + \beta_{i19}X_{i19} + \beta_{i20}X_{i20} + \beta_{i21}X_{i21} + \beta_{i22}X_{i22} + \beta_{i23}X_{i23} + \beta_{i24}X_{i24} + \beta_{i25}X_{i25} + \beta_{i26}X_{i26} + \beta_{i27}X_{i27} + \beta_{i28}X_{i28} + \varepsilon_i \qquad (2)$$

The dependent variable is cocoa farmers' willingness to adopt PATs. This is measured as a dummy with 1 and 0 indicating willing and not willing to adopt PATs respectively. The main set of independent variables (determinants-see Table 1) are:

- Demographic and farm-related characteristics of cocoa farmers: **(X_1-X_{19}),**
- Cocoa farmers' perceived technology-related characteristics of PA (Cocoa farmers' perceived attributes of PA innovations): **(X_{20}-X_{25}),** and
- Cocoa farmers' perceived awareness level of cocoa farmers in PA innovations **:(X_{26}- X_{28}).**

Multicollinearity diagnostic test

Before the regression, multicollinearity diagnostic tests were done using tolerance and variance inflation factor (VIF). These were used to determine whether a predictor has a strong linear relationship with any other predictor or predictors (Field, 2013**)**. The tolerance values were between 0.283 and 0.988 and VIF values between 1.0 and 3.5. These values implied no significant concern for multicollinearity since tolerance value less than 0.10 and VIF greater than 10 indicate significant concerns for multicollinearity (Pallant, 2011; Field, 2013).

Table 1 shows the codes and expected signs of the 28 independent variables **(X_1-X_{28})** used in the regression equation

Table 1: Codes, and expected sign of the independent variables in the regression equation

A	**Demographic/Farm Related Variables**	**Codes**	**Sign**
1	Sex (X_1)	1=Male, 0=otherwise	+
2	Marital status (X_2)	1=Married,0=otherwise	-
3	Age at last birth day (X_3)	Number of years	-
4	Educational level (X_4)	Ordinal scale	+
5	Farming experience (X_5)	Number of years	+
6	Household size/dependents (X_6)	Number of years	-
7	Size of land under (X_7)	Hectares	+
8	Land size where fertilizer was applied (X_8)	Hectares	+
9	Access to Credit (X_9)	1=yes, 0=otherwise	+
10	Access to credit from financial institution (X_{10})	1=yes, 0=otherwise	+
11	Row planting (X_{11})	1=yes, 0=otherwise	+
12	Access road to farm (X_{12})	1=yes, 0=otherwise	+
13	Land Ownership (X_{13})	1=Inherited, otherwise	+
14	Land Rights (X_{14})	1=Sell out right, 0 =otherwise	+
15	Main source of labour (X_{15})	1=hired, 0=otherwise	+
16	Amount of fertilizer applied per hectare (X_{16})	Kilograms	+
17	Yield (X_{17})	Kilograms	+
18	Have mobile phone (X_{18})	1=yes, 0=otherwise	+
19	Frequency of visits by Extension Agents (X_{19})	Ordinal scale	+
B	**Technology related characteristics**	**Codes**	**Sign**
20	Relative Advantage (X_{20})	Likert-type scale	+
21	Compatibility (X_{21})	Likert-type scale	+
22	Complexity (Ease of Use) (X_{22})	Likert-type scale	+
23	Trialability (X_{23})	Likert-type scale	+
24	Observability (X_{24})	Likert-type scale	+
25	Voluntariness (X_{25})	Likert-type scale	-
C	**Awareness levels**	**Codes**	**Sign**
26	Awareness of PA information/Data (X_{26})	Likert-type scale	+
27	Awareness of PA Technology /Tools (X_{27})	Likert-type scale	+
28	Awareness of Management of PA information (X_{28})	Likert-type scale	+

RESULTS AND DISCUSSION

Summary of demographic and farm-related characteristics of cocoa farmers in Ghana.

The majority (about 76%) of the respondent cocoa farmers were males and about 78% have some form of formal education; however, their level of education was low since about 65% had received basic education (Table 2).

Table 2. Descriptive statistics of the demographic characteristics of cocoa farmers

Variables	Categories	f	%	$\bar{X}$	SD
Sex (n=416)	Male	317	76.2		
	Female	99	23.8		
Educational Level (n=413)	No Formal	92	22.3		
	Basic	268	64.9		
	Secondary	38	9.2		
	Tertiary	15	3.6		
Marital Status	Married	349	83.9		
	Not Married	67	16.1		
Age (Years) (n=412, Min=22, Max=94)	<30	14	3.4	51.8	13.6
	30 – 39	69	16.8		
	40 – 49	96	23.3		
	50 -59	113	27.4		
	60 – 69	75	18.2		
	≥70	45	10.9		
Years of Experience (n=407, Min=3, Max=54)	1-10	76	18.7	21.0	10.2
	11 -20	156	38.7		
	21-30	117	28.7		
	>30	58	14.3		
Household size (n=409)	None	4	1	6.4	3.9
	1-5	181	44.2		
	6 -10	173	42.3		
	11-15	43	10.5		
	> 15	8	2		

n= 416.

