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Determinants of Ex-Ante Adoption of Precision Agriculture Technologies by Cocoa Farmers in Ghana

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Abstract. *The study was to identify the best predictors of cocoa Farmers willingness to adopt future Precision Agriculture Technology (PAT) Development in Ghana. Correlational research design was used. The target population was all cocoa farmers who benefited from Cocoa High Technology Programme (an initiative of distributing free fertilizer by government to cocoa farmers) in Ghana. Multistage sampling technique was used to select 422 out of 400,000 cocoa farmers in the six (6) out of the seven (7) cocoa growing regions in Ghana. A content-validated and reliable structured interview schedule was used to collect primary data from respondents. Descriptive statistics and Binary Logistic Regression were used to identify the best predictors of cocoa farmers willingness to adopt PA from the main predictors (i. Demographic and farm related characteristics of cocoa farmers (18 predictors), ii. Cocoa Farmers Perceived Attributes of PA innovations (6 predictors); iii. The Awareness level of respondents in PA technologies (3 predictors). Majority (83%) of the respondents were willing to adopt future PA technology development in Ghana. The Binary Logistic regression analysis, showed that the model as a whole explained between 37.5% to 60.4% of the variances in cocoa farmers' willingness to adopt any future PATs. Only Five (5) (Educational Level of cocoa farmers; Cocoa farmers who plant in rows; Credit from financial institution; Relative advantage of PATs and the perceived Ease of use of PATs) out of the 28 predictors made a unique statistically significant contribution to the cocoa farmers willingness to adopt future PATs developed. The odds ratio showed that 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 of the potentials of PAT development in cocoa production in Ghana.*

Keywords: Determinants, Precision Agriculture, Future Adoption, Cocoa Production in Ghana.

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 whiles 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% in 2013 due to the expansion of the oil sector (ISSER, 2014). However, it still contributes to about 50% of National employment (ISSER, 2014).

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 the agricultural sector and has contributed to an average of 26% of Ghana's export earnings between 2007 - 2012 (ISSER, 2013). Therefore, a significant growth of the economy, to some extent, depends on the growth of the cocoa sector. In Ghana, the average national annual yield which is around 350-760 kilograms per hectare (kg/ha), is very 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 the need to increase productivity in Ghana. However, the concerns 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 general consensus among many agricultural development practitioners in the world is to increase productivity as well as prevent soil erosion, reduce pesticide and fertilizer contamination, protect biodiversity, preserve natural resources and other relevant climatic indicators. (Hamideh, Kurosh & Abdol-Azim, 2011).

Precision Agriculture (PA) technologies have been identified to have the potential of addressing two major problems: 1. increase agricultural productivity to address this anticipated food insecurities and 2. Mitigate and adapt to some climate change effects (Najafabadi, Hosseini and Bahramnejad, 2011). Precision Agriculture is a highly mechanized and information and technological based Agriculture production system that emphasis site- specific application of inputs to achieve high and optimum productivity as well as environmental sustainability though judicious use of inputs. To achieve these, PA combines innovations such as Geographic Information System ***(***GIS), Global Positioning system (GPS), Variable Rate application (VRT) and Yield Monitors in farming. The site specific application of inputs and monitoring helps minimize cost since inputs like fertilizer, pesticides, water are applied only when it's needed. This also reduces environmental loading by applying agrochemicals only where and when they are needed; and also reduces excess applications of agrochemicals and other input 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 PA technologies for over two decades now, however, *its use are limited in sub-Saharan Africa including Ghana (*Blackmore et al., 2003). With the exception of few yield monitors in South Africa and some VRA 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 provided by TomTom company now covers all 54 African countries with maps that are 3D and interactive (African Business, 2014). Even though these services are mainly for the roads, their use can be harness to develop vegetation and soil maps to facilitate the development of PA in Africa including Ghana. Moreover, the awareness level as well as the potential factors that affects farmers' willingness to adopt these technologies (when they become available) are not known.

Objective of the paper

The main objective of this paper was to identify the predictors of cocoa Farmers willingness to Adopt Future Precision Agricultural Technologies Development in Ghana.

