UNIVERSITY OF CAPE COAST

MAIZE FARMERS ACCEPTANCE AND WILLINGNESS TO PAY FOR DRONE SERVICES FOR THE CONTROL OF FALL ARMYWORM IN NORTHERN GHANA

SELORM OMEGA

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BY

SELORM OMEGA

Thesis submitted to the department of agricultural economics and extension of the school of agriculture, college of agriculture and natural resource, University of Cape Coast in partial fulfilment of the requirements for the award of Masters of Philosophy degree in Agricultural Economics

SEPTEMBER 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature ……………………… Date ………………………..

Candidate's Name: Selorm Omega

Supervisors' Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Supervisor's Signature: ………………………Date ……………………………

Supervisor's Name: Dr. William Ghartey

ABSTRACT

In Ghana, maize is one of the major staple food crops. Since 2016, it has been plagued by fall armyworm, leaving production capacity below the national average. The introduction of drone technology is to assist farmers to reduce havoc caused by fall armyworm. Majority of research done in the area of drone technology has focus on the technical and mechanical aspect. This gap gives rise to this study, as the study seeks to; describe the socio-economic characteristics of maize farmers, examine preferred options by maize farmers for control of FAW, assess and compare the total perceived effect of the field usage of various spraying methods of pesticide, assess and compare the Enterprise analysis of experimental plots for the application of pesticides for the control of FAW, ascertain farmers' willingness to pay for drone services for the control of FAW and determine factors that influence the acceptance of drone services for the control of FAW. The study adopted cross sectional survey design to ascertain the interplay of variables. The research used a multi-stage sampling technique to obtain 152 sample out of 301 population. The research used questionnaire as the data collection tool. The data was stored and analysed using Microsoft Excel, SPSS 25.0 and StataSE 13.0. The results of the study revealed synthetic control was the preferred control option. With objective two, it was revealed that drone technology had high financial effect on farmers. Whiles, on the Enterprise analysis, it was revealed that the cost of drone plot was high relatively to that of knapsack but the gains from it was better off. Majority of respondent were willing to pay for drone service but did not have enough resource. Willingness to pay was influenced by farmers' gender, access to input and information, status in the household and contact with extension agents. Lastly, it was revealed that maize farmer's decision to accept drone service was influenced by maize farmers' status in the household, content and accessibility of drone services. In conclusion, maize farmers in the North-East and Northern Regions showed high level of acceptance of drone services but faced financial difficulties in accessing it. The study recommends that MoFA and NGOs into agriculture should help provide credit to maize farmers to boost their acceptance of drone services.

KEY WORDS

Drone Technology

Fall armyworm

Knapsack

Market Acceptance

Pesticide

Willingness to pay

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DEDICATION

To my younger brother Sydney Kwame Senam Omega and the Department of Aquaculture and Fisheries Management of the University of Ibadan, Nigeria.

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LIST OF ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
CABI	Centre for Agriculture and Bioscience International
CAPI	Canadian Agri-food Policy Institute
CMV	Contingent valuation method
FAO	Food and Agricultural Organisation
FBO	Farmer Based Organisation
IPM	Integrated Pest Management
MOFA	Ministry of Food and Agriculture
NEPAD	New Partnership for Africa Development
OECD	Organisation for Economic Co-operation and Development
PwC	PricewaterhouseCoopers
UNECA	United Nation Economic Commission for Africa
UNICEF	United Nations International Children's Emergency Fund
US EPA	United State Environmental Protection Agency
USAID	United State Agency for International Development
USDA	United State Department of Agriculture
USDA FAS	Department of Agriculture Foreign Agricultural Service
USFWS	United State Fisheries and Wildlife Services
WHO	World Health Organisation
WTP	Willingness to pay

CHAPTER ONE

INTRODUCTION

Background of the Study

Maize is the most commonly consumed staple cereal crop cultivated by farmers in sub-Sahara Africa and is also one of the main cereals cultivated in other parts of Africa (Pingali & Heisey, 2001). The crop is grown in all the agro-ecological zones, where an estimated 200 million individuals rely on the crop for food security (United Nations Economic Commission for Africa, 2015). In East and South Africa maize constitutes almost half the amount of calories and protein eaten and one-fifth in West Africa (Alliance for Green Revolution in Africa [AGRA], 2017). However, the crop has been under threat from different pest and diseases in the past, and recently the Fall Army Worm.

Spodoptera frugiperda J.E.Smith, Fall Armyworm ((FAW) is a lepidopteran plague indigenous to tropical and subtropical America regions that feed mainly on cereals and over 80 distinct plant species but has a preference for graminaceous plants and, in particular, maize (Baudron, Zaman-Allah, Chaipa, Chari & Chinwada, 2019). Central and Western Africa recorded the first plague case in early 2016 (Goergen, Kumar, Sankung, Togola & Tamò, 2016) and then, later most other sub-Saharan Africa countries (Day, Abraham, Bateman, Beale, Clottey, Cock & Gomez, 2017). There is no clear evidence of how the invasion started in Africa but it’s has been suggested that it originated from Florida and the Caribbean (Huesing, Prasanna, McGrath, Chinwada, Jepson & Capinera, 2018).

It is known that FAW caterpillar or larva causes the most harm (FAO & CABI, 2019). Young larvae generally feed on leaves, producing a distinctive "window" impact and moist sawdust-like frais near the funnels and upper leaves of plants such as maize (Huesing et al., 2018). It is estimated that female FAW can lay up to 1,000 eggs at a moment and can generate numerous generations in tropical settings very rapidly without a break (Baudron et al., 2019). FAW moths can fly distances of up to 1,600 kilometers in 30 hours (nearly 1,000 miles) if permitted to achieve maturity (Farias, Andow, Horikoshi, Sorgatto, Fresia, dos Santos & Omoto, 2014). As the larvae mature, plant seeds and reproductive structures are burrowed in a whorl pattern. Larger larvae may even cut the plant's foundation. Untimely detection can cause farmers to lose their farm products (Sebby, 2010). There is no isolation of the infestation and it poses a danger to smallholder groups throughout Africa, particularly Ghana. In sub-Saharan Africa, FAW is making the realization of food security and poverty reduction an increasing mirage (Day et al., 2017).

The Government of Ghana as part of its responses to the invasion has invested hugely into chemical pesticide applications (Harrison, Thierfelder, Baudron, Chinwada, Midega, Schaffner & van de Burg, 2019) and it continues to be their main strategy to controlling the pest. The practice has yielded mixed results, hence there is doubt over its effectiveness (Kumela, Simiyu, Sisay, Likhayo, Mendesil, Gohole & Tefera, 2018). Agronomic control techniques are an exciting option, more accessible to resource-constrained smallholders and with reduced health and environmental risks (Thierfelder, Niassy, Midega, Sevgan, van de Burg, Prasanna, Baudron & Harrison, 2018). However, this measure is unsustainable in the long run. To enhance adequate agronomic management practices, modern technologies such as drone has been introduced recently in crop farming.

The use of drones has moved from the battlefield to the agricultural field in recent decades. In 2016, PricewaterhouseCoopers International Limited (PwCIL) report that the market for agricultural drones is estimated at USD 32.4 billion (PwCIL, 2016). North America presently manufactures the largest number of drones in the business and agriculture industries in general. According to Greenwood, Cressman, Quiroz, Hall, Francisca and Bustos (2016), "Various forms of agriculture aircraft have been developed since 1932 but these aircraft did not pay attention to the needs of individual farms". Although it is unlikely that drones will completely replace manned aircraft or satellites, these more traditional remote sensing methods have several advantages. The technology can collect high-resolution images under the cloud, with a lot more detail than the satellite scans that developing nation analysts generally have (Sylvester, 2018).

Drone technology can assist farmers to track their plants, prevent pests, enhance land tenure and more (Greenwood et al., 2016). A drone can provide detailed information like revealing the problems of soil variation that are not perceived at eye level. Apart from agricultural drones, multi-spectrum pictures and infrared information can also be taken, which shows the differences to the naked eyes between healthy and distressed crops (Sayem, 2017). The drone can merge information and generate a time series animation that can demonstrate image modifications in the crop throughout the entire process.

According to Hall and Khan (2003), “The biggest challenge, unsurprisingly, is the cost of adoption of drone technology”. Although drone prices in recent years have declined significantly, for most smallholder farmers in developing nations the cost of drone services remains far too high. Medium to large scale farmers are more willing and able to pay for drone services, however, smallholder farmers are now forming cooperatives to enhance access to drone technology applications in their farming activities.

Drones ' awareness and public laws hamper drone use in tackling the agricultural yield gap. Some rural communities do not know drones and are understandably reluctant to use it in the community (Johnson, Ricker & Harrison, 2017). Therefore, organizations operating drones are being encouraged to work with communities to facilitate buy-in and understand the uses and benefits of drones to their activities. Government drone laws, or their absence, can also restrict the use of drones for agricultural purposes. Around 77% of African nations lack drone laws, which can make the operation of drone difficult (Stöcker, Bennett, Nex, Gerke & Zevenbergen, 2017).

Studies done in the area of drone technology in agriculture in Ghana shows that drone technology has been used in rice production. Most of the studies used drone technology as a means of scaring pests like birds from rice farms to ensure high yield and income to farms. However, farmers acknowledge the costliness of drone technology despite its benefits. This has led to the formation of cooperative societies to share the cost, whiles enjoying the benefits (Kimani, 2019).

The Northern Region (Northern and North- East Regions) according to MoFA (2017) was the third highest producer of maize after formerly Brong Ahafo, Ashanti and Eastern. Majority of the regions maize output is produced by small scale farmers who account for an estimated 70 percent of maize production (Bariw, Kudadze & Adzawla, 2020). The region like others have experience shortfall in their production capability and this have been largely attributed to the activity of Fall Army Worm. FAW infestation in the Northern Region has rendered farmer income insignificant. Farmers in attempting to savage their incomes have restored to the use of various control option. In this study, the Department of Agricultural Economics and Extension of the University of Cape Coast, Acquahmayer Drone Technology Limited and Savannah Agricultural Research Institutte (SARI) and Bayer conducted trials to find out the efficacy of application modes for the control of FAW infestation.

Statement of the Problem

Agriculture remains a difficult, low margin business for many farmers, with governments frequently assisting when adversity befalls them. However, the government has done little in the fight against FAW since its discovery in 2017 in Ghana(Nunda, 2018). This limitation is due to the absence of empirical data to guide the government in its policy formulation for effective control of FAW. Data used in Africa is based on information from the Americas and sometimes anecdotal observations taken in the region (Harrison et al., 2019).

Africa was estimated to have lost 70% of its total maize, sorghum, rice and sugarcane yield in 2016 mainly due to the activities of FAW (Prasanna, Huesing, Eddy & Peschke, 2018). This was quantified by Rwomushana, Beale, Cameron and Clottey (2018)as approximately USD13.38billion. It is expected that this will have dire consequences on the livelihoods of people in affected regions of Africa (Abdoulaye, Alene, Maroya, Aighewi, Wobill & Asiedu, 2016). Day et al. (2017) estimated that the impact of FAW in Ghana was 22% of yield in Ghana, translating to millions of dollars in losses. However, the estimates were based solely on socio-economic studies that focused on the perceptions of farmers.

Maize farmers in the Northern and North-East Region of Ghana continue to use the tradition backpack (knapsack sprayer) for the control of FAW infestation despite FAW fast feeding rate. Knapsack as a spraying mode for controlling FAW has been reported to be less efficient and labour intensity (Meikle, Markham, Nansen, Holst, Degbey, Azoma & Korie, 2002). This makes it not suitable for large scale operation. Secondly, knapsack sprayers have been regarded as not environmentally friendly due to the high drift margin (Matthews, 2008). This has made it necessary to introduce application modes which are fast and are environmental friendly, hence the introduction of drone technology.

Surprisingly, drone which is widely renowned for its military use now offers promising prospect in the field of agriculture. This technology is recognized as an appropriate platform for collecting information on the health circumstances of agricultural plots and individual plants (Petkovics, Petkovics & Petkovics, 2017) and that data collected could be analysed to determine the extent of damage and the effectiveness of the various agrochemicals used (Mabe, Talabi & Danso-abbeam, 2017).

To acquire drones and correctly use them require significant capital investment and technical expertise which make it harder for many small to medium-Sized farms, which are less likely to benefit from economies of scale to justify their use.

Despite the large-scale use of drones in agriculture in other parts of the globe, literature in Africa's agricultural use of drones for pesticide application is less to be desired. In Ghana, for instance, there have been no reports of drone technology application in the control of fall armyworm. Hence, the dearth of data on market acceptance and the willingness of farmers to pay for drone technology application services. This research has therefore been conceived to close this gap and to provide information that might be useful.

Purpose of the Study

The purpose of this study is to ascertain the extent of drone application in the management of FAW infestation and its effect on maize farmer's acceptance and willingness to pay for drone service usage. FAW has been reported to have caused major destruction to maize farmers in Ghana. The Government of Ghana through the Ministry of Food and Agriculture and its stakeholders have adopted several strategies like free pesticide to mitigate the activity of FAW infestation. However, the major problem to these strategies is the mode of application. Due to the fast feeding rate of FAW, the traditional pesticide application mode (knapsack) is rendered less effective. Therefore, necessitating the need for faster application mode like drone.

Research Objectives

The overall objective is to ascertain empirically the extent of drone application in the management of FAW infestation and its effect on maize farmers' acceptance and willingness to pay for drone application services for the control of FAW.

The following specific objectives have been outlined to achieve the main objective:

1. To describe the socio-economic characteristics of maize farmers in the Northern and North-East Region of Ghana.
2. To examine preferred options by maize farmers for control of FAW in the Northern and North-East Region of Ghana.
3. To assess and compare the total perceived effect of the field usage of various spraying methods of pesticide.
4. To assess and compare the Enterprise analysis of experimental plots for the application of pesticides for the control of FAW.
5. To ascertain farmers' willingness to pay for drone services for the control of FAW.
6. To determine factors that influence the acceptance of drone services for the control of FAW.

Research Questions

1. What are the socioeconomic characteristics of maize farmers in the districts?
2. What are the preferred options used by maize farmers for control of FAW in the study area?
3. What is the total perceived effect of the field usage of various application of spraying methods of pesticide?
4. What is the Enterprise analysis of experimental plots for the application of pesticides in the control of FAW?
5. Are farmers willing to pay for drone services for the control of FAW?
6. Which factors influence acceptance of drone services for the control FAW?

Significance of the Study

With the world population likely to grow by approximately 34% by 2050, there is the urgency and the need to increase food production (FAO, 2009). The burden of farmers is that they cannot apply needed agrochemicals on time to ensure increase production. Also, farmers, especially in Africa, are still stacked with primitive agricultural practices like rain-fed agriculture, labour-intensive practices among others, this makes the goal of increasing food production implausible (NEPAD, 2018).

The study introduced farmers to alternative technology (drone technology) which is applies pesticide faster than the knapsack sprayer. Maize farmers can control pests and diseases like fall armyworms that attack their crops, thereby maintaining the same or increasing output to overcome possible food shortage. The study also helps maize farmers strengthen their ability to monitor and manage the core aspect of farming that cannot be maintained remotely.

The study will help companies that deal with drone technology and its allied services to know the specific drone requirement of farmers as they try to fight FAW infestation. If the specifications of farmers are met, it will make farmers willing to accept drone technology over other methods of pesticide application.

The study revealed the preference of farmers in the control of FAW. This is relevant as it will guide MoFA and other stakeholders in agriculture to know how farmers feel about the various control methods and also build on such methods to achieve the desired goal of eradicating FAW.

Furthermore, the study provides relevant data on farmers' willing level to pay for drone technology and factors that are likely to hinder their acceptance of the technology and its allied services. This research will also serve as reference material for further research in the area of drone technology, market acceptance, willingness to pay and efficiency.

Delimitations

This study was carried out in some selected district of the Northern and North-East Region (Walewale, Mion and Nyamkpala districts) of Ghana, where maize farmers were introduced to drone technology for the management of FAW infestation. The study focused on the set objectives. With data collection, only questionnaires and interview schedules were used.

Limitations

The study focused on only farmers that have been introduced to the use of drone technology in the application of pesticides to control FAW. Poor record-keeping led to farmers basing their responses on memory recall. This made data on farmers output in the previous year's difficult to obtain, making the study base it findings on memory call of farmers. Also, time and finances affected the study. This led to the selection of only a few number of maize farmers and inability to scale the study to other ecological zones. Project Protocols made it difficult to sometimes act outside the framework of the project. Lastly, language differences made the interpretation of the questions difficult, as the study had to rely on enumerators who spoke the local language for interpretation. This made it difficult to find out if farmers actually understood the questions read out to them. This has the tendency of skewing the results of the study.

Definition of Terms

This section provides the operational definition of terms used in this study.

Efficiency: relates to the use of any input, including personal time and energy, in generating output. The inputs relate to the factors of production used by maize farmers in maize production. Whiles, the output refers to the yield in terms of bags obtained at the end of the farming season.

Drone: is an aircraft without a human pilot aboard. The drone can be partially or fully controlled remotely by a pilot. The drone used in the study was an agriculture drone used for applying pesticides.

Willingness to pay: is the highest cost that a customer is sure to purchase one unit of an item at. The likelihood of purchasing drone technology is based on its attributes or value to the user. The economic value is associated with attribute preference or the maximum price that a farmer is willing to exchange his resource for drone technology (services).

Market acceptance: a condition where the goods or services meet the requirements of a large number of clients so that their production or accessibility is continued or increased. Market acceptance revealed whether drone technology (services) is satisfying the needs of maize farmers concerning pesticide application.

Pesticide: are substances that are meant to control pests and diseases, including weeds. A pesticide is a substance used by maize farmers to repel fall armyworm either before, during, or after the invasion of their maize farms.

Knapsack: This is a handheld spraying device consisting of a tank, pressurizing device, line and sprayer nozzle used mainly for applying chemicals. The knapsack is the known used method of applying pesticides by maize farmers in the study area.

Fall Army Worm: This is the current maize plant disease-causing huge havoc, through it feeding on leaves and stem of the maize plant. Its ability to hide in maize leaves makes it difficult to kill.

Organisation of the Study

This research will be structured into five sections. Chapter One will consist of the background to the study, statement of the problem, objectives of the study, research questions, research hypothesis, significance of the study, delimitations, definition of terms and organization of the study.

Chapter Two of the study will concentrate on the literature review with more light thrown on the research results of other writers linked to the issue under study. Issues reviewed included; the theoretical framework of acceptance and willingness to pay, willingness of consumers to pay, maize and fall armyworm, market acceptance, profit and profitability, cost and benefit analysis, gross margin, preferred control measures of FAW, drone technology in agriculture and effect of pesticide application.

Chapter Three will examine the research methods to be used for the study. It will include the research design, sampling procedures, population, data collection instrument and methods for data collection and analysis.

The fourth chapter will deal with the results as well as the discussion of the findings of the study. With the final chapter comprising; the summary, conclusions and recommendations based on the results of the study. Suggestions for further studies will also be covered.

Chapter Summary

The chapter was on the introduction to the study which focused on the background to the study, the problem under study, outlining of the objective as while the research question and hypothesis that guided the research. Also, the significance of the study, limitation and delimitation of the study were presented. Lastly, was the organization of the study that showed the content of the chapters.

CHAPTER TWO

LITERATURE REVIEW

General Overview

The literature review tries to look at the various theoretical and conceptual frameworks underpinning the study. It also looks at existing works relevant to market acceptance and consumer willingness to pay, the preferred option of a control application, Benefit-cost analysis, Maize and FAW in Ghana, Drone technology among others.

Unified Theory of Acceptance and Use of Technology (UTAUT)

In 1989, Davis used the Theory of Acceptance Model (TAM) to explain computer usage behaviour. TAM explains the overall predictors of computer-based acceptance that helps to explain user behavior along with a wide range of end-user computing technologies and user population. TAM tested the perceived usefulness (PU) and perceived ease of use (PEU) as the basic beliefs. In the theory, perceived usefulness was defined as the subjective likelihood of a potential user seeing the use of a certain system (e.g: E-payment System (single platform)) to improve their action. Whiles, perceived ease of use meant the extent to which the potential user is likely to see the targeted system to be effortless (Lee, 2009). However, the belief system is not straight forward as other factors can influence the belief system of an individual, this was termed external variables in TAM. One of the major setbacks of the TAM model was the elimination of user's subject norms and interests (Lee, Kozar & Larsen, 2003). This led to the development of the unified theory of acceptance and use of technology.