About 84% of the respondents were married and with more than half (56.5%) of them above 50 years ($\bar{X}$= 52 ± 13.6 years) and very experienced ($\bar{X}$= 21±10.2 years) in cocoa farming. Marcella (2007) had also reported that most cocoa farmers in Ashanti and Brong-Ahafo regions of Ghana were aged (65-70 years). This gives an indication that cocoa farmers are still aged in Ghana with few (20%) youths (below 40 years) in the sector. These conditions, especially the advanced age of cocoa farmers, could have negative impact on the adoption of any future PATs (Robert at al. 2004). The mean household size was approximately 6 members with about 55% having more than 5 dependents.

The result on the educational level (78% having formal education) is almost similar to the findings of Bosompem et al. (2011) who reported that about 80% of cocoa farmers in Eastern region of Ghana had formal education. Okorley et al. (2014) also reported that about 78% of cocoa farmers in Western region of Ghana had formal education even though their level of education was low.

Table 3 presents the summary of the farm-related characteristics of respondent cocoa farmers.

Table 3. Descriptive statistics of farm-related characteristics of respondent cocoa farmers

Variables	Categories	f	%	$\bar{X}$	SD
Farm size under cocoa (Ha) (n=401, min=0.20, max= 40.5)	≤ 2	83	20.7	5.2	5.32
	2.1 - 4.0	162	40.4		
	4.1 - 6.0	66	16.5		
	Above 6.0	90	22.4		
Number of cocoa farms (n=413 min-=1, max=15)	1-2	234	56.7	2.6	1.6
	3-4	140	33.9		
	≥5	39	9.4		
Farm size fertilized (Ha) (n=380, min=0.1, Max= 40.0)	≤ 2	182	48.3	3.2	4.0
	2.1 -4.0	130	34.5		
	4.1-6.0	42	11.1		
	> 6.0	23	6.1		
Age of fertilized farm (years) (n=362), min= 4, Max.50)	Less than 10	70	19.3	18.3	8.4
	11-20	187	51.7		
	21-30	81	22.4		
	>30	24	6.6		
Amount of fertilizer applied (kg) n=338	≤ 500	142	42.0	950	1225
	501 – 1000	93	27.5		
	1001 -1500	52	15.4		
	> 1500	51	15.1		
Land Rights of fertilized land (n=370)	Sell out right	150	40.5		
	Otherwise	220	59.5		
Land ownership (n=403)	Inherited	266	66.0		
	Otherwise	137	34.0		
Row planting (n=399)	Yes	82	20.6		
	No	317	79.4		
Access road to farm (n= 399)	Yes	231	57.9		
	No	168	42.1		
Access to credit (414)	Yes	103	24.9		
	No	311	75.1		
Access to credit from financial institution (n=103)	Yes	53	51.5		
	No	50	48.5		
Main source of labour (n=404)	Hired	204	51.5		
	Other sources	200	48.5		
Have mobile phone (n=404)	Yes	315	78		
	No	89	22		
Frequency of contact with extension agents (n=337)	At least once Monthly	181	53		
	Less than once a month	156	47		
Current yield of fertilized farm (kg /ha)		-	-	741	1059**

n= 416. * 1 bag of fertilizer =50kg, ** I bag of dried cocoa beans = 64kg

The majority of the cocoa farmers (61%) had 4.0 ha or less of cocoa farm with a mean farm size of 5.2 ha. However, a mean of 3.2 ha cocoa farms were fertilized even though a majority (83%) of the farmers fertilized about 4 ha or less of their farms (Table 3). A little over half of the farmers (56%) had 2 cocoa farms. The mean age of the cocoa farms fertilized was approximately 18 years with about 52% of the farms aged between 11 to 20 years. Most farmers (66%) inherited their land from family members and the other 34% either bought their land, or acquired them through sharecropping, hence, about 41% had the right to sell their land outright to others. About 58% had access roads to their farms. However, only 21% had their cocoa trees planted in recommended rows and planting distance. Dankyi, Dzomeku, Anno-Nyako, Adu-Appiah, and Gyamera-Antwi (2007) found only 22% of selected farmers in three regions of Ghana had adopted row planting in their farms.

Planting using the recommended planting distances and in rows in most plantation and other crops in Ghana had been a problem for farmers because most farmers view these practices as a waste of land especially if the recommended planting distances are more spacious than what farmers have been using originally. Crops planted haphazardly on the field and without using the recommended planting distances, can pose a challenge to the movement of farm machinery such as tractors, variable rate applicators and yield monitors etc. that are essential tools used in PA. These machineries require enough spaces between and within rows of planted crops to enable them move and perform their respective functions.

Only 25% of farmers had access to credit either in kind (inputs) or in cash, hence the majority (75%) used their own resources or cash to finance their farming activities. Fifty-three out of 103 respondents (52 %) had their credit from financial institutions such as the rural banks and the micro finance. The rest (48%) had credit from either LBCs, money lenders and other family members and friends. A little over half of the respondents (52%) used hired labour. The rest used either their own, family or cooperative labour. About 78% had mobile phones which were mostly analog mobile phones. A mean 950 kg of fertilizer were applied per farmer with a mean of 309 kg/ha instead of the recommended 370 kg/ha. The mean yield was about 741 kg/ha. This is relatively lower compared to the minimum of about 1500 kg/ha expected under the CHTP (Appiah, 2004). However, the result is quite similar to the findings of Bosompem et al. (2011) who found a mean yield increase of 448.9 kg/ha to 768.5kg/ha from cocoa farmers who adopted fertilizer application in Eastern region of Ghana. The active ingredients of the fertilizer used under the CHTP are sulphur, magnesium, phosphorus and potassium [NPK O-22-18 + 9CaO + 7S + 6MgO (s)] and are very important for development of cocoa plant. The rate of application is 300-400 grams/tree/year and it is applied 70-100 cm around the root zones of each cocoa plant (Appiah, 2004).