LITERATURE REVIEW/CONCEPTUAL FRAMEWORK

The study was guided by the (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 by Davis (1989) illustrated by Kim and Garrison (2009). Hence, in this paper, the researcher posits that the behavioral intension 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 iii. Cocoa farmers' awareness level of PA technologies.

The demographic and farm-related characteristics

The study considered the following demographic and farm related characteristics**:** sex**,** age, educational background, years of experience in cocoa farming, household dependants, size of farm, agrochemical use, source of finance and labour, yield and farmers etc. (Akudugu et al., 2012; Rogers, 2003; Maheswari, Ashok, & Prahadeeswaran ;2008). These individual variables (see Table 1) were expected to have either positive or negative impact on cocoa farmers' willingness to adopt PATs if available.

Technology characteristics (Perceived Attributes) of precision agriculture

The study adapted Rogers' (1985) five (5) characteristics of innovations that affect the likelihoods of its adoption namely (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability. 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, the study considered only voluntariness since image has been found to be embedded in Rogers' attribute of 'Relative advantage'(Rogers, 2003). Moreover, since the* Technology Acceptance Model (TAM) by Davis (1989), is rooted in two (2) of the five (5) attributes of innovation by Rogers (2003): 1. Relative Advantage and 2: Complexity for which TAM called it 'Perceived Usefulness' and 'Perceived Ease of Use' respectively, the study viewed Relative Advantage and "Perceived Usefulness' to mean the same and Complexity and Perceived Ease of Use are also used interchangeable.

Hence, six (6) main constructs of cocoa farmers' perceived technology characteristics or attributes of PA innovation that were considered are:

- **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 or tried 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.

***Awareness level of PA*.**

Farmers' awareness levels were assessed based on how they perceived the three (3) main components of PA namely (a) Information or data base, (b) Technology or tools, and (c) Management of information components. Generally, cocoa farmers' perceived awareness of these three (3) Main components are expected to have direct impact on cocoa farmers' willingness to adopt the PATs (Watkins, Lu, & Huang, 2008; Morgan & Ess, 2003; Forouzanmehr & Loghavi, 2012).

METHODOLOGY

This Paper is Part of a scholarly research to investigate the Prospects and Challenges of Precision Agricultural Development and Implementation in Cocoa Production in Ghana. Correlational research design was used. The target population was all cocoa farmers under the Cocoa High Technology programme in seven (7) Cocoa Regions in Ghana. The New Cocoa High Technology programme (CHTP) was instituted by government of Ghana in 2014 that distributed mainly free fertilizer to **selected cocoa farmers in Ghana**. Because PA emphasis site-specific application of inputs especially fertilizer, cocoa farmers under the programme were identified as ideal target population. A total of approximately 140,000 cocoa farmers benefited from the programme. Multistage sampling technique was used to select 425 cocoa farmers in the six (6) out of the seven (7) cocoa growing regions in Ghana (the remaining one cocoa region was used for pilot study).

A content-validated structured interview schedule was used to collect primary data from respondents. The instrument consisted of four (4) main parts: i. Demographic and farm related characteristics of cocoa farmers, ii. Cocoa Farmers Perceived Technology related Characteristics (attributes) of PA; iii. The Awareness level of respondents in PA technologies and tools and, iv. Cocoa farmers' willingness to adopt the PA technologies. Items in the part ii and iii were measured using a six point Likert-type scale ranging from 0 to 5 from No Agreement (0) to Strong Agreement (5) and Not Aware (0) to Very Much Aware (5) respectively. A pilot study was done to pretest the structured interview schedule to ensure its reliability. Cronbach's alpha reliability coefficient and Kuder-Richardson (20) coefficient was 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 instrument (Nunnelly, 1998). The data collection was done between May 2015 and July 15, 2015. Out of the 425 targeted interviews, 416 was successful indicating about 98 response rate.