The unified theory of acceptance and use of technology which is an improvement on TAM identified four key factors, thus, performance expectancy, effort expectancy, facilitating conditions and social influence. It also added four moderator variables, thus, age, experience, Voluntariness and gender in behavioral intention prediction to use technology and the actual technology used in both organizational and non-organisational settings. The increasing number of research using UTAUT based research has growth due to the diffusion and proliferation of new ITs like enterprise systems (Sykes, 2015; Sykes, Venkatesh & Johnson, 2014), mobile internet (Thong, Venkatesh, Xu, Hong & Tam, 2011; Venkatesh, Thong & Xu, 2012), agile IS (Hong, Thong, Chasalow & Dhillon, 2011), collaboration technology in knowledge-intensive firms (Brown, Dennis & Venkatesh, 2010), e-government for citizens (Chan, Thong, Venkatesh, Brown, Hu & Tam, 2010) and health IS in the healthcare industry (Venkatesh, Sykes & Zhang, 2011) in a social system.

The theory in this study helped to reveal the usefulness and expected performance farmers associate with drone technology. This will be tested by using both drone and convectional pesticide application mode on different experimental fields with the same field size. The performance will be measured per the research in terms of time-saving and resource use (pesticide). Social interaction with farmers will reveal how such a technology can influence their social life given their socio-demographic characteristics. Conditions that will facilitate maize farmers acceptance of drone technology over the conventional approach of pesticide application, given their characteristics is made possible by the theory.

However, the theory has been criticized in most cases for its chaotic number of 41 independent variables for predicting intention and 8 other variables for predicting behavior (Bagozzi, 2007).

Theory of Planned Behaviour (TPB)

The theory of Planned Behaviour has been used in literature frequently to explore behaviors in pro-environmental, travel mode choice, energy consumption, water conservation, food choice, and ethical investment (Stern, 2000). According to Ajzen (1988) to predict the behavior of an individual, it’s best to ask if they are intending to behave in a certain manner. Individuals are expected to behave differently when there exist barriers that prevent the performance of an action. However, using intention to explain behavior was considered appropriate but its difficulty was obvious, given that it is somehow impossible to express intention without some level of bias. But Ajzen (1988) developed three determinants to explain behavioural intention. Thus

1. The attitude (opinions of oneself about the behaviour);
2. The subjective norm (opinions of others about the behaviour);
3. The perceived behavioural control (self-efficacy towards the behaviour).

According to the theory, attitude, and subjective norms and perceived behavioural control predict the individual intention and this will then predict acceptance. It is expected that the background characteristics of the individual will influence the intention of the individual through his attitude, his subjective norm and perceived behavioural control before an action is performed.

The model implies that farmers will make a decision by calculating the cost and benefit of action and chose the option that maximizes his expected net benefit. Hence, it's expected that from the study, it will reveal why a farmer will choose Knapsack or drone technology, given the expected net benefit he is expected to gain.

However, the theory has been critiqued for the fact that individual behaviour is not simple as the theory implies, rather behave is a complex process and not a one-stop act. The individual's behaviour is not only determined by the three said determinant but consist of social, moral and altruistic attributes as well as other self-seeking attributes (Stallen, 2013).

Consumer Theory

Consumer theory is considered the most used theories in understanding consumer behaviour. The theory has been thoroughly examined, tested and applied in areas of economics(Brown & Walker, 2019). The understanding of consumer using the consumer theory has produced different results across various works. However, the common finding has been the rejection of consumer rationality. In the view of the classical, consumers will always prefer what is good for themselves and will always want more of it to the point of satiation (Ketcham, Kuminoff & Powers, 2019). But this notion has been criticised by many scholars. For example; Stigler (1996) wrote "consumers are lazy and dominated by advertisers or poor arithmetic's, hence, they do not maximize satisfaction". This formed the bases for other works which critique the concept like Madrian and Shea (2001) (enrolment in retirement saving plans), Woodward and Hall (2012) (access to credit), Handel

(2013) (health insurance) and Abaluck and Gruber (2011) (Prescription drug insurance). In all these studies, it was discovered that people were willing to cash in instance where stakes in the financial sector is high. Some scholars simply put this as people making choices that do not maximise their utility, hence abusing the building block of the theory.

Economists have come into agreement that choices of individuals are not a straight jacket principle but rather subjective. Subjective in the sense that what one consumer may prefer may not necessarily be preferred by another, hence moral judgement on individual choice cannot be passed. The decision making process is not solely about the economic implication but also how society and the individual in question will be affected. Therefore, the individual decision-making process is influenced by economic and sociological factors. Consumers are believed to be influenced by the desire for risk(Žitković & Larsen, 2019), price and income(Galichon & Quah, 2019), cost of good(Ketcham, Kuminoff & Powers, 2019) among others. Also, consumer characteristics like age, income, education, wealth, taste, and religious group among others differ from one location to the other, which influence the variety of good and service purchases to satisfy wants (Rani, 2014).

In developing countries like Ghana, income constraint has a very high effect since, on consumers, the disposal income of people living in such areas is low. This implies that despite the increasing desire for more resources for societal and individual development, income insufficiency will make its achievement difficult. This is evident in Kinsey (1988), in which it was discovered that the majority of people living in developing counties have low disposal incomes, and supply and demand conditions in these countries vary. Therefore, their purchasing power and attainment of maximum satisfaction will always vary.

In current times, the increase in the educational level of consumers has created a demand pattern for certain goods and services over others. The benefit and demand patterns have ended up favouring products that ensure the health and environmental quality (Priem, 2007). This shows that consumers are not only concerned about the product itself but also the attribute of the product. Consumers will always be faced with the choice given the existence of scarcity. Even if, a product is offered for free, the consumer will be faced with making a decision as to the amount to consume to attain satisfaction.

In this research, the consumer is faced with the option of choosing between the conventional approach of spraying pesticide (knapsack) and a new approach of performing the same activity with a drone. The consumer (farmer) is expected to select the method that will give him/her the highest level of satisfaction. It's expected that not only the usefulness of the method but also the attribute of the method will influence the choice of the consumer.

Discrete Choice Theories

Discrete choice model application has increased dramatically in the field of economics especially; agriculture economics, resource, and environmental economics as well as health economics, since the mid-1990s (Louviere, Flynn & Carson, 2010). The model is an attribute-based measure of benefit that assumes that benefits can be described from the attributes of a service or product. The individual valuation of a good is dependent on the valuation of the attribute(de Bekker-Grob, Ryan & Gerard, 2012). Under the model, consumers are offered alternatives to select from, which is underlined by a utility function revealed by choice. The discrete choice model combines experimental design theory, econometric analysis, random utility theory, and consumer theory (Hoyos, 2010).

The choice set under the model is generally discontinuous and must exhibit the following features; the given options should be independent of the decision-makers' viewpoint. Secondly, the choice set should be all-inclusive, given that all possible alternatives are included. And lastly, the options available should be determined. This implies that the characteristics are restrictive and the most important assumption of the discrete choice model.

The assumption of rationality which emanates from consumer theory assumes that when a consumer decides the presence of a consumption option of goods, they tend to rank their preference and select the bundle that offers them the most. Train and Weeks (2005), added that the assumption of consistency and transitivity of preferences also holds.

Contingent Valuation Method

Contingent valuation method (CMV) is often associated with an environmental economist who seeks to measure environment valuation thus, the willingness of consumers to pay for environmental goods or willingness of consumers to accept environmental goods, mostly not in connection with the market price at a particular period. CVM estimates the use and non-use value of a good.

Various writers have attributed different definitions to the contingent valuation method. According to Bostan, Ardakani, Sani and Sadeghinia (2020), defines CVM as a "non-market estimation approach that places value on specific changes from the status quo". Thus, CVM directly reports if consumers will be willing to give up a good (WTA) or be willing to pay to obtain a specified good (WTP), other than inferring from their observed behavior in the marketplace. "The CV method in finding out if consumers will be willing to pay for improvement in public goods employs the survey questions to elicit preference for public goods. It then values the willingness to pay elicited in monetary terms" (Mitchell & Carson, 2013). Although effective when used alone, some environmental economists have argued that CVM works more effectively when applied in conjoint with other techniques for valuing non-market goods such as hedonic approaches and travel cost approaches.

In current times, however, CVM has come under intense scrutiny considering its use to litigate issues of damage to natural resources and amenities as a result of pollutants. As some schools of thought feel CVM is the quantity of stated preference which is inferior in most instances to observe revealed preference in valuing non-use goods. Again, some researcher often has troubles attaching direct monetary values to environmental goods which they are not used to valuing. However, most economists often critic CVM for its unfamiliar and sometimes unrealistic scenarios about real-life choices. Identifying winners and losers in resource change situations is not enough to determine whether WTA or WTP is the most appropriate indicator of value (Just, Hueth & Schmitz, 2005). The strongest critics of the concept have been non-economists like philosophers, psychologists, scientists, and political scientists(Spash, Stagl & Getzner, 2005).

Despite, all these flaws, according to Mitchell and Carson (2013), "the most renowned works of CVM can be found in the areas of hunting (Richardson, Loomis, Kroeger & Casey, 2015), recreation (Lee & Han, 2002), toxic waste dumps water quality (Keiser, Kling & Shapiro, 2019), decreased mortality risk from a nuclear power plant accident (Slovic, 2016; Thampapillai & Ruth, 2019).

In this study, the Contingent valuation method will help to know the various choices farmers are willing to make when confronted with different choice option. If the price of drone technology were reduced or increase, how will farmers behave and what quantity of the service will they demand. Which price will farmers be willing to pay? If farmers are faced with the same offer as the conventional method of pesticide application given price and quantity the same, what will be their decision? And the contingent valuation method helps to answer all these questions.

FAW and Maize

Maize is a major staple crop in Ghana, representing approximately half of the countries cereal production capacity and cultivated in all ecological zones of the country (Akramov & Malek, 2012). The majority of maize grown are mainly for consumption with few for industrial purposes. Probably the most significant food safety crop with 43.8 kg/head per capita consumption in 2005 (MoFA, 2011). Although there has been an increase in average yield from an estimated 1.5mt/ha from 2005 to 2007 to 1.7mt/ha from 2008 to 2010. This falls short of the national achievable yield for the period (6.0 mt/ha). To stimulate agricultural development, there is a need to increase production capacity to meet the target.

However, FAW (*Spodoptera frugiperda)* is native to the western hemisphere tropical area. (The United States to Argentina). It causes significant damages to over 801 plant species (Capinera, 2014). It commonly feeds on cereals like corn, millet, sorghum, rice, Bermuda grass, and grass weeds like Digitaria spp and crabgrass. FAW is known to injure other farm crops like buckwheat, cotton, Sudan grass, ryegrass, soybeans, sugarcane, cotton, timothy, sugar beet, barley, alfalfa, peanut, clover, oat, wheat and tobacco (Pashley, 1986; CABI, 2017). Spodoptera frugiperda was first discovered in Africa in 2016 in Western African counties of Nigeria, Sao Tomé, Benin, and Togo (Erik, 2017), causing substantial damage to maize (CABI, 2017; Erik, 2017) and in Zimbabwe (Erik, 2017; FAO, 2018) and some cases have been recorded in Malawi, Mozambique, Namibia, South Africa and Zambia (Erik, 2017).

Young larvae start by consuming leaf tissue from one side leaving the opposite epidermal layer intact. Then later begin to make holes in the leave by eating from the edges inward. The feeding of young larvae in the whorl of the crop especially corn produces a row of perforations in the leaves. Whiles, the older larvae cause severe dethatching, often exposing only the ribs and stalks of the maize plant (Capinera, 2014). Marenco, Foster and Sanchez (1992) also reported that the late whorl stage and mid whorl stages are the most affected stage of the maize plant destruction by FAW. Larvae of FAW burrow into the growing point of plants (buds, whorls, etc.) and destroy the plant's growth potential. They even burrow into the ear in corn and feed on kernels like the corn earworm, Helicoverpa zea (Boddie). Unlike corn earworms, FAW feeds at the side of the ear by burrowing through the husk. However, it is possible to determine which species is responsible for the damage through close examination as the holes formed by FAW have smooth edges whereas holes cut by maize stem borer larvae have ragged edges (Goergen et al., 2016).

According to Sparks (1986), FAW has been described as the second damaging pest in agriculture causing $ 39 to $ 297 million worth of loss annually. Similar data in other parts of the world like Brazil shows that FAW causes an estimated annual loss of up to $ 400 million (Sena, Pinto, Queiroz & Viana, 2003). However, in Africa, there is no record of the actual level of damage but base on farmers' perception, it assumes to be very large. FAW due to its genetic variability and gene flow has made it susceptible to insecticides. This implies that FAW is a serious threat to the worlds thrive to food security and improving the livelihood of farmers.

In Ghana, 37% of farmers confirmed that they experienced FAW in 2016 or earlier, 58% in 2017 and 5% in 2018(Nunda, 2018). The extents of distraction associate with FAW in Ghana in 2016 were relatively few as compared to 2017 where the infestation was significant and widespread (USDA-FAS, 2017). The quantitative extend of the level of loss is still speculative, with many variables coming into play when analyzing the yield reduction and FAW infestation(FAO, 2017). The level of maize response to FAW infestation is highly dependent on the level and timing of infestation, the natural enemy and pathogen levels that can help regulate the population, and the maize plants' health and vigour.

Sub-Saharan African farmers are mostly smallholder farmers, who often rely on constant production to maintain food supply to their household and also meet their nutritional requirements. There are more than ten million maize farmers across the region, farming an estimated 34 million hectares of maize lands across the region(FAO, 2017). For these farmers, they have to battle with risks and uncertainties of farming through risk transferable systems and marginal economic viability of their production system, making farmers more vulnerable with the infestation of FAW(FAO, 2017).

Preferred Measure of FAW Control

Recently, studies on the preferred control measure of FAW are few. As farmers are just coping with strategies to manage and deal with the pest in a way that influences the status of the pest. Although, governments are trying to find chemicals pesticide and other control methods, which will be more affordable to resource-constrained farmers and also minimize risk to the health and environment. However, farmers have little idea about the most effective agronomic practices that could control FAW.

Integrated pest management (IPM) has been reported to be the most preferred option for FAW management (Day et al., 2017). It’s preferred because it combines various control methods that fit the concept of sustainability and cost-effectiveness. It puts off FAW, keeps the use of pesticides to the barest minimum and other measures to acceptable levels that justifiable to humans, animals and the environment (Pimentel & Burgess, 2014). The basic principle guiding the introduction of IPM is to help grow crop healthy in a farming system that's healthy by starting with healthy soil, the use of high-quality seeds and varieties of crops that are well suited to the local environment and resistant to pest and disease like FAW(Prasanna et al., 2018).

However, many stakeholders have turned to chemical pesticides for control in the face of potentially devastating losses due to FAW. African governments have resorted to purchasing and distribution of millions of dollars' worth of pesticide, often favouring higher-risk products and the cheap. The commonly used pesticides are; methomyl, methyl parathion, endosulfan, and lindane. FAO (2018) classified them as highly hazardous pesticides (HHPs). According to FAO (2016), HHPs are pesticides "recognized to show high levels of chronic or acute hazards to the health of living organisms or the environment as a whole under internationally accepted classification systems and pesticides which cause serious or irreversible harm to the environment or health under conditions of use in a country". In a report by Abrahams, Beale, Cock, Corniani, Day, Godwin and Vos (2017), it revealed that interview conducted on farmers in Ghana and Zambia showed that 60% has applied some form of pesticide, while, Kumela et al. (2018) research in Ethiopia and Kenya showed 48% of farmers applying pesticides. The growing number of farmers applying pesticides has created a market for pesticide dealers and local producers of "organic" concoctions, which are mostly unregistered and unproven. In the study, 48% of the farmers used the synthetic control method in the form of chemical spray, whereas, a quarter in Ethiopia combined this with handpicking. In Kenya, 39% used a biological method like drenching tobacco extracts to damage plants. The most used chemical used in the areas were Ethiolathion 50% EC (Malathion) and Dursban 48% EC (chlorpyrifos). However, 46% of farmers in Ethiopia perceived that these chemicals were effective in the control of FAW, and in Kenya, 60% of farmers perceived that sprayed chemicals were not effective in the fight against FAW.

Furthermore, farmers stand a high risk of the harmful impact of using these toxic products, of which they know little or absolutely nothing about. With these concerns raised about pesticide, the development of low-risk management alternatives approaches to controlling FAW has necessitated the introduction of bio-pesticide. Bio- pesticide is also another alternative used FAW control method by farmers in the control FAW. This is a combination of the biological control method and that of pesticides in the control of FAW. “Biopesticide is a term used to refer to substances derived from nature, such as semi-chemical, botanicals and microorganisms that are formulated and administrated like conventional chemical pesticides” (FAO, 2018). Thus, biopesticides are living formulation generated from plants, animals, or microorganisms. Bio- pesticide like Baculoviruses, fungi (such as Beauveria bassiana), and Bacillus thuringiensis (Bt) have been reported to be effective in the control and management of FAW (FAO, 2018).

Bio-pesticides are based on biochemical, microbial, or microbial pest management products, which is high on the list of short term measures plan to help the fight against FAW at continental, national, and regional levels (FAO, 2018). Reference to such plans is that of Ghana’s “national FAW response plan”, which has four components covering “identification, control, management and research” with testing and deployment of low-risk options such as bio-pesticides. Also, the Food and Agriculture Organisation of the United Nation (FAO) framework for partnership 2018, emphasized the need for alternatives to pesticides such as botanicals, semi chemicals, and inorganic bio-chemicals, microbial and their extracts, predators, and parasitoids. This has been translated into a wide range of long languages for farmers.

In Zimbabwe, farmers were using cultural control methods in the form of zero tillage, weeding, and intercropping. It was realised that frequent weeding, minimum and zero tillage reduce the influence of FAW on maize farmer due to higher densities of natural enemies. Whiles, the intercropping of maize with pumpkins and graminaceous weeds were seen to attract FAW (Baudron et al., 2019). These cultural practices like a mixed planting system in the form of using certain non-crop plants or the practice of Polly-culture. These practices reduce the chances of FAW oviposition on its host while creating an environment that attracts natural enemies of FAW to feed on it (FAO, 2017).

Again, other farmers also reported using local mixtures like sand, soil, ash, soap solution into the whorls of maize and this was seen to have a significant effect on controlling FAW larvae (FAO, 2017). While, other farmers used local botanical mixtures like an extract from neem trees with other solutions, which according to FAO (2017) is producing good results. Some farmers even go to the extent of spraying a mixture of a pinch of grounded hot chill with 2kg of wood ash and apply it into the funnels when maize is at knee height.

Botanical extracts have been the closest substitute to synthesis pesticide for farmers in Sub-Saharan Africa for pest management(Sisay, Tefera, Wakgari, Ayalew & Mendesil, 2019). Botanicals extracts are said to be eco-friendly, economical, target-specific, and biodegradable. Its greatest advantage is its specificity and it's essentially being nontoxic and non-pathogenic to animals and humans (Isman, 2015; Stevenson, Isman & Belmain, 2017). Farmers also leave the maize farm to chances of natural enemies of FAW feeding on them. These natural enemies are mostly called 'farmers' friends' or 'biological control agents'(FAO, 2018). These natural enemies are not restricted to any stage of the growth period of the FAW, unlike, synthesis pesticide or botanicals. The presence of FAW naturally attracts these natural enemies to feed(FAO, 2018).

However, their presence is not enough to eradicate FAW, as other factors like; host specificity, agronomic practices, and pest management methods, timely abundance, local presence, diversity of organisms being active, and their lifestyle all play a role in the effectiveness of the natural enemies. Biological control agents are classified into; parasitoids, predatory insects and mites and parasites, and microbial pathogens.

Farmers are advised to plant a leguminous crop, for example, beans around the edges of their maize field 10days before planting maize. This moves the attention of FAW to the beans rather than the maize. Planting early is also recommended to farmers because early planting reduces the pest count on the farm. Lastly, the ploughing of farmland before planting helps expose FAW to the surface for predators like a bird to feed on.