Since about 41% of the respondents can sell their land outright, it stands to reason that these farmers have better land rights and therefore may commit resources to increase the productivity of their land than those with rented lands. Antolini et al. (2015) reported that farmers are more likely to manage their own land in a more favorable way than rented lands and have more chances to enjoy the advantages that comes with their investments. Therefore, if farmers have higher land rights (for example, if lands are bought or inherited), they are more likely to adopt PAT (which is capital intensive) since they have the advantages of enjoying their own farm management practices and investments. This is so because rented lands can easily be taken over by their owners or family members of the owners, hence farmers are less likely to commit resources that are capital intensive (like PA tools) to rented lands.

About 53% of farmers reported to have contact with CEAs at least once a month. Adoption of PATs was reported to be higher among those who received information from trained extension agents (Larson et al., 2008). About 52% of cocoa farmers using hired-labour is quite similar to that of Baidoo and Amoatey (2012) who reported that about 55% used hired labour on their farms. Since farmers pay for hired labour, adoption of PATs are likely to suffer if access to credit is low or not existing (Dormon et al., 2004).

Cocoa farmers' perceived awareness and attributes of PATs

The perceived level of awareness of cocoa farmers in PATs were assessed based on the three (3) main components of PA namely (a) information or database, (b) technology or tools, and (c) management of PA information**. (see** Appendix A**).** The level of awareness of cocoa farmers was low in both the 'information and database' ($\bar{X}$=2.38, SD=.97) and the 'management of PA information ($\bar{X}$=1.54, SD=.77)' components of PA but that of the 'technology or tools component' ($\bar{X}$=2.61, SD=1.34) was fair (Table 4). Majority of the respondent cocoa farmers (78%) were aware of the use of GPS receivers because these were used to estimate the farm sizes of farmers before the right amount of fertilizers were supplied to the farmers under the CHTP.

Table 4. Descriptive statistics of farmers' awareness level and perceived attributes of PATs

Variables		
1. Awareness level in PA	$\bar{X}$	SD
Awareness of PA information/data	2.38	.97
Awareness of PA technology /tools	2.61	1.39
Awareness of management of information in PATs	1.54	.77
2. Perceived Attributes of PATs	$\bar{X}$	SD
Relative advantage	4.31	.88
Voluntariness	3.57	.99
Observability	3.40	1.07
Compatibility	3.35	.98
Ease of use	3.45	1.33
Trialability	3.13	1.17

n=416
Scale:
1. **Levels of agreement on attribute**s: 1= Very Low, 2=Low, 3= moderate, 4= High, 5=very high
2. **Awareness level**: 1=Least aware; 2=Less aware; 3= fairly aware, 4=Much aware, 5= Very much aware.

Cocoa farmers perceived that PATs would have relative advantage ($\bar{X}$=4.31, SD=.88) over cocoa farmers' current practices in Ghana. They were, however, not too sure of its compatibility with current technologies ($\bar{X}$=3.35 SD=.98), its ease of use ($\bar{X}$=3.45, SD=1.33), its trialability ($\bar{X}$=3.13, SD=.88) and observability ($\bar{X}$=3.40, SD=1.07). The high agreement of farmers on the relative advantage of PATs over their existing technologies implies that cocoa farmers perceived PA to have the potential of (a) being more profitable than the existing cocoa technologies, (b) improving cocoa farmers' social prestige, (c) being most effective means of achieving optimum productivity and (d) being environmentally sustainable (See Appendix A). Another implication is that cocoa farmers have high expectation that PATs implementation in cocoa industry would be advantageous over their existing technologies in Ghana. However, they are generally not too sure of ease of use PATs in cocoa industry, its compatibility with existing technologies as well as ability to try or experiment PAT on limited bases as a results of the current cocoa technologies and practices used by cocoa farmers in Ghana.

Cocoa farmers' willingness to adopt precision agriculture technologies in cocoa production.

A majority (83%) of the respondent cocoa farmers were willing to adopt future PATs in Ghana (Table 5). This is an indication of bright prospects of any future PATs development in Ghana since farmers' intentions to adopt technologies have been found to have positive impacts on actual future adoption of PATs (Aubert et al., 2012).

Table 5. Cocoa farmers' willingness to adopt Precision Agriculture Technologies in Cocoa Production.

Willingness	F	%
Willing	344	83
Not willing	70	17
Total	414	100

n=416.

Best predictors of cocoa farmers' willingness to adopt PATs in Ghana

The model summary in Table 6 shows that the model, as a whole, (with 28 variables) explained between 37.5% (Cox and Snell R square) and 60.4% (Nagelkerke R square) of the variances in cocoa farmers' willingness to adopt any future PATs **(**see Appendix B for the overall model showing the 28 independent predictors used in the model).

Of the 28 predictor variables, only five made a unique statistically significant contribution to the model at 0.05 alpha level. These significant best predictors were (a) educational level of cocoa farmers, (b) row planting, (c) credit from financial institutions, (d) relative advantage of PATs, and (e) the perceived ease of use (complexity) of PATs.