With the help of IBM SPSS version 23 measures, 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) Precision Agriculture from the main independent variables (i. Demographic and farm-related characteristics of cocoa farmers (19 predictors), ii. Cocoa Farmers Perceived Technology-related (attributes) Characteristics of PA (6 predictors); iii. The Awareness level of Cocoa farmers in PA technologies (3 predictors)

Model specification of the binary logistic regression

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

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

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 $\ln\left(\frac{p}{1-p}\right)$ 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 PA technologies measured as 1 =adoption; Y=0 define otherwise. The X's define independent variables that explain the probability that a farmer would be willing to adopt PA technologies measured as 1 = adoption and ε_i is error term (equation 2):

$$logit[P(Y_i=1)] = \beta_{0i} + \beta_{i1}X_{i1} + \beta_{i2}X_{i2} + \beta_{i3}X_{i3} + \beta_{i4}X_{i4} + \beta_{i5}X_{i5} + \beta_{i6}X_{i6} + \beta_{i7}X_{i7} + \beta_{i8}X_{i8} + \beta_{i9}X_{i9} + \beta_{i10}X_{i10} + \beta_{i11}X_{i11} + \beta_{i12}X_{i12} + \beta_{i13}X_{i13} + \beta_{i14}X_{14} + \beta_{i15}X_{i15} + \beta_{i16}X_{i16} + \beta_{i17}X_{17} + \beta_{i18}X_{i18} + \beta_{i19}X_{i19} + \beta_{i20}X_{i20} + \beta_{i21}X_{i21} + \beta_{i22}X_{i22} + \beta_{i23}X_{i23} + \beta_{i24}X_{i24} + \beta_{i25}X_{i25} + \beta_{i26}X_{i26} + \beta_{i27}X_{i27} + \beta_{i28}X_{i28} + \varepsilon_i \quad (2)$$

The dependent variable was farmers' willingness to adopt PA technologies if available. This was measured as dummy with 1 and 0 indicating willing and not willing to adopt PA technologies respectively. The main set of independent variables (determinants) were:

- Demographic and farm-related characteristics: (X_1-X_{19}).
- Technology related-characteristics (Attributes of the innovation): (X_{20}-X_{25}).
- Awareness level of cocoa farmers respectively :(X_{26}- X_{28})

Table1 shows the codes and expected signs of the 28 individual predictors used in the equation.

Table 1: Codes, and expected sign of predictors in the 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)	Number of Acres	+
8	Land size where fertilizer applied (X_8)	Number of Acres	+
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 acreas (X_{16})	Number of bags	+
17	Yield (X_{17})	Number of bags	+
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	+
38	Awareness of Management of info. (X_{28})	Likert-type scale	+

Source: Author's Construct (2015)

FINDINGS

Summary of demographic and Farm-Related characteristics of cocoa farmers in Ghana.

Table 2 provides the descriptive statistics of the respondent cocoa farmers' demographic characteristics: sex, educational background, marital status, age, experience in cocoa farming and household size. The table shows that the majority (about 76%) of the respondents 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. Moreover, about 84% of the respondents were married and with more than half (56.5%) of the respondents above 50 years ($\bar{X}$ = 52 ± 13.6 years) and were very experienced ($\bar{X}$ =21±10.2 years) in cocoa farming. The mean household size was approximately 6 members with about 55% having more than 5 dependents.

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,	<30	14	3.4	51.8	13.6
Min=22 Max=94)	30 – 39	69	16.8		
	40 – 49	96	23.3		
	50 -59	113	27.4		
	60 – 69	75	18.2		
	≥70	45	10.9		
Experience (Years n=407)	1-10	76	18.7	21.0	10.2

Min= 3, Max=54	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. Source: Field Survey, Bosompem (2015)

The result on the educational level (78% having formal education) is almost similar to the findings of Bosompem et al. (2011b) who reported about 80% of respondent cocoa farmers in Eastern Region of Ghana had formal education. Okorley et al. (2014) also found 78% of cocoa farmers in Western Region had formal education even though their level of education was low (67%). The results on the age of farmers ($\bar{X}$=52±14 years) show that cocoa farmers are still aged with few (20%) youths (below 40 years) in the sector. Marcella (2007) reported that most cocoa farmers in Ashanti and Brong-Ahafo regions of Ghana were aged (65-70 years). These conditions especially the age could have negative impact on the adoption of any future PATs.