Effect of Pesticide Application

Pesticide continues to be a significant contributor to the development of agriculture production and food security (Sexton, Lei & Zilberman, 2007). Pests associated with agriculture include; plants, fungi, insects, animals, and bacteria, which result in crop loss or crop yield reductions relative to potential yields. Pest destruction can also decrease the quality of the product and may include defects in products that reduce the value of agricultural commodities. There has been pest damage since the beginning of time, just like control measures.

However, there is a current growing interest in environmental protection, human and food security implication of the use of pesticides in agriculture. This growing concern has paved way for the rising demand for pesticide-free foods (organic foods). With the current world population overshadowing the supply of food in the face of food shortage and per capita food production combined with rapid growing urbanisation, the need to improve the productivity of agriculture is urgent. This is supported by Sexton, Lei and Zilberman, (2007) that considering the world population which has more than doubled today with more than approximately 6 million people per 2700kcal daily compared to the estimated daily average of 2450kcal for 2.5 million people in 1995.

As farmers and stakeholders in the agriculture sector look for an alternative to pesticides like biological and genetically modified foods, the US Department of Environmental Protection (EPA) (2007) estimated the pesticide industry to be worth $32 billion per year. Assuming production, regulation and innovations trends continue as currently, it’s projected that the global estimate for pesticides will increase by 2.7 times in 2050, exposing more humans and the environment to high levels of pesticide (Sexton et al., 2007). As demand raises for agricultural production, global warming is expected to be a challenge.

In Ghana, farmers have adopted highly motivational approaches because of the growing emphasis by most agricultural development policies, which values the use of external inputs such as machinery and agrochemicals as the engine to increasing agriculture productivity (Mabe et al., 2017). This has promoted the usage of synthetic agrochemicals at the expense of environmentally friendly alternatives like; cultural and mechanical methods, biological control for pest, weeds, and diseases than intend boost productivity (Ngowi, 2001).

According to Omari (2014), agrochemical is the collective name for fertilizers, pesticide (weedicide, insecticide, rodenticide, and fungicide), and also plant regulators that are used in the control of pest and disease to achieve higher agricultural productivity. In Ghana where maize is a staple crop, these pesticides are used to control common pest and disease of maize like downy mildew, leaf blight, leaf spot, maize rust, stem borers, silkworm, and armyworms. The ability to apply the right amount of pesticide is based on the health implication and the effect it has on the crop output and quality physiologically (Mabe et al., 2017). In the case of maize, overdose and much exposure to pesticides cause distortion, yellowing, necrosis of the foliage, and scorches of the leaves. These residues from pesticides remain in the edible part of the maize becoming hazardous to consumer health (Mabe et al., 2017). Farmers face the highest risk of inappropriate use of pesticides especially on their health and this is attracting global attention among researchers and other stakeholders in the industry (Okoffo, Mensah & Fosu-Mensah, 2016).

Pesticide usage has become an integral part of the Ghanaian agricultural activities, as it's been used in the production of eventually every crop produced in the country (Mabe et al., 2017). Dinham and Malik (2003) reports of 87% of vegetable farmers use pesticides of different forms in farming. The pesticide control and management Act (528) of 1996 is the sole regulatory act spearheaded by the Environmental protection agency of Ghana. The Act covers registration, licensing, enforcement, and general provisions, but this has not been effective as the Ghanaian market is flooded by badly labeled and packaged products coupled with an irresponsible advertisement promoting these products at the expense of farmer and consumer health. This is reinforced by the farmer's high level of illiteracy, poor training, lack of protective equipment, and safety information on the pesticide (Asante & Ntow, 2009).

Environmental Effect

A pesticide which is meant for controlling pest and diseases is having an undesired effect on the environment than the intended target (Stoytcheva, 2011). Wind blowing and run-off water carry these pesticide residues from the desire plant target to other non-target areas like water bodies and into the air leading to air and water pollution (Rockets, 2007). The level of pesticide drift off the intended target is influenced by the propensity for binding with the soil, water-solubility, its resistance to breakdown over time, chemical properties, and vapour pressure (UNDP, 2015). Gilliom (2007) reports that pesticide residues meant for field application drifts into wells near, while, Kellogg, Nehring, Grube, Goss, and Plotkin (2002) also revealed that pesticide residue tends to be found in rain and groundwater. These pesticides impact aquatic life's especially application fields that are close to water bodies. Bingham (2007) reported a study conducted by the government of the UK showing that samples were taken from rivers and groundwater outlets in the country had pesticide concentration beyond the acceptable rate for drinking water.

Factors that affect a pesticide's ability to contaminate water are; water solubility, the distance between the field and water body, weather and soil, growing crop, and the method used in applying the chemical (Stoytcheva, 2011). Volatile pesticides applied to crops will volatilize and are blown by winds to nearby areas posing a threat to wildlife (Reynolds, 1997). As a way of controlling this, farmers can employ a buffer zone around their crop, consisting of empty land or non-crop plants such as evergreen trees to serve as windbreaks and absorb the pesticides, preventing drift into other areas (US Department of Environmental Protection, 2007).

Pesticides in soil hinder the development of higher plants due to the deficiency of nitrogen fixation. It has been shown that insecticides; DDT, methyl parathion, and in particular pentachlorophenol interfere with chemical signals from legume-rhizobium. Reducing this symbiotic chemical signalling ends in a decreased fixation of nitrogen and therefore decreases crop yields (Rockets, 2007). The formation of root nodules in these crops saves the world economy $10 billion annually in synthetic nitrogen fertilizers (Fox, Gulledge, Engelhaupt, Burow & McLachlan, 2007).

Pesticides may enter the human body by inhaling pesticide-containing aerosols, dust, and vapour; by exposure through food and water and by dermal exposure through direct contact with pesticides (Eldridge, 2008). Small residues of pesticide have been suspected to be carcinogens and disrupting endocrine activities, and becoming increasingly anxious in drinking water and food. Despite, international restriction and regulatory agencies meant to regulate the number of pesticide residues, there is numerous account of residues found in both imported and domestic foods (Wessel & Yess, 1991). Over the last 50 years, it has been estimated that 20,000 persons have severed from various human diseases and deaths annually as a result of exposure to these pesticides. The majority of this death have comes from developing countries, where farmers are careless in the handling of pesticide and have insufficient protective clothing and equipment. Pesticides have more harmful replication on human health based on the chemical's toxicity and the length and magnitude of exposure (Lorenz, 2009). Farmworkers and their families are most exposed to agricultural pesticides through direct contact with chemicals. Pesticide exposure has been reported to have led to genetic changes, blood and nerve disorders, and irritation to birth defects, tumors, coma, and death (Lorenz, 2009).

Social Effect

The benefit associated with the use of pesticides has been enormous to society from public health, forestry, and domestic spheres(Aktar, Sengupta &

Chowdhury, 2009). The pesticide has been an integral part of the process of reducing societal food basket losses resulting from pest and diseases. According to Webster, Bowles and Williams (1999), economic losses would have been high without pesticide use, this was quantified in the significant yield increase and improve economic gain from the use of pesticides. With countries battling with malaria and other vector-borne diseases, pesticide in the form of insecticide has come to the rescue of society to safe an estimated 5000 deaths every day (Ross, 2005). Other areas like the transportation industry use a large number of pesticides like herbicide and insecticide to control weeds along driveways. Despite all the benefits of pesticides, it poses various forms of cost on society at large. Society is not completely free of potential health effects of pesticides although the share of the effect is not proportional across geographic location and groups within countries (WHO, 1990). Income base analysis with pesticide use between low-income countries and high-income countries shows that low-income country farmers, although use low quantities of pesticide compared to high-income countries, tend to be more vulnerable to pesticide risks (Grovermann, Schreinemachers & Berger, 2012). Policymakers in these low-income countries do not have proper or adequate channels of addressing both the associated human and environmental risks of using these pesticides because of believing that high food production is dependent on pesticide usage (Carvalho, 2006).

The relationship between the fear that restricting pesticide usage will lead to a decrease in food production and food insecurity has not been proven through empirical studies. Falconer and Hodge (2001), report of few tools in existence to making such an assessment. Most studies like Huang, Pray and Rozelle (2002), Qaim and De Janvry (2005), and Jah and Regmi (2009), tried to give a quantitative figure to the overuse of pesticide, their conclusion focusing on the private cost, overestimated the optimal levels of pesticide that can be applied to a field. In the work of Huang et al. (2002), Qaim and De Janvry (2005), Sexton et al. (2007), and Jah and Regmi (2009) defined the overuse of pesticides as the amount of pesticide applied (used) over the economic optimum acceptable level. The socially optimal of pesticide use results from maximizing the net benefit to society which includes a net benefit for farmers, consumers, chemical producers, and the environment (Sexton et al., 2007). The private economic optimum level of pesticide usage is occurring at the point at which the marginal return equals the farmers' purchase price for that same pesticide and the social-economic optimum as while as the marginal return equalling the sum of the marginal private costs, the purchase price, and the marginal external costs. It is observed that the users and the regulators of the pesticide face different degrees of hazards and uncertainties, which tends to affect their social optimum capacity. The socially optimal level of pesticide use results from maximizing the net benefit to society which includes a net benefit for consumers, farmers, chemicals producers, and the environment

Incertitude of production is linked to variation in climatic circumstances which may influence choices on the use of pesticides by farmers. For example, elevated precipitation concentrations can boost the development of weeds, leading to enhanced applications of herbicides. Skevas, Lansink and Stefanou (2013) reported that the disregard for the impact of manufacturing variability where farmers' measuring output may lead to an overestimation of the environmental inefficiency of farmers' pesticide usage. Consumer's uncertainty about pests leads to the overuse of pesticides above the optimum private or social gain. As different agents make private decisions to enhance their private net economic benefit, their choice will deviate from the social equilibrium unless they pay for the pesticide's externality cost. Therefore, planners or farmers have determined a point at which the overall cost to society of applying pesticides is equal to the benefit to society. In its simplest form, the threshold for applying a pesticide helps in the determination of the time to apply pesticides such that the pesticide is applied when the damage caused by the pest is above the social cost of pesticide application (Sexton et al., 2007).

Uncertainty in pesticide scheme give rise to greater and most common misuse of pesticides, there is also uncertainty about pesticide efficacy. Farmers lack full awareness of the relationship between pesticide and pest mortality (Feder, 1979). Fluctuation in temperature, wind, and air humidity affects pesticide application. Thus, the population of pests may differ according to modifications in climate circumstances, although these modifications may also change the impact of pesticides, with each pesticide having its distinct durability.

Despite, pesticide use in a variety of other settings apart from agriculture which the general public is unaware of. In the same light, the pest and disease that are killed by these pesticides can cause undesirable effects on human activities, infrastructure, and the materials of everyday life. The benefits from pesticides can accrue to several different recipients, not only to consumers and farmers but the society as a whole. An example is a fact that pesticide helps to maintain the aesthetic quality, the protection of human health from disease-carrying organisms, the suppression of nuisance causing pests, and the protection of endangered species from pests.

As the debate on the degree of risk posed by pesticides continues, society has become increasingly concerned about the emergence of a general concern about the quality of the environment and growing health consciousness among the public. This is compounded by the distrust of authorities aimed at protecting both the environment and human health. According to Pimentel (2009), everyone in the United State consumes a small amount of pesticide daily in his food and water. For example; Duggan and Duggan (1973), discovered that about 50% of U.S foods sampled by the food and drug administration contain detectable levels of pesticides.

Financial Effect

The most obvious and easiest benefit derives from using pesticides by a farmer is the financial empowerment it offers him. The farmer benefit from the protection of commodity yield, quality, and the reduction of other costly inputs such as labour and fuel. Globally, about 3 billion kg of pesticide is applied at the purchase price of $40 billion (Pimentel & Burgess, 2014). Oerke, Dehne, Schönbeck and Weber (2012) showed that the estimates of global losses from pest induced losses were more than 50% of attainable crop output, while, Damalas (2009) reported that insects destroyed crops amounted to 15%, disease pathogens and weeds 13% each and post-harvest pest infestation 10% of total crop yield in 2009. Without pesticides, food production and food price would have soared and further dropped. All other things being equal, if production were to below as a result of not using a pesticide, prices will go higher and farmers would be less competitive in global markets for major commodities. Pimentel (2009) estimated that losses resulting from the non-use of pesticides would rise by 9% or $8700 million, while, preventing a loss of this magnitude requires an investment of $ 2200 million annually in pesticide treatments. Therefore, reducing agricultural losses to pest with the use of pesticides improve yields and thus ensure constant supplies to consumers and improve the quality of the product in terms of cosmetic appeal to consumers (Damalas, 2009).

Raw commodities and packaged grocery products are protected from insect contamination by the use of insecticide in processing, manufacturing, and packaging facilities. Davis, Brownson, and Garcia (1992) revealed that families used 57% of pesticide to control weeds, 50% for fleas and ticks control, and 33% for garden and orchards. This shows that pesticide usage improves the quality of life and the general quality of the environment. Sadly, these non-monetary benefits of pesticides are difficult to calculate. Policymakers around the world are battling how to place dollar-based values on such things as the aesthetic quality, survival of endangered species, and peace of mind resulting from pesticide usage (Damalas, 2009). The few attempts to calculate the market value have always started with the development of pesticide use, which in some cases has been biased (Popp, Pető & Nagy, 2013). However, data are often unavailable for minor crops and non-agricultural uses of pesticide and this is a major impediment for determining accurate estimates of the impact of changes in pesticide availability.

Additionally, the overall benefit of pesticides is difficult to evaluate when they are distributed unevenly among various impacted groups such as pesticide users, non-users, other market participants, and the residence of areas where the pesticide will be applied, consumers of products treated with pesticides, formulators, marketers, and applicators. Tomlin (2009) claim that pesticides are made up of nearly a thousand active ingredients and do not have a direct impact on crop yields other than limiting the adverse effects of pests. Although pesticides are generally profitable in agriculture, their use does not always decrease crop losses(Pimentel, 2009). People who argue against pesticide use believe that pest elimination can be achieved without the use of pesticides. This is true in most isolated cases but to achieve the full pest management on the farm, parks, around the home among others, non-chemical and chemical combination is the way to go (Damalas, 2009).

However, the opportunity to maximise the benefit and minimise the risk of pesticide usage is available, but it will require the investment of time, money, and effort into developing a diverse toolbox of pest control strategies that will include; safe products and practices that will integrate pesticide into the general framework of ecology to optimise sustainable production, environmental quality, and human health.

The pesticide demand elasticity which is a regulatory framework for levies on pesticides shows that the price elasticity of demand for pesticide is low in most cases, indicating that pesticide usage is indifferent to pesticide price increases(Skevas et al., 2013). The inelastic demand nature of pesticide use indicates a lack of knowledge among farmers about alternative control measures, a strong intention to risk aversion, or due to behavioural factors of farmers (Hoevenagel, van Noort & de Kok, 1999). In that same study, it was discovered that an increase in tax on a pesticide will increase revenue but will have a small contribution to reducing the externalities. U.S. agricultural production, according to Tegtmeier and Duffy (2004), hurt the environment and human health at an estimated price of $6–17 billion per year. It is estimated that total external costs from agriculture range from $30 to $96 per hectare per year. About 75 percent of these costs are due to pesticides applied to crops.

Undoubtedly, the use of pesticides has been and always will be controversial in our society. It involves a trade-off that concerns people. It will be difficult to get people to understand and accept the risks and the same time the benefit of using pesticide as an individual, we base our beliefs on what we know and that also depends on the availability of information. Therefore, a person's knowledge and values form the bases of their stance on pesticide usage.

In this research, the researcher will like to find out the effect of the use of pesticides on the society, environment, and the financial implication of the use of pesticides. The fields used for the study were four with one designated to the drone application, knapsack application, and two controlled plots. A buffer zone of 150m was left around the fields to contain possible drift or spillage of the pesticide used. Also, the plots were constructed outside the communities.

Drone in Agriculture

As the world grows, we are bound to have a wide range of challenges in the coming decades caused by climate change, resource scarcity, and population growth(Sell, Vihinen, Gabiso & Lindström, 2018). In agriculture, it will require new approaches, methods, and technologies. Using innovative technologies has become a popular approach to engage smallholder farmers (Hart & Sharma, 2004). Involving farms especially smallholder farmers in a holistic innovation system opens up possibilities to understand not only technological innovations but also innovations relating to food systems, markets, incentives as well as local dynamics and power structures affecting them(Sell et al., 2018). The advantages that “an eye in the sky” provides with a combination of analytic tools that can interpret data and images to actionable information have ushered in a new revolution in agriculture(Sylvester, 2018). Precision agriculture is a means of applying interventions at the right place at the right time (Gebbers & Adamchuk, 2010). Precision agriculture is regarded as a contemporary system of agriculture backed by different technology (Yao & Wu, 2011) based on field detection and application of each input depending on these differences (Robert, 2002). A key feature is the use of global positioning systems (GPS) and timely spatial data that are major enablers of precision (Rao, Pandey, Ahuja, Ramamurthy & Kasturirangan,2002).

Drone, which is mostly called Unmanned Aerial Vehicle is a pilotless aircraft system that flies over short to relatively long distance. In the past few years, drone usage has extended from the area of industrial monitoring, photography, battlefield surveillance, air ambulance, package delivery to eventually all fields of human endeavour (Puri, Nayyar & Raja, 2017). The drone provides a sophisticated advantage compared to conventional means which were used in this field like the ease of use, precise monitoring of fields which were hard to achieve by humans, illegal activity tracking, observation of forest fires, and tracking of crop yields of big agricultural holdings. Currently, 85% of the world population of the drone is used by the military, whiles the remaining 15% by civilians for diverse applications (Puri et al., 2017). Despite, certain restrictions and no-fly in some countries like India by drone, the association of unmanned aerial system international report was an annual increase of 85-92% every year especially in the upcoming market of agriculture (Puri et al., 2017). A report by auditing firm PricewaterCooper international limited (PwCIL) (2016) places the value at USD$ 32.4 billion. While manufacturers of drones continue to develop new versions of drones for the various sector of the world's economies. It's in this regard that it is expected that the drone market can reach $200 billion by the year 2020 (Puri et al., 2017). Surprisingly, drones are inexpensive as it can cost less than $ 1000 and can even be built at home for even less but the processing software can be expensive (Greenwood et al., 2016).

Organisation like the United Nation has been a principal experimental of drone technology in the area of humanitarian aids and agriculture crises. Known evidence of the United Nation usage of the drone is its collaboration with the Belgian government for the world food program, the drone facilitates quick data collection with greater accuracy together with providing a safety monitoring system in emergencies (Sylvester, 2018). Also, the United Nations children's fund

Buscemi (2019) used a drone in partnership with the Republic of Malawi for humanitarian aid through testing, imagery, connectivity, and transport of aid. In 2016, FAO and Google partnered to make remote-sensing data more efficient and accessible (FAO, 2016), intending to provide access to quality and timely data.

Agriculture drones are mostly either fixed-wing or rotary motor helicopters, where the fixed-wing drone flies at a high speed of 25-45mph and can cover the range of 500 to 750 acres per hour depending on the battery span. While, the rotary motor also focuses on specific problems on the farm area at a constant speed but this type suffers from lower battery life but has a good landing especially in small confined areas(Puri et al., 2017).

Drone technology in agriculture has led to the ease of agriculture farm analysis. Through its high flying ability, farmers and farm managers do not have to move through acres of cropland in search of deficient crops as a drone with its 3-D imaginary automatically point to crops with certain deficiencies from miles away and it's could help the farmer to take prompt measures to curb spread(Sylvester, 2018). Drones with its 3-D maps help in soil analysis which is useful for farmers during seed ploughing. In the same context, soil and field analysis through drones also provides data useful for irrigation, fertilizer, and pesticide application for better crop yield. The outcome of the drone on the field would not only ensure high yield but also saves time and resources of the farmer. Also, the consumer through ensuring healthy plant products are delivered (Sylvester, 2018). A study by Su, Yahya, Mazlan, and Hamdani, (2018) on the use of drone in the spraying of rice field showed that drone application was relatively faster and efficient to conventional methods but is influenced by wind speed, ambient temperature, and also the uniformity of the spraying, which was dependent on the altitude of the drone.