Table 6. Binary logistic regression showing the significant best predictors of cocoa farmers' willingness to Adopt PATs in Ghana

Predictors	B	S.E.	Wald	Sig.	Odds Ratio	95% C.I. for odd Ratio
Constant	-5.542	3.313	2.798	.094	.004	
Educational Level	-3.994	1.860	4.61	.032	.018	.00 - .71
Credit from financial institution	2.899	1.327	2.06	.047	1.38	.10 -18.66
Row planting	3.995	1.636	5.96	.015	54.30	2.20 -134.5
Relative Advantage	1.176	.423	7.73	.005	3.242	1.42 - 7.43
Ease of Use	.787	.294	7.16	.007	2.196	1.23 - 3.91

Model Summary	Value	Sig	-2 Log likelihood
Cox Snell R- Square	0.375		81.96
Nagelkerke R- Square	0.604		
Omnibus test of model Chi- square	77.052	0.000	
Hosmer and Lemeshow Test	2.195	.974	

n=416. *p*>0.05. CI=Confidence interval

Educational level as a predictor of cocoa farmers' willingness to adopt PATs : Educational level was the only demographic characteristic found to be significant but negative predictor (β= -3.994) of cocoa farmers' willingness to adopt PATs (Table 6). This implies that respondent cocoa farmers who had higher level of education are less likely to adopt PATs in cocoa production. The odds ratio of 0.02 (less than 1) also indicates that for every additional level of education, respondents were .02 times less likely to adopt future PATs. The result is contrary to the theorized expectations and almost all the adoption studies in PATs reviewed. For example, Aubert et al. (2012) found formal education as a positive predictor of adoption of PATs in Canada. Walton et al. (2008) also found a positive and significant relationship between education and adoption of precision soil sampling among cotton farmers in 11 southern states in USA. Adrian et al. (2005) also found educational level as a positive predictor of farmers' intention to adopt PAT.

The negative relationship observed may be due to how farmers with higher level of education perceive the enormous challenges that need to be surmounted before PA become a reality in Ghana. This is possible because Gamble and Gamble (2002) state that in some cases, high educational levels can become a barrier rather than a facilitator or aid to communication and by extension adoption since educated farmers may be skeptical about the feasibility of PATs development in cocoa industry in Ghana. Many PA advocates in the past (who were researchers with higher educational level) were even skeptical about whether PA is feasible for small-scale farmers despite the proven empirical evidence that PATs are feasible even among small-scale farmers in a number of Asian countries (Shibusawa, 1999 ; Mandal & Maity, 2013).

Row planting as a predictor of cocoa farmers' willingness to adopt PATs : Row planting was one of the two farm-related factors that was found to be significant and positive predictor (β=3.995) of cocoa farmers' willingness to adopt PATs. The odds ratio of 54.30 indicates that cocoa farmers who had planted their cocoa trees in rows are over 54 times more likely to adopt any future PATs in cocoa production in Ghana than those who have not, controlling for all other predictors in the model. This gives an indication that cocoa farmers who had already planted in rows are more likely to adopt PA technology than those who had not yet done so. However, most cocoa farms in Ghana are not generally planted in rows using the recommended planting distance of 3m x 3m (10ft x 10 ft) spacing (CRIG, 2010). Only about 21% of respondent cocoa farmers (see Table 2) reported that they planted in rows. This may have negative implication for movement of PA machinery and equipment such as tractors, planters, VRAs, yield monitors in their farms. Estimating and predicting future yields could also be affected since it is more difficult to extimate plant population on farms not planted in rows that those planted rows.

Source of credit as a predictor of cocoa farmers' willingness to adopt PATs : Cocoa farmers' access to credit from financial institutions was a significant (positive) predictor (β=2.899) of cocoa farmers' willingness to adopt PATs (Table 6). The odds ratio of 1.38 indicate that cocoa farmers who had credit from financial institutions (eg. banks, micro finance institutions etc.) are about one and a half times more likely to adopt any future PATs in cocoa production in Ghana than those who received credit elsewhere (e.g friends, family, and moneylenders). Whether farmers had "access to credit or not" itself was not a significant predictor of their willingness to adopt. Hence, for those who have access to credit, if the source is from financial institutions, then they are likely to adopt future PATs in cocoa production. The findings are contrary to assertions of Swinton and Lowenberg-Deboer (2001) that availability of financial capital irrespective of the source (either from farmers' own resources or credit from other sources) is expected to have positive impact on adoption. A tentative explanation to the source of credit (in this case from financial institutions) as an important determinant of future adoption of PATs is that because PA is capital intensive, credit or finance from financial institutions could provide adequate funding for successful implementation of PA than other sources from friends and money lenders since these sources may not be able to provide adequate funding to support PAT development. Nevertheless, credit availability and access have been found to have a positive relationship with adoption of PATs since PA is capital intensive (Antolini et al., 2015).

Relative advantage as a predictor of cocoa farmers' willingness to adopt PATs: Relative advantage (perceived usefulness) of PATs was one of the two technology-related factors that had positive (β=1.176) and significant relationship of cocoa farmers' willingness to adopt PATs (odds ratio = 3.24). This implies that cocoa farmers who perceived PATs as better than their previous technologies are three times likely to adopt future PATs in cocoa production in Ghana than those who do not. This is significant for the prospects of PATs development and adoption in cocoa industry in Ghana since the degree of relative advantage has been expressed in economic profitability and social prestige (Rogers, 2003). The results also confirm other research findings. For example, perceived usefulness or relative advantage had been found to have a positive significant impact on farm operators' decision to adopt PATs among cereal farmers who adopted PA technologies such as GPS, GIS, yield monitors, yield maps, remote sensing, VRA and navigation systems in Quebec, Canada (Aubert et al., 2012). Also Kim and Garrison (2009) reported a positive relationship between perceived usefulness and intention to use mobile wireless technology adoption which is an integral part of PATs adoption (Kim & Garrison, 2009). Walton et al. (2008) also found that perceived profitability (relative advantage) was a positive significant predictor of adoption of PATs.