Table 3 presents the summary of the farm-related characteristics of cocoa farmers namely: farm size under cocoa production, farm size fertilized, land ownership, land rights, row planting, quantity of fertilizer used, yield per acre etc.

Table 3. Descriptive Statistics of Farm-Related Characteristics of Respondent Cocoa Farmers

Variables	Categories	f	%	$\bar{X}$	SD
Farm size under cocoa (Acres) (n=401, min=0.50, Max= 100)	≤ 5	83	20.7	12.8	13.2
	5.1 -10	162	40.4		
	10.1-15	66	16.5		
	Above 15	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 (Acres) (n=380, min=0.25, Max= 99)	≤ 5	182	48.3	7.8	9.9
	5.1 -10	130	34.5		
	10.1-15	42	11.1		
	>15	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 (bags) n=338	1-10	142	42.0	19.0	24.5
	11-20	93	27.5		
	21-30	52	15.4		
	>30	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 month	156	47		
Current Yield of fertilized farm (bags/acre)				4.6	6.7

n= 416. Source: Field Survey, Bosompem (2015)

Table 3 shows that the majority of the farmers (61%) had 10 acres (4.0 ha) or less of cocoa farm with a mean farm size of 12.8 ± 13.2 acres (5.2 ha.). However, a mean of 7.8 acres (3.2 ha) cocoa farms were fertilized even though a majority (83%) of the farmers had farm size of about 10 or less acres fertilized. Also, 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. Also most farmers (66%) inherited their land from a family member and the other 34% of the respondents either bought the land, or acquired it through sharecropping, hence, about 41% had the right to sell their land outright to others. The majority of the farmers (58%) had access roads to their farms hence inputs like fertilizers were conveyed easily to the farms. However, only 21% of them had their cocoa trees planted in recommended rows and planting distance and anything contrary to that can retard the movements of farm machineries (e.g. tractors) and Precision Agriculture tools (eg. VRA and Yield monitors) to those farms planted haphazardly.

Also only 25% 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 (53) out of 103 respondents who had access to credit representing about 52% had the credit from financial institutions such as the rural banks and the micro finance, the rest (48%) had the credit from either Licensed Buying Companies(LBCs), money lenders and other family members and friends. A little over half of the respondents (52%) used hired labour in their farms but the rest used either their own, family or through cooperative labour. About 78% of respondents had mobile phones which were mostly analog. About 53% of respondents had contact with Cocoa Extension Agents (CEAs) at least once a month. A total mean of 19 ±24 bags of fertilizer were applied with a mean of 2.5±1.9 bags/acre instead of the recommended 3 bags/acre. The yield was also 4.7 bags /acre relatively lower compared to the expected 10 bags/acre or more expected from the programme

Since about (66%) inherited their land and 41% of the respondents can sell their land outright, it stands to reason that they are likely to have better land rights. 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. Therefore, if farmers have higher land rights (for example if bought or inherited lands), they are more likely to adopt PAT since they have the advantages of enjoying their own farm management practices and investments.

About 53% of the farmers having contact with CEAs at least once a month is quite encouraging since information on agricultural practices (including PATs) is provided by either extension services or consultants and Adoption of PATs was reported to be higher among those who received information from trained extension agents or those who hired consultants (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. The use of hired labour has been found to have significant influence on the likelihood of adoption of fertilizer (Degu et al., 2000). However, since farmers pay for hired labour, if access to credit is low or not existing , adoption of PA is likely to suffer (Dormon et al., 2004).

The mean yield of 4.7 bags /acre relatively lower compared to the expected 10 bags/acre or more expected from the CHTP (Appiah, 2004). However, the result is quite similar to the findings of Bosompem et al. (2011) who found a mean yield increase from 448.9 kg/ha (2.85 bags/acre) to 768.5kg/ha (4.9 bags/acre) from cocoa farmers 3 years (2002-2005) after the adoption of fertilizer application in Eastern Region of Ghana.