In the area of forestry, drones have been used for forest and landscape mapping to provide prospects on forest valuation, monitoring, and research. Pictures taken of forest areas are stitched together to high-resolution ortho maps. These ortho maps are then integrated into GIS systems and used for analysis, planning, and management. Evidence-based research is Novadrone (2017), which was used to improve forest management and operational planning, including monitoring of illegal activities and encroachment. Goodbody, Coops, Marshall, Tompalshi, and Crawford (2017) also reported the use of drone technology in the update of enhancing forest inventory in a small area in interior British Columbia, Canada. Similarly, Puliti, Ǿrka, Gobakken, and Nǽsset (2015), used drone for an inventory of the small area in the Kingdom of Norway concluded that drone imagery provides relatively accurate and timely forest inventory information at a local scale.

In the area of fisheries and wildlife conservation, drone technology has been used to track, inspect, and monitor livestock and fish stock remotely. In countries such as the Republic of Palau, Belize, Jamaica, and the Republic of Costa Rica governments are using drones to detect illegal fishing activities. Howard (2016) reports of the government of Belize using the drone to enforce fishing regulations above the Glover’s Reef Marine Reserve and other marine areas in the country. Whiles in India, Panday, Pratihast, Aryal and Kayastha (2020) reports of the government partnership with Tata consulting services (TCS) in the use of the drone to conduct surveillance, identify unauthorized settlements, and deter poachers in Kaziranga National Park, which is estimated to over 480square kilometers of land.

Drone technology in this study will be used for pesticide application to measure its efficiency in spraying. The volume of chemicals it can hold will also be noted and the time used. These results will be compared to the conventional means of pesticide application, thus, knapsack. Farmers will be allowed to witness the process and determine the most effective and efficient means of pesticide application.

Cost-Benefit Analysis

The most commonly accepted technique of assessment among government and economists is the cost-benefit assessment (CBA). In 1936, CBA was initially implemented by the government to assess water projects in the US and around 1960 in the UK, also used this method for over 40 years to assess investment worldwide. Government procedures related to the preparation of company cases, regulatory impact assessments, and the assessment of strategic planning alternatives have now usually required the use of CBA.

Cost-benefit analysis (CBA) shows the worth of investment by doing a comparison of the costs involved with the benefits. Ultimately, CBA's goal is to support decision-making based on resource efficiency. Efficiency here means the extent to which the use of labour, capital, land, and environmental resources for a specific purpose contributes to a community's welfare compared to the next best use of these resources. It determines whether a policy initiative or project will provide a net advantage to the society above the cost of the opportunities available to multiple members of the society in the implementation of a policy or project.

It is also used for financial analysis of projects to estimate the financial viability of the project. The financial analysis takes into consideration both output and the cost of inputs. The costs of inputs include all fixed input and variable input of production like the drone, pesticides, and other equipment needed for the control of fall armyworms. The output only includes the yield of maize produced at the crop season. There are two principal types of formulation of cost-benefit analysis, according to the European Commission (2004). One is the use of the net value of cost-benefits. The Net Present Value (NPV) as defined by Gittinger (1982) as the difference between the value today of all present and future benefits and the value today of all present and future costs. This approach uses a net present value formula to make future costs and benefits comparable with present cost and benefits. This is given as; $NPV= \sum_{I=0}^{T}\left(\frac{Bt-Ct}{(1+r)^t}\right) - K_0$ 2. 1

NPV = net present value

B_t = Benefits of the project at time t C_t = operational costs of the project at time t

r = rate of discount   T = lifetime of the project K_o= initial costs of the project in the base period

From this approach, a project is financially feasible if the calculated NPV> 0

The alternate approach is the case where the quotient of the net present benefit and cost is calculated. If the CBR > 1, the benefit outweighs the cost. This is given as;

$$CBR= \frac{\sum_{I=0}^{T}\left(\frac{Bt}{(1+r)^t}\right)}{\sum_{I=0}^{T}\left(\frac{Ct}{(1+r)^t}\right)} \qquad 2. 2$$

Despite the usefulness of cost-benefit analysis, it has the following disadvantage; false accuracy critics point out that because there are hypotheses engaged, especially in quantifying ' intangible ' or non-traded expenses and advantages, false accuracy is ascribed to CBA's outcomes. To solve the issue of ' false precision ' is to perform a sensitivity test. There are inherent uncertainties in predicting the future, but at least if the modeling inputs are systematically varied, the range of potential outcomes can be considered.

However, for this research, the cost-benefit approach will be used to determine how much is spent on the project and the outcome of the project after its completion. The cost and benefit will be quantified in ratio terms. With the cost calculated at all stages of production, which will combine both the variable and fixed cost of production and this will be done for all four plot used in the studies. Whiles, the benefit will be the yield obtained from each plot after the harvest and it will be quantified at the current maize selling price.

Profitability of an Enterprise

Profitability is an important concept of enterprise growth. The concept of profitability is essential to keep an enterprise viable. Profitability is derived from two words profit and ability. Profit refers to the power of an enterprise to earn profits, whiles ability means its earning power or operating performance(Tulsian, 2014). The term profit and profitability are closely related and interdependent, hence, the generic association in nature but actuality both have a different role in business or enterprise settings. Profitability is the ability of a given investment to earn the enterprise returns from its operations.

Profitability has been referred to as the magic eye to measuring the operating efficiency of the whole enterprise. The amount of profit that an enterprise earns is affected by efficiency, condition of the market, size of the business, localisation among others. Balabanov (2007) refers to profitability in the board sense as efficiency and returns. It is the generalised, qualitative indicator of the economic efficiency of an entity's activity; it allows you to compare the amount of profit with the value of the means, by which it was obtained. Therefore, it can be interpreted as a measure of returns and business efficiency(Shvachych &Kholod, 2018).

Also, the profitability of production can be interpreted as the ratio of income and capital invested, allowing for the level of profitability of an enterprise and comparing it with the alternative use of capital received by the enterprise on equal risk terms. Profitability depicts the survival and long term achievement of an enterprise(Fareed, Ali, Shahzad, Nazir & Ullah, 2016). Thus, profitability affects the performance of the entire enterprise setting including its financial, economic development, technological change, employment, and innovation. Fareed et al. (2016) revealed that the effect of profitability on performance is made possible by the increased competition in the use of the resource, price fluctuations, and issues of efficiency.

Eriksen and Knudsen (2003) revealed that different enterprises have been operated to have a different effect on the level of profitability but when considered at the industry level, its effect reduces. This was supported by Spanos, Zaralis, and Lioukas (2004) that if each enterprise cost strategy were low, the profitability of that enterprise will be sustained or increase. Indicating that industry variables play an indirect role in contributing to the gains of the individual enterprise since entry cannot be restricted in a free market. Liu and Hung (2006) work on service and profitability also revealed that increasing the number of enterprises turns to increase the profitability of an enterprise. The increasing branches lead to increasing profitability by taking into consideration the total overhead expenses along with the average salary taken as a proxy for services delivered. While Al-Hawari and Ward's (2006) findings on services and profitability showed customer satisfaction as a positive mediating variable between profitability and service quality. Showing that service quality will lead to customer satisfaction and this is expected to increase enterprise profitability. Park and Weber (2006) also showed that the market structure and efficient market hypothesis were the major determinants of profitability.

The efficiency and efficient market structure hypothesis will level to increasing profitability which will ultimately lead to a concentration of the market. Love, Roper, and Du (2009) revealed that innovation, non-indigenous and R &D had various levels of effect on profitability. Asimakopoulos, Samitas, and Papadogonas (2009) believed that size, sales growth, and investment had a positive correlation with the level of profitability of an enterprise, while leverage and current assets had a negative relationship with profitability. Stierwald (2010) revealed that the determinant of profitability was heterogeneous between that of the industry and firms.

Profitability in this research will refer to the measure of the operating performance of drone technology relative to knapsack in the application of pesticide and the level of efficiency of the enterprise as a whole. As the enterprise becomes profitable, the more the efficiency of the enterprise is increased and this will lead to the acceptance of its product and allows the enterprise to be competitive.

Gross Margin

Gross margin is among the oldest and simplest analytical tools used in farm management analysis (Fani, Choumbou, Odoemenem & Oben, 2015). Gross margin is defined as the value obtained by finding the difference between gross production value and variable expenses (Semerci, Parlakay & Celik, 2014). With the variable expenses defined as the total operating expenses excluding interest cost, labour cost, property taxes, general building, and fencing repairs, miscellaneous farm expenses, and depreciation. While, gross production value represents the interest deposited on capital by the business owner or proprietor, the labour of the proprietor and family labour, thus, the natural sum of profit (Erkus & Demirci, 1996). Thus, the volume of the output multiplied by the price. Abbott and Makehan (1979) added that for a farm enterprise with a multi-farm unit, the total gross margin will be the sum of the gross margin on each activity. To reduce the burden of using gross margin in analysing farm profitability, it is relevant to ensure farm enterprise entities are sufficient and distribution of its variable expenses are easily accounted for.

Gross margin is one of the several components of enterprise selection in agriculture. Semerci, Parlakay and Celik (2014) view it as one of the best and most suitable criteria for the comparison of the operation of an enterprise. This is because the gross margin is not affected by the size of the enterprise nor the type of enterprise. This is affirmed by the Canadian Agri-food Policy Institute (CAPI) (2009) suggesting that gross margin is a better measurement of farm profitability across a wide range of farm types and agribusiness. Hence, concluded that gross margin is a proxy for farm profitability. This is supported by Fani et al. (2015) that gross margin is an economic analysis of the profitability of a farm enterprise. Semerci, Parlakay and Celik (2014) found out that in planning assumptions at the level of the farm enterprise operation rise, there is an equal linear rise in gross margin, “all other thing being equal”.

Inan (2008) reports that the absence of fixed cost in the calculation of gross margin meant there is no need for the distribution of fixed cost to the farm enterprise operations. Hence, there is no time restriction in the calculation of the gross margin as it embraces time. Hence, its usage in several researches. Where fixed capital is an infinitesimal portion of the farm enterprise, as in the case of small scale subsistence agriculture, the gross margin becomes a very useful tool in planning (Olukosi & Erhabor, 1998). With fixed cost eliminated in the analysis of gross margin, it can be used by the farm enterprise owner to assess the performance of a single enterprise on the same farm from year to year and also, compare the performance of different enterprise on different farm from one year to another (Lampkin, 2001). Agriculture merges in risk inherently, organisations like horticulture Australia (2011) like other researchers feel that gross margin can help farm owners not to only decide on the type of enterprise to be involved in but also how much input should be applied to achieve the highest level of profit in the face of uncertainty and increased risk.

According to Albertazzi and Gambacorta (2009), gross margin is a reliable but simple gauge of how well an enterprise is doing in financial terms. Hence, gross margin is simply an indication of the financial performance of a farm enterprise. Furthermore, Halberg, Verschuur and Goodlass (2005) referred to it as a single figure indicator of the technical performance of a farm enterprise, and the economic environment of operation, and the relative financial success of management decisions. Firth (2002) added that the comparisons give a useful indication of the level of production and the efficiency (economic) of a farm enterprise. Gross margin has been used since 1960 as a concept of contribution from the marginal cost in farm management. Johnson (1990) referred to gross margin analysis as a group of interdependent, productive enterprise, centered on the farm unit, which provides common services and the necessary co-ordination.

The gross margin in this research will be defined as the difference between the overall revenue generated by the enterprise minus the total variable cost incurred in the production process of a farm enterprise. Gross margin analysis which is a good indicator of profitability will help give a clear view of the performance of the various enterprises. This would likely be expected to influence the decision of maize farmers to select the enterprise that gives them the highest return on their investment. This is based on the assumption that farmers are rational given “all other factors are held constant”.

Willingness to pay (WTP)

In the applied economics literature, empirical studies on consumers’ willingness to pay have taken different approaches. Willing to pay has been defined as the maximum amount an individual is willing to pay to receive a good (Dimitri & Greene, 2002). This falls in line with (Mersha, 2018), “ is the maximum amount a person would be willing to pay or sacrifice ins exchange for a good”. While, Gunatilake, Yang and Pattanayak (2007) defined WTP as “the economic value of a good to a person or household under given condition”. The term willingness to pay is the opposite of willingness to accept. According to Brookshire and Whittington (1993), WTP provides relevant information for assessing the economic viability of projects, setting affordable tariffs, evaluating policy alternatives, assessing financial sustainability, as well as designing socially equitable subsidies. In measuring the willingness of a consumer to pay for a product or service, it’s necessary to consider the viability of the product or service, cost of production, and consumer demand for the product (Kimenju & De Groote, 2008; Quagrainie, 2006).

Several authors have used a different approach to measure consumer willingness to pay over the years. However, these various methods of estimating willingness to pay have been differentiated into a measure of consumer hypothetically or actual WTP and measure of willingness to pay directly or indirectly(Mersha, 2018). The direct measure of WTP is often referred to as the preferred methods, which include; choice experiments (conjoint analysis and choice modeling) and contingent valuation, and the indirect methods are referred to as revealed preference methods which include hedonic pricing, travel, and cost method. (Hanky, Shogren & White, 1997; Asafu-Adjaye, 2000).

However, the revealed preference methods have been criticised for its unsuitability for non-market valuation because of its limitation to the experience of the individual (Bennet & Blamey, 2001). Also, revealed preference methods may be of little interest where new circumstances are expected to the proposed change. Lastly, there is a limited number of cases where non-market values exhibit a quantified relationship with marketed goods. Whiles stated preference is preferred by most researches because of flexibility and its ability to estimate the economic values of non-marketed goods. It's also straightforward for eliciting individual valuation of non-market goods and services (Asafu-Adjaye, 2000).

In measuring quantitative willingness to pay in monetary estimates, several authors have used the traditional contingent valuation method. This method is a direct elicitation method by questioning an individual consumer on what he/she would be willing to pay contingent on there being a product or service. For example; Boccaletti and Nardella (2000), used the contingent valuation method to assess willingness to pay for pesticides-free fresh fruit and vegetables in Italy. Cobbinah (2017), a case study in Nicaragua, also used the contingent valuation method to assess willingness to pay to avoid health risks from pesticides.

Also, economists have used discrete choice, stated choice experiments, and a host of other elicitation methods to elicit direct monetary estimates of willingness to pay for a product. For example; Goldberg and Roosen (2005), used both the choice experiments and contingent valuation methods to measure consumers' willingness to pay for a health risk reduction of *Salmonellosis* and *Campylobateriosis* in Germany whilst Travisi and Nijkamp (2004), used the stated choice experiment approach to measure Italians´ willingness to pay for Agricultural environmental safety.

A broad range of factors has been found to influence consumers' willingness to pay. In Boccaletti and Nardella (2000), it was found that consumers' willingness to pay is positively related to income and risk concern but negatively related to education. Goldberg and Roosen (2005) used both contingent valuation method and choice experiment and found that household net income and age were positively related to willingness to pay, while the experience of foodborne disease, gender, and presence of children (<18 years) in the household was negatively related to willingness to pay. Garming and Waibel (2007) found that willingness to pay depended on farmers' experience with poisoning, income variables, and pesticide exposure. Income, education, risk index, presence of children in the household, and females had a positive relation to consumers' willingness to pay (Buzby, Fox, Ready & Crutchfleld, 1998).

Also, Bani (2016) found that gender of the consumer, age of the consumer, education, farmer perception to climate change, and access to land are factors that influence the willingness of consumers to pay for environmental services, while, years into farming was insignificant. Mersha (2018) found out that savings, family size, farm size, age, radio ownership, land certification, and crop index were significant determinate of willingness to pay for weather index insurance, while, variables like Education, livestock ownership, off-farm activity, sex, access to credit, and extension services and awareness of weather index insurance were insignificant in the study. Kakumanu (2013), found out that farmer age, farmer education, farm size, annual income, awareness about crop insurance were significant to determining willingness to pay, while, factors such as farming experience, institutional credit access were insignificant in the study.

Myyrä and Liesivaara (2014), found that age, cultivated area, education were all significant in determining willingness to pay. Mahieu, Riera, and Giergiczny (2012), Channa, Chen, Pina, Ricker-Gilbert and Stein (2019), Ulimwengu and Sanyal (2011), Asrat, Belay and Hamito (2004), and McCorkle (2007) all revealed that the size of the farm was not a significant determinant of a farmer's willingness to pay for a technology or service. Alimi, Oyeyinka and Olohungbebe (2016), Lee, Hsieh and Hsu (2011), and Holden and Shiferaw (2002) revealed out in their research that income was a very vital factor that influences farmers' willingness to pay for a service. Tanrivermis (1998) and Xiong, Kong, Zhang, Lei and Sun (2018) found out that gender was not a significant determinant of willingness to pay. Also, Xiong et al. (2018), Faye and Deininge (2005), and Mahieu et al. (2012) that age was not a significant determinant in willingness to pay for a service, as, Xiong et al. (2018), Lee and Yoo (2020), Holden and Shiferaw (2002) and Asrat et al. (2004) reported that education has a significant influence on a customer's willingness to pay for technology. Holden and Shiferaw (2002), Asrat et al. (2004), and Mahieu et al. (2012) also revealed that extension services did not influence the willingness of the farmer to purchase or not to purchase a service and

Chai, Han, Liang, Su and Huang (2020) found that age, gender, education, marital status, attitude towards insects, awareness of insects as feed, availability of agricultural inputs, availability of training and market information, distance to feed trader use of commercial feeds, had a significant influence on the WTP.

However, for this research, willingness to pay was used to find out how much farmers will pay for drone services per land area. And also, the possible factors which will influence them in quoting the desire price for drone service. Also, factors that influence willingness to pay were reported.

Acceptance of Drone Service

Technology has played no small role in the transformation of societies into post-industrial or information society(Folorunso & Ogunseye, 2008). With the world experiencing rapid technological advancement, the number of people using technological innovation has already increased (Gui, Qin &Qi, 2012). Consumers as the main source of acceptance of product produce will a great power of influence which is a challenging experience to their preference (Overby & Lee, 2006). The world population is growing into an early adopter population of technology and invention (Revels, Tojib & Tsarenko, 2010). However, the issue of intrusiveness like trust and privacy of consumers has been an increasing concern for governments and agencies who are trying to protect consumers again the increasing rate of adoption of new technology (Sultan, Rohm & Gao, 2009).

For a consumer to accept a technological invention, the technology needs to be useful in addressing his need. The usefulness of the technology will influence the consumer or end-user to adopt a technology (Ismail & Razak, 2011). Usefulness has been defined by Davis (1989), as the degree where a person believes that using a particular technology or system will enhance and accelerate (Mathwick, Malhotra & Rigdon, 2001) his or her performance. Whiles, Aldás-Manzano, Lassala-Navarré, Ruiz-Mafé and Sanz-Blas (2009), defined it has the effectiveness, time-saving and the relative importance of a technology or system towards the individuals work, thus, technology is useful to consumers depending on its benefit or influence on their daily life's(Gui et al., 2012).

The perceived usefulness of technology has been found to have a strong and direct effect on the intention of end-users to adopt and use the technology (Davis, 1989). Other studies have confirmed the relationship between the perceived usefulness and intention to use a technology like Adam, Nelson and Todd (1992), Agarwal and Karahanna (2000), Hu, Chau, Sheng and Tam (1999). Venkatesh and Morris (2000) and Pan, Cheah and Chew (2012) report that systems that do not help people to perform jobs are not likely to receive favourable acceptance in the marketplace. In the case of drone, it implies that drone technology should be beneficial to the farmer at all times when his or her needs are met. Therefore drones will be accepted if users perceive it to enhance user's productivity. In this research, the perceived usefulness of the drone is based on the amount of work that can be done by the drone per period compared to its alternatives and also the output of maize that will be harvested at the end of the maize growing season.

Second, is the perceived ease of use of technology. Davis and Venkatesh (1996), Adams et al. (1992), Ramayah and Lo (2007), and Yousafzai, Foxall and Pallister (2007) claim that perceived usefulness and perceived ease of use are the key determinants of technology usage in terms of user attitudes. Davis (1989) defined perceived ease of use as the “degree to which a person believes that using a particular system would be free of efforts.” Dillon and Morris (1996), indicated that the usefulness and the ease of using technology has a significant correlation with self-reported indicators of system use. Thus, his studies showed that usefulness regarding ease of use has a greater influence on system use, and as a result, end-users are driven to adopt a technology primarily base on how easy or hard it’s to get a technology to perform a function. Im, Kim and Han (2008) noted that the usefulness of technology and the ease of using technology before and after is significant to its acceptance.