Ease of use and cocoa farmers' willingness to adopt PATs: The perceived ease of use (complexity) of PATs was the other technology-related factor that was positive (β=.776) and a significant predictor of cocoa farmers' willingness to adopt future PATs with the odds ratio of 2.196. This implies that cocoa farmers who perceived PATs as being easier than their previous technologies are two times more likely to adopt future PATs in cocoa production in Ghana than those who did not. The findings confirm other findings. For example, Aubert et al. (2012) reported that 'perceived ease of use' was a significant and positive predictor of the adoption of PATs among farmers in Canada. Also 'perceived ease of use' has also be found to have indirect relationship with intention to adopt PATs, mediated by perceived net adoption (Adrian et al., 2005). Since cocoa farmers viewed the PATs to be "moderately complex"**,** it is likely to affect the rate of its adoption when even implemented in cocoa production in Ghana. Secondly, since ease of use (complexity) of an innovation has been found to be important for adoption in computer-based innovation and computer self-efficacy (Pierpaoli et al., 2013; Rogers, 2003) like PATs, it stands to reason that adoption of PATs by cocoa farmers may also largely depends on their self-efficacy as far as their abilities to use various forms of computers related to PATs are concerned.

Both cocoa farmers' perceived usefulness (PU) and perceived ease of use (PEOU) of PATs had significant impact on cocoa farmers' willingness to adopt PATs. The results confirm the technology acceptance model (TAM) by Davis (1989) that posited that only these two (2) attributes (i.e. PU and PEOU) are significant predictors of the adoption of IT-related innovations.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Generally, farmers perceived that their awareness level of PATs was low. However, majority of the cocoa farmers were aware of the use of GPS receivers since they were used to estimate the size of their cocoa farms. The use of GPS receivers to estimate the size of cocoa farms under cultivation was a requirement under the CHTP before fertilizers were supplied to individual farmers based on the size of the cocoa farms measured with the help of CEAs.

Cocoa farmers are highly convinced that PA would have relative advantage in terms of profitability, social prestige, optimum profitability and environmental sustainability over cocoa farmers' current practices in Ghana. However**,** they are not too sure that the other five (5) attributes or technology characteristics (compatibility, complexity, trialability, and observability and voluntariness) of the PA innovation could be easily achieved in cocoa production in Ghana.

A majority (83%) of the cocoa farmers was willing to adopt future PATs. Cocoa farmers' access to credit, especially from financial institution, would likely provide them adequate funding to start or invest in PATs in the cocoa industry. Also, cocoa farmers who have planted in rows and with recommended planting distance are more likely to adopt PATs since adequate spaces are available for easy movement of PA tools and machinery between planted cocoa trees to enable site specific application of inputs to cocoa trees. Cocoa farmers' awareness of the usefulness of PATs expressed in terms of monetary, social and environmental impact will improve the future adoption of PATs among cocoa farmers in Ghana.

Recommendations

There is the need to create awareness and educate cocoa farmers and other major stakeholders (Ghana Cocoa Board, private GIS operators in Ghana, Licensed buying companies, International cocoa organization, World cocoa foundation and financial institutions in Ghana) on the potentials of PAT development in cocoa production in Ghana. Stakeholders should consider the best predictor variables in any future development of PA innovations in cocoa production in Ghana. Future PA on-farm trials should begin with cocoa farmers who practise row planting since this would facilitate easier movements of PA tools and equipment in the farms as well as facilitate the site-specific application of farm inputs. Such farms could also be used to demonstrate to cocoa farmers the relative advantage (usefulness) and the ease of use of PAT principles and practices. Future studies could investigate cocoa farmers who adopted row planting to identify empirically farmer characteristics and other technological reasons that explain why they would adopt PATs.

ACKNOWLEDGEMENTS

I wish to acknowledge the following organizations for their financial assistance towards this research:

1. The University of Cape Coast, Ghana (http//ucc.edu.gh)
2. The Association of African Universities (AAU-www.aau.org)
3. The Council for the Development of Social Science Research in Africa (CODESRIA-http://www.codesria.org).

REFERENCES

Acquah, D.H. (2013). *An introduction to quantitative methods.* Aachen German: Shaker Verlag.

Adrian, A. M., Norwood, S. H., & Mask, P. L. (2005). Producers' perceptions and attitudes toward precision agriculture technologies. *Computers and Electronics in Agriculture*, *48*(3), 256–271.

African Business (April, 2014). Finding your way-GPS comes to Africa. *African Business Magazine*, 48 (4), 23-24.

Agarwal, R., & Prasad, J. (1997). The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. Decision Sciences, 28(3), 557–582.

Akudugu, M., Guo, E., & Dadzie, S. (2012). Adoption of modern agricultural production technologies by farm households in Ghana: What factors influence their decisions? *Journal of Biology, Agriculture and Healthcare, 2*(3), 1–14.

Antolini, L. S., Scare, R. F., & Dias, A. (2015). Adoption of precision agriculture technologies by farmers: A systematic literature review and proposition of an integrated conceptual framework. In *IFAMA's Scientific Research*. St Paul, Minnesota

Appiah, M. R. (2004). *Impact of cocoa research innovations on poverty alleviation in Ghana.* Accra: Accra Printing Division, CSIR-INSTI.