Farmers' Perceived Awareness and attributes of PATs

Farmers' awareness levels were assessed based on the three (3) main components of PA namely (a) Information or data base, (b) Technology or tools, and (c) Management of information components**.** That level of awareness of cocoa farmers was low in both the 'information and data base' ($\bar{X}$=2.38, SD=.97) and the 'management of information ($\bar{X}$=1.54, SD=.77)' components but that of the 'technology or tools component' ($\bar{X}$=2.61, SD=1.34) was fair (Table 4). There was an exception of one of the sub-components of the 'technology or tool' component (GPS receivers) where majority of cocoa farmers (78%) were much aware of its use. Cocoa farmers reported that Cocoa Extension Agents in Ghana used the GPS receivers for measuring their farms before the right quantity of fertilizers was supplied to them under the Cocoa High Technology programme. GPS receivers and GIS have been used to determine the supply base of producing firms and established a system for traceability and precision production for some vegetable and fruit farmers through mapping to establish the spatial locations and concentrations of fruits and vegetable farms in Ghana (ISPA, 2013).

Table 4. Descriptive statistics of Farmers' Awareness level and Perceived attributes of PATs

Variables		
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	1.54	.77
Attributes of PA	$\bar{X}$	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 attributes: 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
Source: Field Survey, Bosompem (2015)

Table 4 again shows cocoa farmers perceived attributes of PA innovation in cocoa industry in Ghana. 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 Observability ($\bar{X}$=3.40, SD=1.07), compatibility with current technologies ($\bar{X}$=3.35 SD=.98), Ease of use ($\bar{X}$=3.45, SD=1.33) and its trailability ($\bar{X}$=3.13, SD=.88). The high agreement of farmers on the Relative advantage of PATs over their existing technologies implies that cocoa farmers perceived PA to have the potentials 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. Another implication is that cocoa farmers have high expectation that PATs implementation in cocoa industry would be advantageous over cocoa farmers' existing technologies in Ghana, however, they are generally not too sure whether the other five (5) aforementioned attributes of PA innovation could be a reality in Cocoa industry in Ghana based on the available cocoa technologies and current practices of cocoa farmers.

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

The results in Table 5 show that a majority (about 83%) of the respondent cocoa farmers were willing to adopt future PATs development in Ghana which is an indication of bright prospects of any future PATs development in Ghana since willingness to adopt or farmers intensions to adopt has been found to have a positive impact on actual future adoption of PATs (Aubert et al., 2012).

Table 5. Cocoa Farmers Willingness to Adopt Precision Agriculture in Cocoa Production

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

n=416. Sources: Field Survey, Bosompem (2015)

Best Predictor(s) of Cocoa Farmers' Willingness to Adopt PATs in Ghana

Binary logistic regression was performed to assess the impact of a number of factors on the likelihood that respondent cocoa farmers would adopt any future PATs introduced in cocoa production in Ghana. The model contained about 28 independent variables. Before the regression, multicollinearity diagnostic test using Tolerance and Variance Inflation Factor (VIF) were used to determine whether a predictor has a strong linear relationship with the other predictor or predictors (Field, 2013**)**. Tolerance value were between 0.283 and 0.988 and VIF values between 1.0 and 3.5 implied no significant concern for multicollinearity (Pallant, 2011, Field, 2013).

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 squared) of the variances in cocoa farmers' willingness to adopt any future PATs**.**

Of the 28 predictors in the equation, only five (5) of made a unique statistically significant contribution to the model at 0.05 alpha level. These 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 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=417. p>0.05. CI=Confident interval

Source: Field Survey, Bosompem (2015)

Educational level as a predictor of cocoa farmers' willingness to adopt PATs

Educational Level was the only demographic characteristics found to be significant but negative predictor (β= -3.994) of cocoa farmers' willingness to adopt PATs. This implies that farmers who had higher level of education are less likely to adopt PATs in Cocoa production. In other words, the lower the educational level of respondents, the more likely they were willing to adopt any future PATs. The odds ratio of 0.02 (less than 1) also indicate that for every additional level of education, respondents were .02 times less likely to adopt future PATs. The result from the study 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 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 farmer's intension to adopt PAT.This negative relationship observed may be as a result of how educated farmers perceived the enormous challenges that need to be surmounted before PA become a reality in Ghana. This is possible because, Gamble and Gamble (2002), opined that sometimes, high level of education 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 Ghana. Many PA advocates (researchers with higher level of education) are even sceptical 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 (positive) predictor (β=3.995) of cocoa farmers' willingness to adopt precision agriculture.