However, the difficulty of applying the concept of ease of use is the testability of the technology before use, hence the ease of using the technology before its actual use should be voluntary (Adams et al., 1992). When the usage is made compulsory as a job requirement, then, perceived use of the technology would be effective in terms of evaluating user satisfaction rather than acceptance(Koh, Prybutok & Ryan, 2010). The concept is applied in this research on the bases that drone technology is easy to learn. Just like mobile phones, drone technology is control by ordinary smartphones with easy operating systems that manage its movement and operations. The operating systems of the drone can be run on mobile devices such as Android, Symbian IOS, and windows phone. These operating systems are designed as user-friendly systems whose operation is experimental. The user does not require long formal training to operate it. Within a few days, an end-user can navigate a drone safely with ease. A drone can be moved into spaces and areas where human access and it can spray the maize crop at all stages of the growth period with a simple control command, this makes it convenient and easy for farmers, who are end-users of the technology to use it. However, for farmers who cannot use drone technology them, they can still be able to understand its operation when used on their behalf.

Thirdly, Acceptance of technology depends on the attitude towards the use of technology. The attitude of a user towards the usage of technology is an important element in determining the acceptance of the technology. Renaud and van Biljon (2008) define attitude toward use as “the user’s desirability to using the technology.” Malhotra and Galletta (1999) claim the determinant of the attitude of an end-user to use technology is dependent on the perceived usefulness and the ease of using the technology. Understanding the response of end-users to accept technology and use it in the real world has lead researchers to use different behaviour models to predict. Au and Enderwick (2000) define attitude as the user’s cognitive process which depicts positive or negative affection to a technology. Theories such as instrumentality, expectancy, social learning and utility models (Ryan & Bonfield, 1975) and more recently Theory of Reasoned Action (Fishbein & Ajzen, 1975), Social Cognitive Theory (Bandura, 1986), and Theory of Planned Behaviour (Ajzen, 1988) have been used to understand user behaviour and attitude.

The overall understanding of the factors behind users’ positive and negative behaviours towards a particular technology is stimulated by both personal and external factors(Şimşek, 2008). In most cases, technologies are forced on end-users without considering their willingness and attitude towards technology. Such a situation leaves end-users excessively exposed and subjected to anxiety especially when the technology is not easy to use. Kim, Rueckert, Kim and Sao (2013) observe that users become frustrated and walk away creating a negative attitude towards the technology. For attitude to enhance towards a particular technology, an enabling technology learning environment should be made possible. Doing so will make end-users receptive to embrace technology for utilization in their daily activity(Mugo, Njagi, Chemwei & Motanya, 2017). This thesis will contextualise the concept of end-user attitude in the acceptance of new technologies (drones). The contextualisation will also take a look at the organisational attitude of farmers to accepting drones and factors that influence their attitude.

Again, the behavioural intention of the end-user through the attitude and perceived usefulness influence the chances of a farmer so accept drone and drone-related services available on the market. According to Fishbein and Ajzen (1972) in the theory of reasoned action, it was revealed that belief, attitude, and intentions are the determinants of behaviour towards the use of technology whether positively or negatively. Benbasat and Moore (1992) also revealed that the determinant of an individual's behaviour is his/her intention. He explained that 'behaviour is triggered by behavioural intentions (conation) which are caused by attitudes (affective evaluations) that reflect the beliefs about the consequences of the behaviour'. Subjective norms (perceived general social norms) on the other hand, reflect "beliefs about the behavioural expectations", which indirectly affect behaviour (Liska, 1984).

In other to use technology (as a consequent behaviour of the user), there should be an intention to use it. The intention to use the technology relates to the user's attitude towards the technology which is a result of positive belief about the consequences of using it(Şimşek, 2008). The belief is then influenced by end-user past experiences, which affects the usage behaviour of the end-user. Ajzen (2005) claimed that the intervention of the determinants of behaviour; namely attitude, subjective norms, or perception of behavioural control, can be manipulated to control behaviour. Truelove and Greenberg (2013) proposed that the cognitive assessment of technology relies on a consciousness-raising process. Pre-consciousness staged people are usually unwilling to use technology, whereas those who reached consciousness consider using it in the future (Prochaska, Spring & Nigg, 2008). For a large group of people to accept technology, it must go through three stages namely; consciousness-raising, establishing debates, and judgment (Yankelovich, 1991). In this research, farmers presented with drone technology would be believed to have an attitude towards technology. The attitude which will be based on the usefulness and the ease of use will translate to the formation of a behavioural pattern of farmers toward drone technology. If the behavioral pattern formed is positive, this will imply that farmers are willing to accept drone technology and use it in the application of pesticides.

Furthermore, social influence is another determinant of end-users acceptance of the technology. The introduction of social influence into the technology acceptance model was initiated by Venkatesh and Davis (2000), the rationale was to replace usefulness in TAM. This was because there exists the presence of captive users who are likely to use a particular technology (Lee & Park, 2008; Nah, Tan & Teh, 2004; Rawstorne, Jayasuriya & Caputi, 2000). Venkatesh and Morris (2000) defined social influence as “the degree to which an individual user perceived the importance of others believe to use an innovation”. The concept has been widely used in technology usage, known researches include; online banking (Tan, Chong, Ooi & Chong, 2010), mobile credit card (Tan, Ooi, Chong & Hew, 2014), and 3G (Tan, Chong, Ooi & Chong, 2010). The concept was later infused into the theory of planned behaviour (TPB) and theory of reason action (TRA) (Venkatesh, Morris, Davis & Davis, 2003) with three components namely; the image, subjective norm, and voluntariness (Karahanna, Straub & Chervany, 1999). With image, it was defined as “the degree to which adoption and use of innovation are perceived to enhance one’s image or social status in a social system (Moore & Benbasat, 1991). Rogers (1995) and Teo and Pok (2003) proved that the motivation for an end-user to accept technology is the desire to gain social recognition. This phenomenon has led to the generation of words like technology savvy, trendy, or socially updated.

While Fishbein and Ajzen (1975) put subjective norm as “the perception of the user about how other people think he should or should not perform the behaviour”. Influence of friends, neighbours, peers, superiors, media, and relatives can influence a user’s acceptance of a technology (Lopez-Nicolas, Molina-Castillo & Bouwman, 2008). In a mandatory environment, even if a user mentally rejects a mandatory technology, he or she is prohibited from outright refusal to use it. This lead to the situation where the user underutilise or sabotage the system and the functioning of the technology (Brown, Massey, Montoya-Weiss & Burkman, 2002; Markus, 1983). This can result in reduced intensity or frequency of use. Whiles, voluntariness according to Rogers (1983), defined as "the degree to which the use of the innovation is perceived to be voluntary or of free will". The concept of voluntarism is an objective condition of the adoption opportunity(Mahadeo, 2009). It's been closely related to ease of use and it reflects users' perceptions of specific technology adoption settings, rather than a subjective consciousness. In most organisation technologies are mandated; hence the basic relationships of conventional technology acceptance models turn to be different (Brown et al., 2002). Recent research has traced the failure of implementation to user commitment stemming from the mandatory usage of technologies(Mahadeo, 2009). Malhotra and Galetta (2005), found out that user commitment plays a critical role in the volitional acceptance and usage of technology.

Also, social influence plays an important role in the acceptance of new technology (Taylor & Todd, 1995; Karahanna et al., 1999). The higher the perception of social influence will result in a greater chance of users accepting a new technology(Gui et al., 2012). In this research, its likely farmers will have a positive attitude towards using a drone and drone-related services, if they realise that the usage of the drone or participating in drone-related activities, will enhance their image, then they will be willing to accept it.

Lastly, apart from the determinant of market acceptance stated above, other exogenous variables play a role in influencing the user's acceptance of the technology. These exogenous variables are called the external and facilitating conditions under the technology acceptance model. According to Davis (1989), facilitating conditions are "the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the technology". External and Facilitating conditions are proposed to be ineffective on behavioural intention but directly effective on usage particular for older workers (Venkatesh et al., 2003).

However, a study by Taylor and Todd (1995) showed that facilitating conditions do not necessarily encourage usage. The absence of facilitating conditions represents an obstacle to the usage and prevents the creation of the intention of usage(Mahadeo, 2009). Facilitating conditions is linked to the triability concept used by Rogers in his theory of diffusion, as the availability of the technological innovation will support its usage (Taylor & Todd, 1995). According to Venkatesh et al. (2003), external and facilitating conditions include demographic variables (age, gender, experience, and voluntariness of use), perceived usefulness, and perceived use (Renaud & van Biljon, 2008). While, Al-Gahtani and King (1999) divided external variables into three groups: demographic variables, (age and gender), end-user background variables (training, computer experience, computing support); and system variables (system rating and compatibility) to examine factors of acceptance of information technology.

Facilitating conditions originally provides two dimensions; resource factors (time and money needed) and technology factors regarding compatibility issues that may constrain usage(Lu, Yu, Lui & Yao, 2003). In the workplace, facilitating conditions are believed to include the availability of training and provision of support. Facilitating conditions were originally viewed as external controls related to the environment (Terry, Gallois & McCamish, 1993; Triandis, 1980). Behaviour cannot occur if objective conditions in the environment prevent it or if the facilitating conditions make the behaviour difficult (Thompson, Higgins & Howell, 1994). This research will treat socio-demography characteristics of farmers as the external or facilitating conditions, which will influence the acceptance of drone technology and its related services by farmers.

Researchers like Sunny, Patrick and Rob (2019) revealed that the ownership of land has a significant influence on acceptance, due to the notion that even if the land is rented or leased, the farmer becomes the owner till the stapled time when the agreement runs out. Udimal, Jincai, Mensah and Caesar (2017) showed that extension services unavailability does not affect the farmers' decision to accept a technology when the farmer understands and knows how to use the technology effectively and efficiently. Tubetov, Musshoff and Kellner (2012), Awunyo-Vitor, Al-Hassan and Sarpong (2014), Ullah, Sepasgozar and Wang (2018), Udimal et al. (2017), and Mwangi and Kariuki (2015) revealed that the size of farmland can influence the owner to accept new technology or services. Zogheib, Rabaa´i, Zogheib and Elsaheli (2015), Sunny et al. (2019), and Kinyangi (2014) showed that gender has a significant relationship with the acceptance of the technology. Lee & Yoo (2020), Kryvobokov and Bouzouina (2014), Kalantari (2017), Corrigan, Kling and Zhao (2008), and Seraj (2008) reported that the accessibility and responsiveness of technology to the needs of the user, gives the user the confidence to be willing to accept it. Foreit and Foreit (2003), Rubino, Vitolla and Garzoni

(2017) and Jaung, Putzel, Bull, Diswandi, Witardi and Markum (2019) revealed that the reliability of technology is also relevant to its acceptance.

Conceptual Framework of the Study

The conceptual framework as depicted in figure 1 showed that the socioeconomic characteristics of a maize farmer like the age, gender, primary occupation, farm size, etc. influence the willingness to pay for drone technology (service) by maize farmers. Willingness to pay for drone service then influences the acceptance for drone services. The indicators of willingness to pay were the cost, reliability, responsiveness, accessibility, and content.

It was also revealed that farmers in attempting to control FAW select their preferred option for control of FAW. The selected preferred option cannot be used directly by the farmer, hence the need for an application mode. The application mode and the preferred option selected by the farmer is expected to lead to some effect on the society, environment and the finance of the farmer. But in the short run, the farmer is more concern about financial gains irrespective of the social and environmental (social and environmental effects are long run issues to the farmer). The result of the total effect lead to the treatment of each application mode as an enterprise, which is expected to yield the maximum returns at a least cost. The result of the enterprise analysis will make a farmer willing to pay for the highest return application mode, hence acceptance is expected to be achieved.

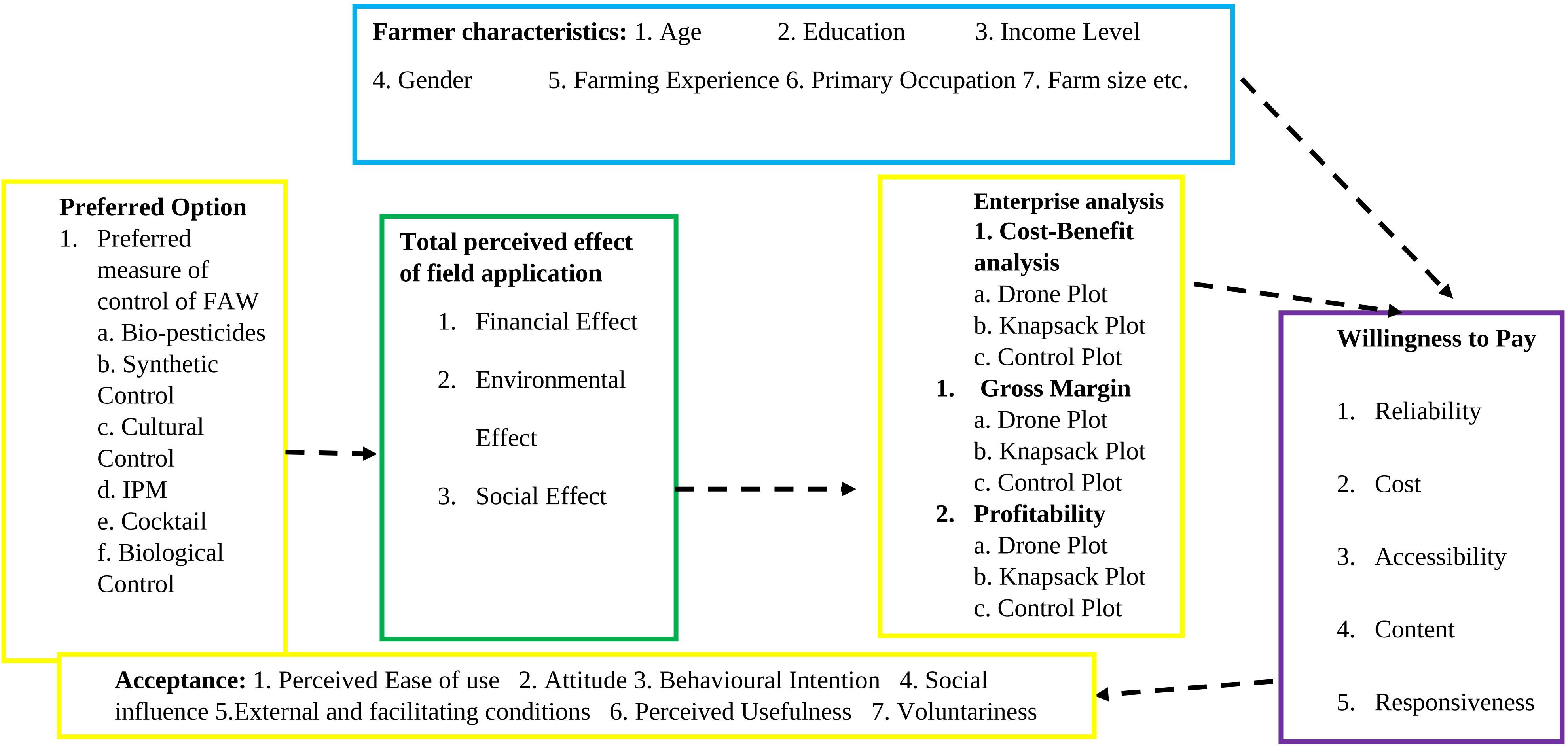

Figure 1: **Conceptual Framework of the Study**
Source: Omega (2019)

Chapter Summary

This chapter reviewed relevant literature on the theories underpinning the research like the Unified Theory of Acceptance and Use of Technology (UTAUT), Theory of Planned Behaviour (TPB), Consumer Theory, and Lancaster consumer theory. The chapter also reviewed the literature on some estimation methods used in the research including Cost-Benefit ratio, gross margin, and Contingent Valuation Method. While, review on FAW and maize, Preferred Measure of FAW Control, Effect of pesticide application, Drone in Agriculture, Cost-Benefit Analysis, Wiliness to pay (WTP), and Acceptance of drone technology complimented the review as other relevant topics.

CHAPTER THREE

RESEARCH METHODS

General Overview

This chapter describes the procedures and techniques used in collecting, managing, and analysing the data. It also presents the research design, the population studied, the sample and sampling procedure, research instrumentation, pilot-testing, data collection procedure, and data processing and analysis that was used as well as the rationale behind the choice of these techniques for the study.

Research Design

A cross-sectional survey design was used for the study to ascertain the status of the variables of the study and their inter-relationships. The study was conducted in the Northern region and the North-east region of Ghana, which were selected purposively based on its maize production capacity. Data was collected at a point in time to determine the acceptance and willingness of farmers to pay for drone technology for pesticide application in controlling FAW.

According to Babbie (1995) and Creswell (2011), a cross-sectional survey design helps the researcher to generalise to a larger population from a sample to make room for inferences about the characteristics of the population. Cross-sectional studies allow researchers to concurrently study various results and exposures. This permits the simultaneity of access to several factors, thus enhancing the precision of an evaluation of the data point burden within the particular population group. If the precision is greater, then the distribution of resources is more precise which decreases the risk that individuals in a population group will fall through the cracks. Although every sort of research may lack important information points, the dangers in a cross-sectional study are significantly lower. For example, in this research not all possible construct was provided despite this not having any effect on the results of this study. Researchers can maximize the integrity of their main information points because they look at a whole population group at a given moment. This leads to fewer errors or variables, as information is not gathered several times. Another reason for adopting this design is that it is economical and facilitates the easy and quick collection and analysis of data (Babbie, 1995; Fowler & Cosenza, 2009).

Its weakness however involves the fact the whole population is examined at once and that in cross-sectional studies a bigger sample is typically needed compared with other kinds of research. The risk of mistake will increase significantly when a small sample is taken because the findings alone could be due to chance or coincidence. Since bigger sample size is needed, cost factors must also be taken into consideration by the researcher. It becomes very difficult if the characteristics of those who react are distinct from those who react within the context of the generalised population study.

Study Areas

One of the sixteen regions of Ghana is the North-East region. It is situated in the north of the nation and was established in December 2018 after a referendum (Bolaji & Gariba, 2020). Nalerigu is the regional capital. The northern region and North-east region occupies an area of about 70,384 square kilometers which makes them the largest region in Ghana in terms of landmass and lies between latitude 9°

29' 59.99" N and longitude 1° 00' 0.00" W. The area shares its northbound with Upper East and Upper West regions, while, its south boundaries is with Oti regions and international boundaries with Togo to the east, and Savannah region to the west. The Black and White Volta Rivers with its tributaries such as Nasia and Daka rivers drained the regions.

Because of its closeness to the Sahel and the Sahara, the northern portion of Ghana is much drier than the southern regions of Ghana. The vegetation comprises mainly grassland, particularly savannas with clusters of drought-resistant trees, such as baobabs or acacias. The dry season is from January to March. The wet season has an average annual rainfall of 750 to 1050 mm (30 to 40 inches) between July and December. At the end of the dry season, December and January, maximum temperatures are reached. However, the Sahara's warm Harmattan winds commonly blow between December and early February. Temperatures may vary between nighttime 14 ° C (59 ° F) and daytime 40 ° C (104 ° F) (MoFA, 2011).

Dagombas, Kokombas, and Basare are the main ethnic groups in the regions, while Kotokole, Hausa, Zabarima, Fulanis, and Ewes are the minor ones. The Ewes are predominantly settler fishermen along the main Oti River, while the Fulanis are indigenous herdsmen.

The regions consist of a total of about 98 percent agrarian with individuals involved in crop production and animal rearing. The district's primary crops are yam, corn, millet, sorghum, cassava, groundnuts, cowpea, and soybeans. Cattle, goats, and sheep, and poultry are the animals raised in the district. Small ruminants are often purchased during the lean season (May to July) to satisfy household food requirements.

The selection of the Northern and North-east regions precisely West Mamprusi, Tolon, and Mion districts was based on the fact that they are among the leading districts in maize production. This is supported by results from the Agricultural Production Survey for the Northern Regions (Brong Ahafo, Northern Region, Upper East, and Upper West) of Ghana (2013-2014) undertaken by Amanor-Boadu, Zereyesus, Ross, Ofori-Bah, Adams, Asiedu-Dartey, Gutierrez, Hancock, Mzyece and Salin (2015). It also showed that the average household land assigned to maize production in 2012 was 1.2 ha compared to about 0.8 ha for rice and soybeans jointly. The average maize household land in the Northern Region is 1.4 ha compared with 0.9 ha in both Upper West, Brong Ahafo, and Upper East areas. The regional distribution also shows that West Mamprusi, Tolon, and Mion were the highest district producers. In addition to that, MoFA (2017) reports on the fall worm army showed that the regions were among the most affected areas in the country, hence the selection of the study area.