Asare, E. (2011). *Modelling cocoa farmer behaviour concerning the chemical control of capsid in the Sekyere area Ashanti Region, Ghana*. Unpublished master's thesis, Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems, 54*(1), 510–520.

Baidoo, I., & Amoatey, H. (2012). Willingness to pay for improvement in the agricultural activities of some six selected villages in West Akim district of Ghana (emphasis on cassava). *International Journal of Development and Sustainability, 1*(2), 326–337.

Batte, M. T., & Arnholt, M. W. (2003). Precision farming adoption and use in Ohio: Case studies of six leading-edge adopters. *Computers and Electronics in Agriculture*, *38*(2), 125–139.

Batte, M. T., Jones, E., & Schnitkey, G. D. (1990). Computer use by Ohio commercial farmers. *American Journal of Agricultural Economics*, *72*(4), 935–945.

Blackmore, B.S., Wheeler, P.N., Morris, R.M, Morris, J., & Jones, R.J.A. (1994). The role of precision farming in sustainable agriculture: A European perspective. *Proceedings 2nd International Conference of Precision* Agriculture, Minneapolis, US.

Bongiovanni, R. & Lowenberg-DeBoer, J. (2004). Precision agriculture and sustainability. *Precision agriculture*, *5*(4), 359-387.

Bosompem (2015). *Prospects and challenges of precision agriculture in cocoa production in Ghana*. Unpublished PhD thesis, Department of Agricultural Economics and Extension, University of Cape Coast, Cape Coast, Ghana.

Bosompem, M., Kwarteng, J. A., & Ntifo-siaw, E. (2011). Towards the implementation of precision agriculture in cocoa production in Ghana : Evidence from the cocoa high technology programme in the Eastern region of Ghana. *Journal for Agrcultural Research and Development*, *10* (1), 11-17

CRIG.(2010). *Cocoa manual: A source book for sustainable cocoa production*. Accra,Ghana : CRIG.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13(3)*, 319–340.

Degu, G., Mwangi, M. W., Verkuijl, H., & Abdishekur, W. (2000). An assessment of the adoption of seed and fertilizer packages and the role of credit in smallholder maize production in Sidama and North Omo Zone, Ethiopia, Mexico. *International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO)*.

Dankyi, A.A.; Dzomeku, B.M.; Anno-Nyako, F.O.; Adu-Appiah, A.; and Gyamera-Antwi (2007). Plantain production practices in the Ashanti, Brong-Ahafo and Eastern regions of Ghana. *Asian Journal of Agricultural Research, 1: 1-9.*
DOI: 10.3923/ajar.2007.1.9

Dormon, E. N. A., Van Huis, A., Leeuwis, C., Obeng-Ofori, D., & Sakyi-Dawson, O. (2004). Causes of low productivity of cocoa in Ghana: farmers' perspectives and insights from research and the socio-political establishment. NJAS - *Wageningen Journal of Life Sciences*, *52*(3), 237–259.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. *Statistics and sex and drugs with rock 'n' roll* (4th ed.). London : SAGE Publications Ltd.

Forouzanmehr, E. & Loghavi,M. (2012). Design, development and field evaluation of a map-Based variable rate granular fertilizer application control system. *Agricultural Engineering International CIGR Journal Open Access, 14* (4), 255 -261.

Gamble, T. K., *&* Gamble. M. (2002). *Communication Works.* (7th ed.). New York: McGraw-Hill/Irwin. Inc., 82–107.

Gloy, B. A., & Akridge, J. T. (2000). Computer and internet adoption on large U.S. farms. *International Food and Agribusiness Management Review*, *3*(3), 323–338.

Greene, W. H. (2008). *Econometric Analysis* (6th Ed.). Upper Saddle River, New Jersey: Prentice-Hall

GSS (2019). *Statistics for development and progress: Rebased 2013-2018 Annual gross domestic product*. Ghana statistical service (GSS), Accra.

Hamideh, M.; Kurosh, R., & Abdol-Azim, A. (2011) Iranian agricultural professionals' knowledge on organic farming: *African Journal of Agricultural* Research 6(2), pp. 907-915:Available online at http://www.academicjournals.org/AJAR

ISPA. (2013). International Society of Precision Agriculture (ISPA) Report.

ISPA (2019). International Society of Precision Agriculture (ISPA), https://www.ispag.org

ISSER (2014). *The state of Ghanaian economy in 2013*. Legon, Accra: ISSER, University of Ghana.

ISSER (2013). *The State of Ghanaian Economy in 2012*. Legon, Accra: ISSER, University of Ghana., 27.

Kim, S., & Garrison, G. (2009). Investigating mobile wireless technology adoption: An extension of the technology acceptance model. *Information Systems Frontiers*, *11*(3), 323–333.

Koutsos, T., & Menexes, G. (2019). Economic, Agronomic, and Environmental Benefits From the Adoption of Precision Agriculture Technologies: A Systematic Review. *International Journal of Agricultural and Environmental Information Systems (IJAEIS), 10* (1), 40-56. doi:10.4018/IJAEIS.2019010103

Larson, J. A., Roberts, R. K., English, B. C., L, L. S., Marra, M. C., Martin, S. W., … Reeves, J. M. (2008). Factors affecting farmer adoption of remotely sensed imagery for precision management in cotton production. *Precision Agriculture*, *9*, 195–208.