This meant that farmers who had planted cocoa trees in rows are likely to adopt future PATs in Cocoa production in Ghana. The odds ratio showed that the strongest predictor of farmers' willingness to adopt any future PATs was "row planting" (odd ratio= 54.30). The odd ratio of 54.30 indicate that respondents who had planted their cocoa trees in rows are over fifty four (54) times more willing to adopt any future PATs in cocoa production in Ghana, controlling for all other factors (predictors) in the model. This gives an indication that farmers who had already planted in rows are more likely to adopt PA technology than those who had not yet done so. However, most 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 has implication for movement of PA machinery and equipment such as tractors and VRAs in cocoa farms.

Source of credit as a predictor of cocoa farmers' willingness to adopt PATs

Another farm-related factor that was found to be a significant (positive) predictor (β=2.899) of respondents' willingness to adopt precision agriculture was cocoa farmers access to credit from financial institutions. The odd ratio of 1.38 indicate that respondents who had credit from financial institutions (eg. banks, MFIs 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), controlling for all other predictors in the model. It is noteworthy however that, 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 from 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) being 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 **(p**erceived usefulness) of PATs was one of the two technology-related factors that was positive (β=1.176) and significant predictor of cocoa farmer' willingness to adopt PATs with the odds ratio of 3.242. This implies that respondent cocoa farmers perceived PATs as being better than their previous technologies and they are likely to adopt future PATs in Cocoa production in Ghana. This result is significant for the prospects of PAT development and adoption of cocoa in Ghana since the degree of relative advantage has been expressed in economic profitability and social prestige (Rogers, 2003). The results also agree with 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 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 intension 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 significant predictor of cocoa farmers' willingness to adopt future PATs with the odds ratio of 2.196. This implies that respondent cocoa farmers who perceived PATs as being easier than their previous technologies are more likely to adopt future PATs in cocoa production in Ghana. The findings are at par with 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 intension to adopt PATs, mediated by perceived net adoption (Adrian et al., 2005).Since respondent 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 depend on their self-efficacy as far as their abilities to use computer and its related peripherals are concerned.

CONCLUSIONS

Generally, the farmers perceived that their awareness level of PATs as a whole was low, however, majority of the cocoa farmers were aware of the use of GPS receivers since they are currently used in estimating the size of their cocoa farmers before fertilizer application in Ghana.

Cocoa farmers had high conviction that PA would have relative advantage 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 the cocoa production.

A majority (83%) of the respondent cocoa farmers was willing to adopt future PATs. The five (5) main predictors to Cocoa farmers' willingness to adopt future PATs where educational level of cocoa farmers, row planting, and credit from financial institutions, relative advantage of PATs, and the perceived ease of use of PATs. However, the model as a whole (with 28 variables) explained between 37.5% to 60.4% of the variances in cocoa farmers' willingness to adopt any future PATs in Ghana. Educational level had negative impact on any future adoption of PATs, as a result, of the reality of challenges farmers perceived in PATs development in Ghana. Cocoa farmers' access to credit from financial institutions would facilitate their adoption of PATs among farmers. Perceived relative advantage (perceived usefulness) and Ease of Use of PATs have positive impact on cocoa farmers' willingness to adopt PATs. The study does confirm the Technology Acceptance Model (TAM) by Davis (1989) that posited that only these two (2) attributes are significant predictors of the adoption of IT-related innovations.

The study recommended among others the need to create awareness among farmers and other major stakeholders of 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.

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