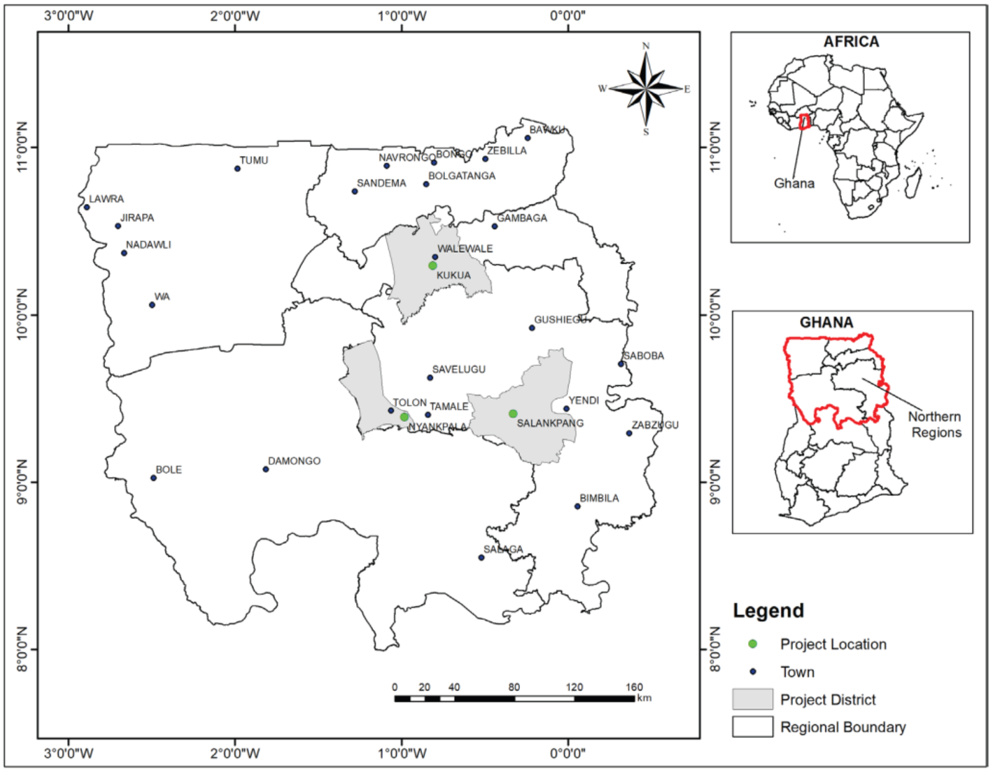

Figure 2: Map of the Study Area-North-East and Northern Region of Ghana. Source: Department of Geography and Regional Planning, UCC (2020)

Sources of Data

The research used primary data sources. A primary data source is an original data source, i.e. one in which the researchers collect the data for a specific research purpose or project first-hand. The primary data employed was be obtained through a cross-sectional survey of 3 maize producing districts in the Northern (2) and North-East (1) part of Ghana namely; West Mamprusi, Tolon, and Mion. The primary data helped to have first-hand information from farmers on the objective to be studied.

Population

In general, a target population has different features and is also known as the theoretical population. The population for a study is the entire set of units to be used to draw conclusions for the study (Cox, 2019). The population for the study was maize farmers in some selected districts in the Northern and North-east Regions of Ghana. According to the Ministry of Food and Agriculture (2013), the Northern region and the North-East region of the country are among the highest producers of maize in the northern belt of the country. The study population used were maize farmers from the selected districts who were registered with the Department of Agriculture of the Ministry of Food and Agriculture under the Local Government Ministry. Maize farmers who were accessible for this study were those who lived and worked in and around the six communities chosen for the study, namely Nyankpala and Kpalsogu in the Tolon district, Salanpkang and Kplijine in the Mion district, and Kukua and Loagri in the West Mamprusi district. To reflect the population and sampling frame of the study, a representative population of 301 registered maize farmers were gathered from the communities. According to the sample frame, 111 maize farmers were registered in the West Mamprusi district (Kukuua and Loagri), 110 in the Tolon district (Nyanpkala and Kpalsogu), and 80 in the Mion district (Kplijine and Salankpang).

Table 1: Population of maize farmers' used for the study

Communities where data was collected	Study Population
Tolon District	
Nyankpala	65
Kpalsogu	45
Mion District	
Salanpkang	36
Kplijine	44
Dijo	
West Mamprusi District	
Kukua	60
Loagri	51
Total	**301**

Source: Department of Agriculture of Mion, Tolon and West Mamprusi (2020)

Sampling Procedure and Sample Size

Sampling is the process of selecting a subset of a population to participate in a study; it is the process of selecting a number of individuals for a study in such a way that the individuals chosen match the large sample from which they were chosen (Ogula, 2005). In this study, two sampling techniques (purposive sampling and simple random sampling) were used. This study used six communities, three districts, and two regions, which were selected using purposive sampling techniques. The study is part of a larger joint research project involving the ACP-EU Technical Centre for Agricultural and Rural Cooperation (CTA), the UCC Department of Agricultural Economics and Extension, the CSIR-Savannah Agricultural Research Institute (CSIR-SARI), Bayer CropScience of Paris, and AcquahMeyer Drone Software Ltd, Accra. The main aim of this collaborative research project was to test the efficacy of a synthetic control for Fall Armyworm

(FAW) control using drone technology. According to the protocols developed by this Collaborative Research Project, two regions within the Guinea Savannah maize development zone were sampled on purpose. The regions were the Northern and North East regions. Following that, three districts reflecting the ecological diversity within the regions were purposively sampled: the Tolon district (within the western corridors of the guinea savannah zone), the Mion district (within the zone's eastern corridor), and the West Mamprusi municipality (representing the Northern corridor of the Guinea savannah zone). As part of the project, experimental plots were set up for trials within the ecologies of the study. The six communities of the project were purposively sampled within a radius of two kilometres from the experimental plots. The six commuinties were Kpalsogu and Nyankpala in the Tolon district, Kplijine and Salankpang in Mion district and Loagri and Kukua in the West Mamprusi district.

Simple random sampling technique was used to randomly select 55 maize farmers from Tolon district, 48 from Mion district and 49 from West Mamprusi districts respectively. The sampling frame was collected from the three Departments of Agriculture in the districts and used for the sampling process. The project population was 301.

In determining the sample size from the study population, Krejcie and Morgan (1970) was used. This was used to find out the equivalent of the population in terms of sample size. From the Krejcie and Morgan table, it was revealed that the sample size equivalent of 301 was 169. This means the total maize farmers to be used for the study should be 169. However, the project was not able to get all

169 maize farmers necessary for the study. The project was able to obtain 152 maize farmers which represents 89.9 percent response rate. According to Holbrook, Krosnick and Pfent (2007), a study which has a response rate of more than 50% has a higher tendency of leading to accurate generalisation from the sample size to the population of the study.

Table 2: Sample Size based on Selected Communities

Communities where data was collected	Sample Size
Tolon District	
Nyankpala	22
Kpalsogu	33
Mion District	
Salanpkang	24
Kplijine	22
Dijo	2
West Mamprusi District	
Kukua	21
Loagri	28
Total	**152**

Source: Department of Agriculture of Mion Tolon and West Mamprusi (2020)

Data Collection Instruments

Questionnaires and structured interview schedules were developed as the instrument for the study to elicit information from respondents. The face validity of the research instrument was ensured, while content validity was checked by an expert in the research study area by checking whether the instruments covered all relevant aspects of the intended study. In ensuring external validity was achieved, maize farmers were given equal chance of being selected as part of the study. This allowed for generalization to be made from the study sample. The instrument was made up of both closed-ended and open-ended questions. The research instruments (questionnaire and structured interview schedule) consisted of six (6) parts as follows:

Part 1: Socioeconomic characteristics of maize farmers. This part elicited information on the socioeconomic characteristics of farmers like their age, gender, farm size, income level, educational attainment, years of farming, membership of a farmer association, and how long they have been members, access to information, access to input, and access to credit. The data on ownership of land and the number of visits by extension agents were obtained through the questionnaire administrated for the purpose.

Part 2: Farmers preferred options by maize farmers for control of FAW. Questions were asked to seek information on the various control measures adopted by farmers and the preferred control measure (s). Farmers were given the various control option available for the control of FAW in their area. They were then asked to rank the option base on its use. The control options made available were the cultural practices, synthetic pesticide, bio-pesticide, and biological control, a cocktail of chemical mixtures, IPM and others if available.

Part 3: Total perceived effect of the field usage of various spraying methods of pesticide. Farmers' perception of the perceived effect of pesticide application using drone technology and knapsack was sought through the questionnaire. The perceived effect was grouped into financial, social, and environmental effects given on a Likert scale of 0-10 (where 0- no perceived effect with 10-very highly). The farmers were to rank the options provided on the various sub-headings. Both negative and positive questions were included. The lesser the score for a question implied that drone technology has a low effect on the farmer whiles, a high score implied that drone technology had a high effect on the farmer. The higher the negative effect on the farmer, the most the farmer preferred the conventional approach (knapsack).

Part 4: Enterprise analysis of experimental plots for the application of pesticide for control of FAW**.** This section looked at the efficiency of farmers using knapsack as the main means of pesticide application compared to that of drone technology. A crop budget was made at the current market prices farmers purchase inputs for maize farming in the study areas. The input used for the preparation of the fields were recorded to reflect the actual cost of starting a maize farm. The fields were made up of the treatment plot (of the drone technology field and knapsack field) and 2 control plots for each treatment plot (drone technology control plot and knapsack control plot), all measuring 0.0801acre. Gross margin and cost-benefit analysis deduced from it, using the yield obtain form the various plots for the study areas.

Part 5: Farmers' willingness to pay for drone service for the control of FAW. Farmers were asked the minimum and maximum amount they will be willing to pay for drone services and their reason for the price. After determining the amount willing to pay they were subjected to a choice model that contains a different combination of packages from which farmers are to select one package at a time. This revealed why a farmer will prefer one package over the other.

In consultation with experts, literature, and observation, the attribute per choice set design was determined through the concept of choice experiment. The choice experiment was to determine the willingness of farmers to pay for drone services or knapsack sprayer services. Farmers were allowed to choose their preferred alternatives from a sequence of grouped options that relate to drone technology and knapsack sprayer. The attributes of drone technology and knapsack sprayer used were reliability, cost, accessibility, content, and responsiveness. By analyzing the choice made by the farmer, it is possible to deduce the trade-off the farmer is willing to make between knapsack sprayer and drone technology. Experimental design procedures were used after the determination of the attributes and levels to use for the study. The study adopted the fractional factorial design, which aims at minimizing the correlation between attribute levels in a choice set (Kuhfeld &Tobias, 2005). The study using the fractional factorial design generated from the full factorial design develop the choice set for the experiment. The result of the generation of the choice sets resulted in 243 (3*3*3*3*3) generic choice sets. The alternatives available to influence his choice were grouped into 10 choice tasks with three alternatives (drone technology, knapsack, and opt-out). The study resorted to the use of pictorial description, where farmers looking at the choice set will have to select one of the choices set given the attributes present in the choice set. The farmer had the option to opt-out if none of the options were favorable to him/her.

Part 6: determine factors that influence the acceptance of drone services for the control of FAW. This section focused on market acceptance of drone services to control FAW. Indicators of market acceptance were introduced to farmers and were asked if these factors will influence them in accepting and recommending drone technology (service). The market acceptance factors were adopted from the technology acceptance model, UTAUT, and the theory of planned behavior. The adopted questionnaire was based on a Likert scale of 0-10. With 0- not applicable and 10- very high. The higher the score, the more likely the farmer accepted the usage of drone services in the application of pesticides.

Data Collection Procedure

A research assistant and 5 enumerators were trained to help the researcher administer the research instrument to the sampled respondents from the selected areas. The validated research instruments were explained to the enumerators in English language and the local dialects. On the field, local dialects was used to explain the questions to respondents to understand and respond appropriately. Data collection was done from the 20th of September, 2019 to 25th October, 2019.

Pre-testing

Pre-testing of the research instrument was done to ensure its reliability and validity. The quality of the instrument was tested in relation to readability, ease of understanding, relevance, and representativeness of the question items in the research instrument by both the interviewer and the interviewees. Pre-testing helped the researcher to identify the error(s) in the research instrument. The necessary correction and modifications were effected before the research instrument was finalized for administration.

The interview schedules were pre-tested on 20 maize farmers at Ankaful village in the Central region to determine the reliability of the instrument. Ankaful was selected for the pre-testing due to maize farmers in the area also facing a similar issue with FAW. The homogeneity of maize production activity to that of the Northern part of Ghana also supported the reason for it selection. Cronbach's alpha reliability coefficient was calculated to test the internal consistency of all items measured on Likert-type scales. According to Pallant (2001), for an instrument to be reliable, its Cronbach's alpha coefficient should be 0.70 or more.

Table 3: Reliability Test Results

Subscale	Number of Items	Cronbach Alpha Scale
Preferred control option	6	.871
Total perceived effect of drone	26	.735
Total perceived effect of knapsack	26	.809
Market Acceptance	40	.964

Source: Omega (2019)

Data Processing and Analysis

The data were analysed using IBM Statistical Product and service solutions version 25.0 and Stata SE version 13 software. The data collected from the study areas were entered, cleaned, and analysed based on the various objectives as follows:

Part 1: Socioeconomic characteristics of maize farmers was analysed using frequencies, percentages and also were regressed on other objectives to determine a relationship.

Part 2: Farmers preferred options by maize farmers for control of FAW. Cross tabulation, Friedman rank test, and Wilcoxon sign test was used to rank the various control measures used by farmers. This helped to know the most used control measure used by maize farmers in the study areas.

Part 3: Total perceived effect of the field usage of various spraying methods of pesticide. Mean and the standard deviation was used to find the effect of drone technology via-a- via a knapsack sprayer in the application of pesticide in FAW control. A chi-square test was also carried out to find out the significant differences that existed.

Part 4: Enterprise analysis of experimental plots for the application of pesticide for control of FAW. The data was analysed using enterprise analysis that included; gross marginal analysis to find the revenue and variable cost of production incur by maize farmers in the area. The gross marginal analysis was also calculated for gross margin per acre and the cost-benefit analysis was also calculated to find whether the benefit of maize farming outweighs the cost or otherwise. The revenue per labour, the revenue per acre, and the revenue per input were calculated through the enterprise analysis.

This was analysed on study area bases and then compared against each other and also to find out the input-output ratio that resulted from the treatment fields (drone technology plot and knapsack sprayer plot) and the control plots.

Part 5: Farmers' willingness to pay for drone service for the control of FAW was analysed using the contingent valuation method. The contingent valuation method was used to estimate whether a consumer was willing to pay or not for drone technology. The maximum and minimum prices that the consumer was willing to pay was also generated and analyzed. The binary logistic model was used to estimate socioeconomic characteristics on willingness to pay for drone service.

Part 6: determine factors that influence the acceptance of drone services for the control of FAW was analysed using ordered logistic regression. The ordered logistic regression had market acceptance as the dependent variable regressed against the independent variable (socioeconomic characteristics, and willingness to pay indicators). The dependent variable (market acceptance) was estimated from selected factors of the technology acceptance model, UTAUT, and the theory of planned behavior favorable to the study objective.

Empirical Model of contingent valuation method (CVM)

The technique of contingent valuation (CV) is used to obtain WTP data from individuals. This technique has three main procedures used in CV surveys, namely joint analysis, dichotomous choice, and approaches to the payment scale. The conjoint analysis procedure requires respondents to rate alternatives rather than price alternatives. The payment scale procedure allows participants to select a value or price (cost) on a specified scale. A variety of values are provided to the participants and they are requested to define a value or price (cost) they are prepared to pay or incur to buy the good or service being evaluated. The selection of the respondent from the given scale shows the WTP for the stated good or service. Positive values show positive demand, and zero values imply zero demand for goods or services. In the dichotomous choice approach, participants are questioned if they would vote to alter the provision of some public good at a price of X for themselves. The respondents will have to answer yes or no (Kaliba, Norman & Chang, 2003).

In gathering data much emphasis was placed on the dichotomous approach. Hence, respondents were asked, "are you willing to pay?" If the respondent answers 'yes' the experiment is repeated by asking the respondent to state additional money he/ she is willing to pay. The stipulated amount plus the money spent becomes the maximum amount the respondent is willing to pay.

Model Specification

The empirical model for a dichotomous dependent variable can be specified as:

$$Y_i = X\beta + \mu_i \qquad 3.1$$

Where:

$$Y_i = \begin{cases} 1 = \text{if respondents are willing to pay (Yes)} \\ 0 = \text{if respondents are not willing to pay (No)} \end{cases} \qquad 3.2$$

X = A vector of all explanatory variables included in the model.

β = A matrix of all coefficients in the model including the intercept.

$\mu_i =$ A vector of the error term

Gross Margin

Goss margin is the total revenue (TR) obtained from engaging in the farm enterprise less than the variable cost. The total variable cost (TVC) refers to all costs that change in the cost of production of the farm enterprise output. Variable cost is sometimes referred to as the operating cost of undertaking the enterprise like the administrative expenses and selling expenses. It reveals how much the farm enterprise is making from the output if sold at a given price. Therefore revenue is captured as the function of price and output or quantity. Indicating that the more unit produces, the cost associated increases. Gross margin is useful when the value of the fixed cost is negligible or remain the same for a set of enterprises. If the total revenue is greater than the variable cost, then we have a positive or favorable gross margin, while a negative gross margin will imply that the variable cost outweighs the revenue, hence unfavorable gross margin. However, there is an instance where the cost and the revenue are the same, in that case, the gross margin remains constant. However, every farm enterprise expects a positive or favorable gross margin.

Mathematically, $GM = TR - TVC$ 3.3

$TR = P.\,Q$ 3.4

$TVC = f(Q)$ 3.5

Where; GM = Gross margin TR= Total Revenue TVC = Total Variable Cost

P = Price per unit of output produced Q = Quantity of output produced

Benefit –Cost Analysis

The use of benefit-cost analysis was to help parties in the project make informed choices on which of the project was more viable to invest in given the cost involved in starting it against the benefit to be reaped from engaging in the project. The various plots (Knapsack, drone, and control plots) were considered as individual investment options available to the farmer. Per the principle of cost-benefit analysis, the farmer is expected to select the option that will give him the highest benefit at a minimum cost. Ideally, the evaluation of the benefit-cost analysis is calculated over the life span of the project allowing for the cost of the project to be discounted over the period. Since this project was performed at a fixed period, the spot rate was used in the discounting process. Where no interest will be accumulated over the life span of the project. Mathematically, this has been specified as;

Benefit-Cost = $\frac{Benefit}{(1+r)^t} / \frac{Cost}{(1+r)^t}$ 3.6

The "r" is the discounted rate of the project. The discounted rate of the project was zero (0) (the price of the project was at a spot rate). Hence the discount rate associated with the project will not affect the project.

t = 1, this is because the project life span stretched over a year (period of start to finish of the project).

Therefore; Cost-Benefit = $\frac{Benefit}{Cost}$ 3.7

Base on the financial accounting principles if the BCR is less than 1, then the project should not proceed. Whiles, BCR> 1- the project should proceed and BCR = 1, the project should proceed with little viability.

Profit

Profit is considered as the core objective of any enterprise in the long run. This guarantees the existence or otherwise of the enterprise in the long run. The ability of the enterprise to maximise profit is an indicator of the lifeline of the enterprise. Thus, profit is the engine of any farm enterprise. The farm owner treats profit as the reward for taking a risk to adopt technology or a program. With agriculture merge in risk and uncertainties, it's a necessary evil for farm enterprise owners to make a profit at one time or the other to remain relevant or to keep up the enterprise. Profit is seen as the revenue in excess of the cost of production.