Maheswari, R., Ashok, K. R., & Prahadeeswaran, M. (2008). Precision farming technology , adoption decisions and productivity of vegetables in resource-poor environments. *Agricultural Economics Research Review 21*(1), 415–424.

Mandal, S. K., & Maity, A. (2013). Precision farming for small agricultural farm : Indian scenario. *American Journal of Experimental Agriculture*, *3*(1), 200–217

Marcella, V. (2007). *Drivers of cocoa production growth in Ghana*. Retrieved from http://www.google.com.gh/q=marcella+v.+(2007)+drivers+ of+ cocoa+ production+growth +in +Ghana

Miller, K., & Shinn, G. (2012). Development in Africa and agricultural innovation. *Journal of International Agricultural and Extension Education*, *19*(2), 6–9

MoFA (2017). *Agriculture in Ghana: facts and figures.* Statistics, research and information directorate: Ministry of food and agriculture, Ghana.

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192–222.

Morgan, M. & Ess, D. (2003). *The precision-farming guide for agriculturists.* Moline: Deere & Company

Najafabadi, M. O., & Hosseini, S. J. F., & Bahramnejad, S. (2011). A Bayesian confirmatory factor analysis of precision agricultural challenges. *African Journal of Agricultural Research*, *6*(5), 1219–1225.

Nunnelly, J.C. (1978) *Psychometric Theory* (2nd ed.). New York: McGraw Hill.

Okorley, E. L., Adjargo, G., & Bosompem, M. (2014). The potential of farmer field school in Cocoa extension delivery: A Ghanaian case study. *Journal of International Agricultural and Extension Education, 21*(2), 32-44.

Pallant, J. (2011). *SPSS Survival Manual*. Maidenhead, United Kingdom: Open University Press.

Pallant, J. (2013). SPSS survival manual: *A step by step guide to data analysis using IBM SPSS* (5th ed.). Maidenhead, United Kingdom: Open University Press.

Pierpaoli, E., Carli, G., Pignatti, E., & Canavari, M. (2013). Drivers of precision agriculture technologies adoption: A literature review. *Procedia Technology*, *8*(1), 61–69

Rogers, E.M. (2003). *Diffusion of innovations* (5th ed.). New York : The Free Press

Rogers, E.M. (1983). *Difussion of Innovations* (3rd ed.). New York: The Free Press.

Shibusawa, S. (1999). *Precision farming approaches to small-farm Agricultrue*. Tokyo: Food and Fertilizer Technology Center

Swinton, S. M., & Lowenberg-Deboer, J. (2001, June). Global adoption of precision agriculture technologies: Who, when and why. *Proceedings of the 3rd European Conference on Precision Agriculture* (pp. 557-562).

Tey, Y. S., & Brindal, M. (2012). Factors influencing the adoption of precision agricultural technologies: A review for policy implications. *Precision Agriculture*, *13*(6), 713–730.

Walton, J. C., Lambert, D. M., Roberts, R. K., Larson, J. A., English, B. C., & Larkin, S.L. (2008). Adoption and abadonment of precision soil sampling in cotton production. *Journal of Agricultural and Resource Economics*, *33*(3), 428– 448.

Watkins, K.B; Lu, Y. & Huang, W. (2008) Economic and environmental feasibility of variable rate nitrogen fertilizer application with carry-over effects. *Journal of Agricultural and Resource Economics*, *23*(2), 401-426.

World Bank. (2013). *Growing Africa:Unlocking the potentials of agribusiness*. Washington, DC: The World Bank.

ABOUT THE AUTHOR

Dr. Martin Bosompem is a Senior Lecturer at the Department of Agricultural Economics and Extension, School of Agriculture, College of Agriculture & Natural Sciences, University of Cape Coast, Cape Coast, Ghana. His research interest includes Precision Agricultural Adoption and Education, ICT and Agriculture, Climate Change and Sustainable Agricultural Development, Livelihood security and Cocoa innovations, Entrepreneurship and Agriculture. He is currently a member and Country (Ghana) Representative for the International Society of Precision Agriculture (ISPA), USA. - https://www.ispag.org/Leadership/CountryRep/Ghana

APPENDICES

Appendix A: Cocoa farmers level of awareness of PA and perceived attribute of PATs.

1. **Awareness level of PATs**

Use below ratings to indicate your awareness level

Ratings	Awareness Level
0	Not aware
1	Least aware
2	Less aware
3	Fairly aware
4	Much aware
5	Very much aware

	Precision Agriculture Components	Awareness Level					
A	**<u>Information or Data base</u>**	**5**	**4**	**3**	**2**	**1**	**0**
1	Soil texture data						
2	Soil structure data						
3	Use of soil moisture data						
4	Use of soil nutrients data						
5	Plant population						
6	Crop tissue						
7	Crop stress						
8	Weed patches (weed type)						
9	Weed patches (intensity)						
10	Determining various species of pest infestation in cocoa						
11	Measuring pest intensity						
12	Measuring Crop yield						
13	Use of temperature data						
14	Use of humidity data						
15	Use of rainfall data						
16	Use of solar radiation data						
17	Use of wind velocity data						
B	**Technologies/Tools**	**5**	**4**	**3**	**2**	**1**	**0**
1	Global positioning system (GPS) receivers						
2	Differential global positioning system (DGPS)						
3	Geographic information systems (GIS)						
4	Aircraft/drone-based remote Sensors						
5	Satellite-based Remote Sensors						
6	Simple hand-held remote Sensors						
7	Uniform rate applicators (URA)						
8	Map-based variable rate applicator (VRA)						
9	Sensor-based variable rate applicators (VRA)						
10	Chlorophyll meter						
11	Yield monitors						
12	Combine harvesters						
13	Planters						
C	**Management**	**5**	**4**	**3**	**2**	**1**	**0**
1	PA information management						
2	PA decision support system (DSS)						
3	Precision agriculture service providers in Ghana or elsewhere						

2. **Cocoa farmers perceived attributes of PATs.**

Please indicate your level of agreement on the following attributes/characteristics of PATs in cocoa production in Ghana.