However, revenue being the same as cost (break-even profit) is desirable but not sustainable. Total revenue is the function of price and quantity of output as the total cost is a function of output. Total revenue is the earning or income that accrued to the enterprise from undertaking the enterprise, while total cost is the cost associated with the production process. The deduction of the cost from the revenue leaves what is termed profit. Therefore Profit can be defined mathematically as;

$$\text{Profit} = TR - TC \qquad 3.8$$

Where;

$$TR = P.\,Q \qquad 3.9$$

$$TC = TFC + TVC \qquad 3.10$$

Hence; TR = Total Revenue TC= Total Cost TFC= Total Fixed Cost

TVC= Total Variable Cost P = Price per unit of output produced

Q = Quantity of output produced

Whiles, the profit margin is profit over the revenue obtained from the farm enterprise. A high-profit margin is considered most desired in an enterprise. This could form the bases for selecting one enterprise over the other base on the profit contribution made by the enterprise.

Mathematically, Profit Margin = $\frac{Profit}{Total\ Revenue}$ 3.11

Logistic Regression (Willingness to pay)

The use of binary logistic regression for the estimation of willingness to pay for drone service was to help explain how socioeconomic variables influence the willingness to pay of maize farmers, thereby allowing implementation agents to accept it as a new and improved method of pesticide application. Socioeconomic variables serve as a driving force for farmers to be willing or not of a technology or service, hence the necessity to measure these variables to find out how they impact farmers' decisions. A binary choice is always suitable in measuring willingness to pay due to the binary response nature of the data available. The most used form of binary choice is the probit and logit. The binary logistic regression was used to estimate the influence of the independent variables on the dependent (Willingness to pay). Willingness to pay was measured on a binary scale with 0- Unwilling to pay and 1- Willing to pay. Logit and Probit have been used extensively in cases with limited dependent variables in obtaining information when the distribution is non-normal in technology studies. The logistic regression model has been used for categorical and a mix of categorical and continuous variables (Agresti, 20017). In this study, the logistic regression model is estimated below:

$$\text{Logit}(p_i) = \log\left(\frac{p_i}{1-p_i}\right) = ß_0 + ß_1(\text{Age}) + ß_2(\text{Gender}) + ß_3(\text{Status}) + ß_4(\text{farmsize}) + ß_5(\text{Credit}) + ß_6(\text{input}) + ß_7(\text{info}) + ß_8(\text{Marital Status}) + ß_9(\text{income}) + ß_{10}(\text{Ext}) + ß_{11}(\text{HHsize}) + ß_{12}(\text{LH}) + ß_{13}(\text{Edu}) + ß_{14}(\text{FExp}) + ß_{15}(\text{POCC}) + e \quad 3.12$$

Where: Logit (p_i) = the odd of the event occurring p_i= the probability of the event will occur **1-** p_i= the probability of the event not occurring $ß_0$ = Constant of the equation e = Error term

Ordered Logistic Regression (Acceptance)

The ordered logit model is a regression model for variables that are ordered in response. The model has to do with the dependent variable's accumulative probability assumed to be linear to the covariates variables with regression coefficients constant across the various categories of the dependent variable. Although, ordinal variables can be analyzed using linear regression, Lu (1999) report that it's completely inappropriate. With maize farmer's acceptance being on a continuous scale measured with the Likert scale of 0-10 from acceptance model variables. The choice of a 10 point Likert scale was to find out maize farmers level of agreement to accepting drone services. The 10 point Likert scale was broken down into three categories in accordance with the assumption of the ordered logistic regression, which according to Fullerton (2009) states that "for an ordered logistic regression to be perform, the dependent variable show be on an ordinal scale". This led to the broken down of acceptance into 0-3.3 being Low acceptance, 3.4-6.7-moderate acceptance and 6.8-10 being high acceptance and regressed along vectors of the independent variables (socioeconomic characteristics and willingness to pay). Convenient one to one transformations of the cumulative probabilities is given as;

$g_i = Pr(Y_i/x_i)$ 3.13

The last cumulative probability is necessarily equal to 1.

However, the ordered logit model for ordinal response Y_i with C categories is defined by a set of C-1 equations with the cumulative probability

$g_{ci} = P_r (Y_i \leq y_c/x_i)$ 3.14

Is related to a linear predictor given as;

$B_1x_i = ß_0 + ß_1 x_1 + ß_2x_2 + \ldots + ß_k x_k$ 3.15

Hence, Logit (g_i) = log $(\frac{g_i}{1-g})$ = $\mathbf{a_c}$ - $ß_1x_i$, c-1, 2, 3…C-1 3.16

a_c is the cut point, which has an increasing order. Due to the difficulty of simultaneously estimating the overall intercept of the linear predictor $ß_0$ and all the possible C-1 cut points, it's mostly omitted or fixed the first to Zero.

Variables in the Equations

Dependent Variables

The dependent variable was the willingness to pay and acceptance. The choice card was used as indicators of willingness to pay to solicit information and the choices made were summed up to form the dependent variable willingness to pay. Willingness to pay was captured as dummy variable with 1- Willing to pay 0- Not willing to pay. However, the indicator of willingness to pay was also used as independent variables for market acceptance. Acceptance as a dependent variable was obtained from the summation of the acceptance model indicators. This was categorized into 1-low acceptance, 2- Moderate acceptance and 3- High acceptance

Independent Variables

Based on a review of the theoretical and empirical literature, the following factors were deemed to influence the dependent variables and these were considered in the model

Age

Age was considered as a continuous variable defined as the age of the respondent at last birthday. Age was measured in years. Its expected as farmers advance in age their output will increase due to the experience gathered over their farming life but that also makes them useful to old practices and unwilling to adopt new technologies. Therefore age is expected to have a negative relationship with the willingness to pay and acceptance.

Gender

Gender was treated as a dummy variable with 0-male and 1-female. Male turn to have more resources and are more likely to accept new services than females who most often are constrained with resources and farms to feed the family. However, the direction of gender in this research was indeterminate as gender could take both positive and negative direction in relation to willingness to pay and acceptance.

Marital Status

Marital Status was captured as a dummy variable with 0-married and 1- not married. It's assumed that married farmers are more likely to produce more compared to unmarried, this is due to the desire to feed the family and also make income for other expenses. But are not too zealous in parting away with capital for new services easily. Therefore, marital status is assumed to have a negative relationship with the willingness to pay and acceptance.

Access to Credit

Credit is a dummy variable assuming 0-yes (there exist credit) and 1- No (there exists no credit). The availability of credit cushions the farmer's income to purchase farming input including new services. Credit has been considered one of the main reasons for the failure of the acceptance of services among farmers (Gregory & Sewando, 2013). Access to credit is expected to have a positive relationship with acceptance and willingness to pay.

Access to Input

Access to input has been lacking to farmers due to its non-availability or unaffordability. Farmer lack of input leads to low or poor acceptance of new services, often than not these inputs are expensive and hard to find on the market, hence, making farmers less willing to pay a higher price for the few on the market. Access to input in this research will be treated as a dummy variable with 0-yes (access to input) and 1- no (lack of access). Access to the input will have a positive relationship with acceptance and willingness to pay.

Access to Information

Access to timely and relevant information is very vital to the acceptance process as while influencing a farmer to pay for a service or not. It's assumed that if farmers have timely information on a service, they will be more likely to accept the service and be willing to pay for the services. In this study, access to information was treated as a dummy variable with 0-yes and 1- no. Access to information is expected to have a positive relationship with acceptance and willingness to pay.

Status

The status of the respondent was categorized into 1- head, 2-spouse, and 3-children. The position of a respondent tends to influence their spending behavior which will also affect their acceptance of service. Ideally, a family head has a high tendency to purchase a new service than that of the other family members due to his position in the household. Status is expected to a positive relationship with acceptance and willingness to pay.

Farm size

Farm size per this study is the area of land used by the farmer for maize farming. The size of the land was captured in hectares and converted to acres for the smooth estimation of other parameters. Farmers with large farm sizes are more willing to pay for new service due to the rationale of the ease and pace it may offer. Farm size was considered as a continuous variable in this research and it's expected to have a positive relationship with willingness to pay and acceptance.

Income Source

The Source of income to the farmer has the likelihood of increasing farmer investment in agriculture technologies. If the farmer makes income from other activities aside from his farming activities, there is a high chance of investing in agriculture services. This in itself serves as a diversification strategy for the farmer. Income sources were treated as dummy as 0- farm income only and 1- Non-farm income only. It's expected that income, willingness to pay, and acceptance will have a positive relationship.

Extension

Contact with extension agents has been the most common form of information and technology transfer to farmers. It's expected that the more a farmer gets into contact with an extension agent, the more the chance that the farmer will accept a technology because education will have taken place and the farmer will become more comfortable with the services. Contact with extension agent was treated as a dummy variable with 0- yes and 1-no. Contact with an extension agent is expected to be positively related to the willingness to pay and acceptance.

Household size

It was treated as a continuous variable measured per the number of people living under one roof at the time of the research. It’s known that a larger household size implies large household expenditure and decreasing disposable family income. As household size increases, the demand for new services will decrease. Hence, there will be a negative relationship between household size and willingness to pay and acceptance.

Landholding

Landholding was treated as a dummy variable with 0- Own and 1- Not owned. It’s expected that if a farmer owns the land for cultivation, he will be more willing to risk paying for a new service. Therefore, landing holding, willingness to pay, and acceptance have a positive relationship.

Education

Education was captured as a categorical variable with 1-Non formal education, 2- formal education, and 3-No formal education. As the education level of a farmer increases, his ability to use information increase with ease. Education shows a positive relationship with the willingness to pay for technology by Paulos (2002). Hence, education in these studies will assume a positive relationship with the willingness to pay and acceptance.

Farming Experience

Experience refers to the number of years a farmer has been farming maize. The decision of a farmer to accept or pay for a service can be influence by how long they have cultivated maize. A farmer with higher years of experience in maize farming is more likely to adopt new technology in maize production than a new farmer. Farming Experience was treated as a continuous variable measured in years. And it's expected that farming experience will have a positive relationship with willingness to pay and acceptance.

Service Reliability

Service reliability is an indicator of willingness to pay. This was introduced into the market acceptance model to find out the effect willingness to pay through reliability can have on market acceptance. It was treated as a dummy variable with 0-yes, 1-no. It's assumed that if a service is reliable to the need of the farmer, then he will be willing to accept it. Therefore, it's expected that there will be a positive relationship between reliability and acceptance

Content

The content in terms of package associated with drone service also induces a farmer to accept drone service. Farmers sometimes may not look at the service in isolation but the added services the technology will offer will make the farmer accept the technology. It is expected that if drone companies add-on additional packages like after spraying like advice, promotion and extension services, will lead to farmers easily accepting drone services. Content was treated as a dummy variable with 0-Package, 1-No package. Package meaning if the farmer will accept drone services if given add-ons and no package meaning the opposite.

Price

It was treated as a dummy variable with 0-yes, 1-no. As the cost of technology increases, it's expected that the level of acceptance will fall. This is due to the farmer not being sure if using all his income to purchase a new service will pay-off as expected. Therefore, the study expects a negative relationship between cost and acceptance.

Accessibility

If technology is difficult to find, farmers begin to find an alternative or stay to their old practices. Also, service difficult to access tend to have a high cost which prevents farmers to accept the service. It was treated as a dummy variable with 0-yes, 1-no. It's expected that there will be a positive relationship between accessibility and acceptance.

Responsiveness

Service should respond to the need of farmers. If a service is considered as responsive by a farmer, he/she tend to be willing to accept it. The study treated responsiveness as a dummy variable with 0-yes, 1-no and it's expected to have a positive relationship with acceptance.

Control Option

Control option was treated as a binary response variable with the base category being synthetic control and the second category being other control option. It is expected that the relationship between control option, willingness to pay and acceptance will be positive.

Table 4: Variables and their measurement included in the model

	Variables	Unit of measurement	Expected direction
Dependent Variables	Willingness to pay	1- Willing to pay 0-Not willing to pay	
	Acceptance	1- Low acceptance 2- Moderate acceptance 3- High acceptance	
Independent Variables	Age	Years	-
	Gender	1- Male, 0- Female	+/-
	Marital Status	0- Married, 1- Unmarried	-
	Primary Occupation	0-Farming, 1- Non-farming	+
	Access to Credit	0-yes, 1- No	+
	Access to Input	0-yes, 1- No	+
	Access to Information	0-yes, 1- No	+
	Status	Position in the household	+
	Farm size	Total land size in acres	+
	Income source	0- farm income only and 1- Non-farm income	+
	Contact with Extension Agents	0-yes, 1- No	+
	Household size	Number of people under one roof	-
	Landholding	0- Own, 1- Non-own	+
	Education	1-Non formal 2-Formal 3-No formal	+
	Farming Experience	Years	+
	Reliability	0-yes, 1- No	+
	Content	0-Package, 1- No Package	+
	Cost	0-High, 1- Low	-
	Accessibility	0- Ease, 1- Difficult	+
	Responsiveness	0-yes, 1- No	+
	Control option	0-Synthesis control 1-others	+
	Challenges	0-yes 1-No	-

Source: Omega (2019)

Experimental Plot Information

Appendix 2, report the experimental plot information obtain during the field experiment. It was revealed from appendix 2 that drone requires less time for spraying in all three district compare to that of knapsack. On average drone spends 1minute 3 seconds to spray 0.0801 acre and knapsack 8 minutes 40 seconds to spray 0.0801 acre. The infestation rate varies from 16%-18% per plot with the infestation high in Tolon. For standardization of measurement across the districts, the plot size (0.0801acre), maize planted per plot (60*22rows), water (3litres) and chemical volume (10ml) were made equal.

Chapter Summary

The chapter dealt with the methodological issues that were studied and used in the research. The study described the area of study, thus, Northern and North-east regions, and also examined the research and design approaches used for carrying out the study. There were also descriptions of processes used for developing quantitative research tools. The section also describes how the variables have been operationalized. The target population for the research was maize farmers in the study area. Using a questionnaire, quantitative information was gathered. The data collected were analyzed using version 25.0 of SPSS and Stata Version SE13.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter seeks to present the results and discusses the objectives of the study. For this reason, the chapter will be divided into the six objectives of the study, with objective one being the first section to look at the socioeconomic characteristics of farmers in the study area. Section two will examine preferred options by farmers for the control of FAW in the study areas. Section three and four will determine the total Effect of the field application of spraying methods of pesticide and assess and compare the economic efficiency of experimental and control plots for application of drone technology for control of FAW respectively. The last two sections, thus, sections five and six will tackle issues of farmer's willingness to pay for the application of drone service for the control of FAW and also predict market acceptance factors for use of drone service for pesticide application to control FAW.

Socioeconomic Characteristics of Maize Farmers in the Study Areas

From Table 5 below, it was revealed that the majority of maize farmers across all the three districts were relatively younger (West Mamprusi- 17-32 years (33.0%), Mion- 33-48 (31.0%) and Tolon-33-48 (25.0%)). This shows a deviation from the report of most literature, where maize farming was dominated by the aged. The results in this study are inconsistent with Ojiako and Ogbukwa (2012), Akpan (2010), and Wongnaa (2016), who reported that the productive labour in maize production are older people and this has the potential to affecting productivity and efficient use of service to increasing maize production. This implies that maize farming is becoming a lucrative venture for young people to engage in. On Gender, the results of Tolon (Female-52.0%) was at variance with that of the other two districts which had male respondents dominated maize farming. This is inconsistent with the findings of Sadiq, Yakasai, Ahmad, Lapkene and Abubakar (2013) and Oladejo and Aderunji (2012) studies in Niger state and Oyo state, that revealed that males are more efficient in maize. This indicates that although males are dominant in maize production, both genders can take up maize production as a business or income-generating activity. The result from table 5 on farming experience corresponds with that of the age of respondents. It was revealed that maize farmers were relatively new to maize farming with 1-15years of experience (West Mamprusi-50.5%, Mion- 50.0%, and Tolon- 62.0%). This shows that more people are being encouraged to enter into maize farming. This is consistent with the findings of Abdulai, Nkegbe and Donkor (2017) that maize farmers were relatively new to maize farming. This implies that maize farming is gaining more attention among farmers.

Also, in Table 5 it was revealed that the majority of the respondents across all the three district were married, however, in Tolon, Widowed (6.0%) were more than single respondents (4.0%). This shows that maize farming is seen by to be reliable such of livelihood to widowed people. With farmer-based organization (FBO), it was revealed that respondents in Tolon belong to FBO more (69.0%) compared to the other two districts. This is inconsistent with the findings of Wongnaa (2016), which reveals that more than half of farmers in the Savannah zone do not belong to any form of FBO. Table 5, also revealed that as Mion and Tolon saw a relatively higher number of agricultural extension agents (AEA) than West Mamprusi with like than 3 visits (94.0%). This is consistent with the findings of Wood (2013), who revealed that there exists a gap in communication between the ministry of food and agriculture and farmers, attributed to the low level of extension services and research in the savannah zone of Ghana. This means maize farmers base their activities on experience gathered from years of farming or other sources.

Furthermore, Table 5, revealed that in West Mamprusi, spouses are more likely to engage in maize farming than other members of the households. This is consistent with Antwi-Agyei, Stringer and Dougill (2014) that spouses were more likely to work on farmlands than heads of households. This implies that although males own farmland, spouses cultivate the lands. With Household size, Table 5, revealed that in Tolon, households were larger (15-29 (54.5%)) compared to the other two districts. These findings are consistent with Kuwornu, Ohene-Ntow and Asuming-Brempong (2012) report that in rural Ghana, households of maize farmers tend to be larger. Lastly, Tolon (Yes (50.9%)) had more access to information than the other two districts. This agrees with Lanjouw and Shariff (2004) that access to information is not even across geographical locations. This implies that farmers who are close to urban areas tend to have more access to information.

In relation to the conceptual framework it shows that socio-economic characteristics of maize farmer is vital to telling the behavioral pattern of choice of farmers in the selection of a particular mode of pesticide application. This is underpin by the theory of planned behavior.

Table 5: Socio-economic Characteristics of maize farmers

Characteristics	West Mamprusi		Mion		Tolon	
	Freq	%	Freq	%	Freq	%
Primary Occupation						
Farming	47	95.0	46	95.0	51	93.0
Trading	1	2.0	1	2.0	4	7.0
Teaching	1	2.0	2	3.0	0	0.0
Age						
17-32	16.0	33.0	15.0	31.0	14	25.0
33-48	13.0	27.0	18.0	38.0	22	39.0
49-64	11.0	23.0	8.0	16.0	14	25.0
65-80	7.0	14.0	7.0	15.0	6	11.0
>80	1.0	2.0	0.0	0.0	0	0.0
Gender						
Male	26	53.0	36	75.0	27	48.0
Female	23	47.0	12	25.0	28	52.0
Farming Experience						
1-15	25	50.5	24	50.0	34	62.0
16-30	11	23.4	13	26.0	11	20.0
31-45	7	14.4	8	18.0	4	7.0
46-61	4	9.0	4	6.0	6	11.0
>61	1	1.8	0	0.0	0	0.0
Level of Education						
No formal Education	29	59.0	41	85.0	43	78.0
Formal Education	20	41.0	7	15.0	12	22.0
Marital Status						
Married	38	78.0	45	94.0	50	90.0
Single	7	14.0	2	4.0	2	4.0
Widowed	4	8.0	1	1.0	3	6.0

Table 5 continued

FBO Group						
Yes	6	12.0	11	24.0	38	69.0
No	43	88.0	37	78.0	17	31.0
Number of contact with AEA						
<3	46	94.0	31	63.0	68	62.0
4-7	2	6.0	12	25.0	28	26.0
8-11	0	0.0	2	4.0	11	10.0
>11	0	0.0	4	9.0	8	2.0
Landholding						
Own land	18	37.0	21	43.0	19	18.0
Family land	29	59.0	24	50.0	31	29.0
Leasing	0	0.0	2	5.0	3	0.0
Renting	2	4.0	1	2.0	2	2.0
Farm Size(Acres)						
1-5	36	73.5	30	62.5	53	96.4
6-10	10	20.4	17	35.4	2	3.6
11-15	3	6.1	1	2.1	0	0.0
Income Source						
Farming	37	75.5	41	85.4	39	70.9
Trading	0	0.0	2	4.2	4	7.3
Farming and Trading	9	18.4	4	8.3	10	18.2
Hairdressing and Farming	2	4.1	0	0.0	1	1.8
Farming and Teaching	1	2.0	1	2.1	1	1.8
Status						
Head	17	36.2	37	77.1	29	52.7
Spouse	29	61.7	7	14.6	22	40.0
Child	1	2.1	4	8.3	4	7.3
Household Size						
0-14	18	36.7	30	62.5	23	41.8
15-29	10	20.4	12	25.0	30	54.5
30-44	7	14.3	6	12.5	2	3.6

Table 5 continued

45-59	10	20.4	0	0.0	0	0.0
60-74	2	4.1	0	0.0	0	0.0
Access to Credit						
No	37	78.7	39	81.3	41	74.5
Yes	16	34.0	9	18,7	14	24.5
Access to input						
No	37	78.7	39	81.3	47	85.5
Yes	10	21.3	9	18.7	8	14.5
Access to Information						
No	28	59.6	28	58.3	27	49.1
Yes	19	40.4	25	41.7	28	50.9
Total	**49**	**100.0**	**48**	**100.0**	**55**	**100.0**

Source: Omega (2019), n =152

Farmers Preferred Option for the Control of FAW

From Table 6, it showed the various control measures adopted by farmers in the three districts and also the extent to which maize farmers are using it in the control of fall armyworm on their maize farms. The cross-tabulation results of Table 6 showed that maize farmers in all three districts prefer to use synthetic control (57.90%) as the first form of control for fall armyworm infestation. While, the remaining control measures were shown as; cultural control (28.30%), bio-pesticides (3.90%), biological (4.60%), Cocktail/mixtures (3.30%) and IPM (2.00%). The findings of this study are inconsistent with Durocher-Granger, Babendreier, Dey, Huesing, Jepson, Eddy and Prasanna (2018), USAID (2017), and Kamau, Stellmacher, Biber-Freudenberger and Borgemeister (2018) findings, which suggested that the most used and consistent methods with farmers control of FAW were the Integrated Pest Management (IPM). This may imply that maize farmers in the selected districts have not been exposed much to the concept of IPM or it is not consistent with their preference for FAW control.