0=No Agreement
1= Least agree/very low
2=Less Agree/low
3=Fairly Agree/ moderate
4= Agree/high
5=Strongly Agree / very high

	Attributes/Characteristics of PA	**Level of Agreement**					
A	**Relative advantage (**	**5**	**4**	**3**	**2**	**1**	**0**
1	PATs would be more profitable than existing Cocoa technologies						
2	PATs would improve the social prestige of cocoa farmers						
3	PA is the most effective means of achieving optimum productivity						
4	PA is the most effective means of achieving optimum environmental sustainability						
B	**Compatibility**	**5**	**4**	**3**	**2**	**1**	**0**
1	PATs would be compatible with most socio-cultural values and beliefs of cocoa farmers						
2	PA would be compatible with previously introduced technologies by researchers						
3	PATs would fit with the current practices of most cocoa farmers						
4	PATs would be compatible with current needs of cocoa farmers						
C	**Complexity (Ease of Use)**	**5**	**4**	**3**	**2**	**1**	**0**
1	Cocoa farmers can easily understand Precision Agricultural practices						
2	Cocoa farmers can easily practise PATs						
D	**Trialability**	**5**	**4**	**3**	**2**	**1**	**0**
1	Cocoa farmers can **easily use** PATs **on trial** bases before they decide to use it full scale						
2	Cocoa farmers would easily adopt PA technologies if they are permitted to use the technology long enough to see the benefits.						
E	**Observability.**	**5**	**4**	**3**	**2**	**1**	**0**
1	PA technologies and facilities include physical and material objects that are easy to observe by cocoa farmers						
2	PA technologies and facilities include physical and material objects that are easy to describe to cocoa farmers						
3	Cocoa farmers would have no difficulty explaining the pros and cons of PA to other cocoa farmers.						
F	**Voluntariness**	**5**	**4**	**3**	**2**	**1**	**0**
1	Cocoa farmers would accept PA technologies when they are mandated by law from government.						
2	Cocoa farmers would accept PA technologies when they are mandated by industrial partners (e.g. licensed buying companies, cooperatives , NGOs etc.)						
3	Even though PA technologies might be helpful their use should be optional for cocoa farmers.						

Appendix B : Overall model of the Predictors of Cocoa Farmers Willingness to Adopt PATs in Ghana

Predictors	B	S.E.	Wald	Sig.	Odds Ratio	95% C.I.for odds Ratio	
						Lower	Upper
Constant	5.542	3.313	2.798	.094	.004		
Demographic characteristics							
Sex	.681	.962	.50	.479	1.98	.30	13.0
Educational Level	-3.994	1.860	4.61	.032	.018	.00	.71
Marital status	-.962	1.136	.72	.397	.38	.04	3.5
Age	.006	.035	.03	.874	1.01	.94	1.08
Experience	-.025	.041	.36	.549	.98	.90	1.06
Households size	.074	.142	.271	.603	1.077	.815	1.424
Farm-Related Characteristics							
Land under cocoa	.005	.029	.03	.868	1.01	.95	1.06
Land Fertilized	-.014	.025	.31	.576	.99	.94	1.03
Land Rights	.189	.875	.047	.829	1.208	.217	6.72
Land ownership	.529	1.602	.109	.741	1.697	.073	39.21
Source of Labour	-.086	1.070	.006	.936	.918	.113	7.478
Access to Credit	-.023	1.116	.00	.984	.98	.11	8.70
Credit from financial institution	2.899	1.327	2.06	.047	1.38	.10	18.66
Row planting	3.995	1.636	5.96	.015	54.30	2.20	1341.5
Access roads to farm	.258	.689	.14	.709	1.294	.34	4.99
Mobile Phone	-1.44	1.023	1.99	.158	.236	.03	1.76
Frequency of contact by Extension Agents	.016	.025	.04	.844	1.11	.94	1.34
Yield	.002	.019	.016	.898	1.002	.966	1.040
Technology -Related Characteristics (perceived attributes of PA)							
Relative Advantage	1.176	.423	7.73	.005	3.242	1.42	7.43
Compatibility	.115	.352	.11	.744	1.122	.56	2.24
Ease of Use	.787	.294	7.16	.007	2.196	1.23	3.91
Trailability	.453	.368	1.51	.219	1.574	.76	3.24
Observability	.457	.408	1.25	.263	1.579	.71	3.51
Voluntariness	-.220	.405	.30	.586	.802	.36	1.76
Awareness Level							
Awareness of data issues	1.051	.883	1.418	.234	2.860	.507	16.132
Awareness of PA Technology/tool	-1.59	.829	3.713	.054	.203	.040	1.028
Awareness of Management of PA	1.275	1.000	1.623	.203	3.577	.504	25.410

n=416