The results of farmers preferences for control option for the control of FAW is related to the conceptual framework in revealing that the choice of control option by farmers is not made in a vacuum rather guided by theory of planned behavior and consumer theory. These theories bring to bear the fact that a farmer is guided by price and income in the selection of a control option. Despite the price and income, the returns becomes necessary. Even after obtaining the best control option possible, the behavioral intention and attitude of the farmers can make the farmer to use or not use the selected option.

Table 6: Farmers Preferred option for the control of FAW

	Synthetic control		Cultural Control		Bio-pesticides		Biological Control		Cocktail/mixtures		IPM			
Control Options	***Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Mean**	**S.D**
Synthetic control	88	57.9	41	27	10	7	3	2	4	3	0	0	41	27
Cultural Control	43	28.3	53	35	20	13	18	12	11	7	4	3	53	35
Bio-pesticides	6	3.9	28	18	74	49	25	17	13	8	1	1	28	18
Biological Control	7	4.6	10	7	17	11	82	54	30	20	0	0	10	7
Cocktail/mixtures	5	3.3	11	7	19	12	10	7	100	66	2	1	11	7
IPM	3	2.0	1	1	2	2	2	1	7	5	133	87	1	1

Source: Omega (2019), n = 152, * Multiple response

From Table 7 below, justifies the cross-tabulation of synthetic control being the most preferred option for FAW control in the three districts. The Friedman Rank Test results confirmed the cross-tabulation that synthetic control was the most preferred option for FAW control with IPM being the least preferred control measure for controlling FAW.

Table 7: Friedman Ranking Test of Farmers Preferred Control Method of FAW

Preferred Control Method	Mean Rank	χ^2	Df	Asymp. Sig*
Synthetic control	1.62	958.63	5	0.00
Cultural Control	2.41			
Bio-pesticides	3.08			
Biological Control	3.81			
Cocktail	4.32			
IPM	5.77			

Source: Omega (2019), n = 152, *p < 0.05

H_o: There exists no significant difference between farmer preferred options for the control of FAW

The results of table 7, revealed that there is a significant difference between farmers' preferred options for the control of FAW in the districts at an alpha value of 5%. Therefore, I fail to accept the null hypothesis of "no significance between farmer preferred options for the control of FAW". These findings are consistent with similar studies by Sisay et al. (2019), Rwomushana et al. (2018), Nunda(2018), and FAO (2017) which found out that there was a significant difference in preference for the various FAW control means. It was also revealed that the most effective means of control by maize farmers was the synthetic pesticide (control) but the continuous usage of them is likely to make FAW resistant to its use.

Again, Table 8 revealed the relationship that exists between the most used control measures (synthetic control) against the other control measures. The Wilcoxon Signed Rank Test was adopted to compute the relationship based on post hoc isolation of the differences between the farmers' preferred option of synthetic control and the other control methods. The results showed that there is a negative relationship between synthetic control measures and all the other control measures. This information is informed by the coefficient of the 5 other control measures aside synthetic control. The negative signs imply that at all times the farmers will prefer the synthetic control of FAW and reject the other control methods of cultural, bio-pesticides, biological, cocktail, and IPM. .At an alpha value of 5%, the negative relationship between synthetic control and the other control measures were shown to be significant.

Table 8: Wilcoxon Signed Rank Test of Synthetic Control and Other Control Methods

Control Methods	***Z* Score**	**Asymp. Sig ***
Cultural Control	-7.16	0.00
Bio-pesticides	-12.89	0.00
Biological Control	-13.96	0.00
Cocktail/Mixtures	-14.26	0.00
IPM	-15.19	0.00

Source: Omega (2019), n = 152, *p < 0.05

Total Perceived Effect of the field usage of various Spraying Methods of Pesticide

Appendix 1 revealed the effect of using both drone and knapsack as a means of spraying. The overall perceived social effect of using knapsack was higher than that of drone (Mean= 5.551) and for knapsack (Mean= 6.099). This shows that knapsack had significantly more effect on the social wellbeing of the maize farmers. An in-depth look at the component of social effect revealed that knapsack was riskier to the health of the sprayers' at all three districts of the study, but showed no significant difference with the drone in West Mamprusi. This is consistent with works of Lidynia, Philipsen and Ziefle (2017), Sylvester (2018), Efron (2015), Greenwood et al. (2016), Clothier, Greer, Greer and Mehta (2015), and Ajewole, Schroeder and Parcell (2016) that remotely used technologies tend to have a low level of risk to the user than technologies that are in close contact with the user. From the appendix 1, on consistency with the practice of control of FAW, farmers considered drone as the method of pesticide application that was consistent with their current FAW control, but no significant difference was recorded in Mion. The findings were consistent with Greenwood et al. (2016) and Puri et al. (2017) report that farmers are becoming increasingly familiar with drone service although there are challenges in replacing it with the existing method. Similarly, from appendix 1, on ease of use, it was revealed that all three districts felt the use of the drone for the control of FAW was easy to use. The relationship between knapsack and drone was not significant in Tolon ($\chi2$= .190). The findings are consistent with similar studies done by CTA on ICT for ACP revealed that 59% of farmers viewed drone usage to be ease (Soesilo & Rambaldi, 2018). Also, other researches by Lidynia et al. (2017) European Commission (2018), and Mckinnon (2016)confirm that drone is useful to farmers in aiding their activities. Results from appendix 1, on West Mamprusi and Mion on the flexibility of manipulation of equipment, revealed that the use of the drone was more flexible in its manipulation, but the relationship not significantly different. This is consistent with the findings of Efron (2015) and Mckinnon (2016) that drone usage has the advantage over other application means by the fact that it's flexible in its manipulation and manoeuvrability. From appendix 1, maize farmers also revealed that there existed support systems available to them with the use of knapsack. However, the difference in the methods of the application was not in Mion. This is inconsistent with the European Commission (2018), and Sayem (2017) that farmers around the globe are receiving support for drone usage but adoption is hindered by financial challenges.

From appendix 1, results on the perceived environmental effects of application modes revealed that overall the effect of knapsack (Mean= 6.679) on the environment exceeds that of drone (Mean= 4.2123). Results from appendix 1 on the constituents of environmental effect revealed that the duration of time for spraying, using a knapsack was much higher than a drone in all the three districts but this was not significantly different in Tolon. This is affirmed by Sylvester (2018), Puri et al. (2017), Rao et al. (2002), Greenwood et al. (2016), and Mckinnon (2016) that drone reduces less time for application of chemicals (pesticide) to achieving required productivity. From appendix 1 on drift during the application, it was revealed that knapsack was more likely to see application drift compared to drones in all three districts but there was no significant difference in West Mamprusi. On drift Puri et al. (2017), Sylvester(2018) and Efron (2015) reported that drone reduces the chance of pesticide runoff which results from the drift of chemicals. This agrees with the findings of this study. Similarly, Su et al. (2018) which compared knapsack and drone spraying in relation to the nozzle structure revealed that knapsack and drone spray distribution is not uniform although knapsack performs better with lower coefficient value, the drone has a better depositing ability of pesticide. On the effect of weather on the usage of equipment and the landscape, from appendix 1, it was revealed that weather and landscape are more likely to affect the performance of knapsack than drone although, the effect of weather on equipment was not statistically significant in Mion. Sylvester(2018), Efron (2015), and Greenwood et al. (2016) agreed with the findings of this study that, drone was able to access remote areas such as terrace fields in mountainous regions.

From Appendix 1, on perceived economic or financial effect, it was revealed that drone (Mean= 6.495) had more effect on farmers financially then knapsack (Mean= 5.371). The results on the cost of service in pesticide application showed that maize farmers saw drones to have a high cost of services in pesticide applications. European Commission (2018), Puri et al. (2018), Godwin, Richard, Wood, Welsh and Knight (2003), and Rao et al. (2002), affirm that drone services were extremely costly and sometimes the desired result is not obtained. On the performance of the two methods, it was revealed that drone was high on performance in pesticide application than a knapsack, but this was not significantly different in Mion and West Mamprusi. This is consistent with findings of Didier and Lucide (2008), Sylvester (2018), and Puri et al. (2017) that drone performance is unprecedented in agriculture and due to its performance, significant improvement in agriculture productivity like reducing the number of labour in spraying and its possibility for mass workers to move into other productive areas of agriculture. Lastly, on affordability of the two method of pesticide application, it was revealed that knapsack was more affordable, despite it not being statistically different in West Mmaprusi. This is consistent with Soesilo and Rambaldi (2018) and European Commission (2018) that the affordability of drone is difficult for most African farmers mainly because farmers operate small to medium scale farmers, hence they cannot afford the service.

The results on the total perceived effect of spraying method is underpinned by the theory of planned behavior and the UTAUT which holds that farmers will prefer any of the use technology base on the technology characteristics (performance and effort expectancy) and the user characteristics like the social influence and facilitating conditions coupled with the farmers attitude. This will leads to a behavioural intention that influence the farmer in selecting one of the two option available to him. This was captured in the conceptual framework by leading to willingness to pay given the selected option maximize farmer utility through the enterprise analysis (Consumer theory).

Ho: There is no Statistically Significant Difference between Drone and Knapsack Application Modes.

The null hypothesis was tested at a 5% alpha value and the result as in appendix 1 revealed that that the social effect of using a knapsack was greater than of a drone and there exist a significant difference between them. This implies that the social effect of the use of knapsack on farmers and their society was high than the use of the drone. With the environmental effect, it was revealed that the level of difference of the effect of knapsack over drone was statistically significant at a 5% alpha value. This implies that the usage of knapsack by farmers has a significant effect on the environment. The result was consistent with Efron (2015), that drone in agriculture was more environmentally sustainable in the control of the pest. Furthermore, agree Robertson, Carberry and Brennan (2007), Stoorvogel and Bouma (2005), Sayem (2017), and Coulibaly, Nouhoheflin, Aitchedji, Cherry and Adegbola (2011) that precision agriculture devices like drone help to protect the environment against environmental pesticide pollution through the use of precise service for application of pesticide. From appendix 1, it was revealed that financially, drone usage for pesticide application had a high financial implication for farmers compared to the knapsack. This is consistent with Ajewole et al. (2016), NEPAD (2018), Godwin et al. (2003), Didier and Lucide (2008), and Rao et al. (2002), that the farmer crop yield potential is determined by the selection of inputs in the farming process, therefore input that optimises production and profit should be preferred and the cost-benefit of the input (spraying method) is dependent on the type of agriculture practiced.

Therefore, the null hypothesis of “There is no statistically significant difference between drone and knapsack application modes” was rejected, implying that there is a significant difference between knapsack and drone sprayed fields.

Enterprise analysis of experimental plots for the application of pesticides for the control of FAW

The results of the economic efficiency of experimental and control plots as displayed in Table 9, revealed that West Mamprusi (Drone-GH₵77. 23, Knapsack-GH₵69.42 and Control plot- GH₵51.02) had the highest cost of production per 0.0801acre among the three districts with Mion (Drone-GH₵53.42, Knapsack-GH₵53.42 and Control plot- GH₵50.22) being lowest. This was as a result of the high cost of land in the district. The average price of a bag of maize at the time of the study was GHC 100.00 across the various district. At the end of harvest, Tolon had the highest yield of three (3) bags (drone), two (2) bags (knapsack), two (2) bags (drone control plot), and two and half (2.5) bags (Knapsack control plot) per 0.0801acre, with Mion the lowest with less than half (0.3) bag (drone), half (0.5) bags (knapsack), less than one (0.6) bag (drone control plot) and less than half (0.2) bag (Knapsack control plot) per 0.0801acre. The reason for the low yield in Mion was due to poor agronomic practices of management. Therefore, the benefit to cost ratio for using both modes of the application shows that it is beneficial to use a drone for pesticide application than a knapsack. This is justified by the profit margin and the cost-benefit analysis as displayed in Table 9. This implies that the knapsack or drone method of pesticide application has its usefulness in controlling FAW at a given period. Maximizing yields and limiting the workload, thus the cost of production is vital to increasing productivity(Leung & Jenkins, 2013; Volkmann, 2017).

Also, in Table 9 it was revealed in West Mamprusi and Tolon that the knapsack control plot had high output than the drone control plot. This could be attributed to the level of drift from the knapsack plot during spraying and the height of the maize plant at the time of spraying (waist height). Table 9, also revealed that labor-revenue from drone use was greater in West Mmaprusi and Tolon compared to knapsack in the same districts. This could be attributed to the use of less labour and time spent using the drone.

The results of the enterprise analysis reflect the consumer theory, theory of planned behavior and UTAUT. These theories hold that the consumer (farmer) is a rational individual who will make the right decision given price and income. The behavioral intention through the theory of planned behavior and UTAUT them makes the farmer to form an acceptable attitude to accepting it. This shows that if the price of a technology is low and the farmer has a positive intention use, acceptance is achieved through willingness to pay.

Table 9: Enterprise Analysis of Experimental plots

	West Mamprusi				Tolon				Mion			
	Drone	Knapsack	DCP	KCP	Drone	Knapsack	DCP	KCP	Drone	Knapsack	DCP	KCP
TVC	61.21	53.40	35.00	35.00	41.17	38.76	35.56	35.56	39.01	35.80	32.60	32.60
TC	77.23	69.42	51.02	51.02	61.20	58.79	55.59	55.59	56.63	53.42	50.22	50.22
TR	300.00	200.00	100.00	150.00	300.00	200.00	200.00	250.00	30.00	50.00	60.00	20.00
PM	222.77	130.58	48.98	98.98	238.80	141.21	141.41	194.41	-26.63	-3.42	9.78	-30.22
GM	76.79	68.57	54.65	69.76	80.94	74.58	75.29	86.78	-75.42	6.44	25.60	-123.21
GM/Acre	958.74	856.04	25.60	870.96	1010.44	931.12	940.00	1083.45	-941.56	80.44	319.55	-123.21
TR/Labour	14.69	9.79	4.90	7.34	13.62	9.08	9.08	11.35	1.63	2.71	3.26	1.09
BCR	3.88	2.88	2.03	3.05	4.90	3.40	3.60	6.73	0.53	0.94	1.19	0.40
TR/Acre	3745.32	2496.88	1248.44	1872.66	3745.32	2496.88	2496.88	3121.10	374.53	702.25	749.06	249.69
TR/Acre/TC	48.50	35.97	25.35	38.03	61.20	42.47	44.91	83.97	6.61	13.14	14.91	4.97
TR/Acre/TVC	61.19	46.76	35.67	53.50	90.97	64.41	70.21	87.76	9.60	19.61	22.98	7.66

NB: DCP- Drone Control Plot KCP- Knapsack Control Plot TVC- Total Variable Cost TC- Total Cost TR- Total Revenue PM- Profit Margin GM- Gross Margin BCR-Benefit-Cost Ratio

Source: Omega (2019)

Farmers' Willingness to pay for Drone service for the Control of FAW

Maize farmers before asked about their willingness to pay for drone services were introduced to drone technology through a screen video and a field day. This was to make farmers similar to drone technology and how it worked. From, Table 10 it shows the district distribution of maize farmers' willingness to pay for drone services for pesticide application. It was revealed that maize farmers in Tolon (34.0%) were more willing to pay for drone services than the other districts. This implies that maize farmers in all three districts were willing to pay for drone service for pesticide application. The test of significant difference for the three districts revealed that there was no significant difference between the willingness to pay for drone service and not willing to pay across the district. This shows that the introduction of new technologies into the control of fall armyworm are likely to face difficulties in the face of existing methods. This is supported by Aubert, Schroeder and Grimaudo (2012) that farmers' willingness to pay for new service faces challenges from already existing services in their adoption.

Table 10: Summary table on maize farmers´ willingness to pay for application modes

	West Mamprusi		**Tolon**		**Mion**		**Sig**
	Freq	**%**	**Freq**	**%**	**Freq**	**%**	
Drone Service							.141
Willing to pay	45	30.0	51	34.0	48	32.0	
Not Willing to pay	2	1.33	4	2.67	0	0.0	
Total	**47**		**55**		**48**		

Source: Omega (2019), n= 152, *** represent significant at 5%.

From Table 11, it was revealed the amount maize farmers were willing to pay to obtain drone services. It was revealed that maize farmers in Tolon were more willing to pay a higher price compared to the two other districts. In Tolon, farmers were willing to pay as much as GH₵ 33.00-GH₵ 43.00 per acre for drone services. This could be due to the extent of FAW infestation in the areas and the urgency with which farmers want to control FAW. While farmers in West Mamprusi were willing to pay the minimum of GH₵ 0.00- GH₵10.00 per acre. Also, this could be due to competition from other methods of pesticide application and low income of maize farmers in the districts, hence, the need for new services to be affordable.

Table 11: Amount maize farmers are willing to pay for drone services

Maximum Amount (Acre)	**Tolon**			**Mion**			**West Mamprusi**		
(GH₵)	**F**	**%**	**mean**	**F**	**%**	**mean**	**F**	**%**	**Mean**
0.00-10.00	4	7.5	3.79	3	6.3	2.50	22	44.9	2.06
11.00-21.00	2	3.8		26	54.2		10	20.4	
22.00-32.00	17	30.9		15	31.3		10	20.4	
33.00-43.00	18	32.7		0	0.0		6	12.2	
44.00-54.00	8	15.1		4	8.3		1	2.0	
55.00-65.00	5	9.4		0	0.0		0	0.0	

Source: Omega (2019), n= 152

From Table 12, it was revealed the reason for the varied opinion by farmers on the minimum and maximum amount willing to pay per acre. It was revealed that farmers in Tolon were willing to pay a much higher price for drone services per acre because that's what they felt they could afford. Whiles, Mion, and West Mamprusi farmers said it's was due to limited resources available to them. This shows that maize farmers' resources to acquiring new technologies or services are not evenly distributed across the geographical locations in the northern part of the country. This is supported by Organisation for economic co-operation and development (OECD) (2001) and Gerpacio, Labios, Labios and Diangkinay (2004) that technology and services are not evenly distributed across communities due to factors like income constraints and changing demand of consumers. Therefore, farmers will prefer to reduce the cost of technology or services due to their limited resources.

Table 12: Reasons for the willingness to pay amount

Reason	Tolon		Mion		West Mamprusi	
	F	**%**	**F**	**%**	**F**	**%**
Effectiveness	**7**	13.2	9	18.8	6	12.2
Faster	4	7.5	8	16.7	12	24.5
Safe	2	3.6	4	8.3	2	4.1
Less Labourous	5	9.4	6	12.5	2	4.1
Limited Resource	16	30.2	20	41.7	24	49.0
That’s what I can afford	21	39.6	1	2.1	3	6.1
Total	**55**	**100.0**	**48**	**100.0**	**49**	**100.0**

Source: Omega (2019), n= 152

From Table 13, the binary logistic regression showed that the extent to which socioeconomic characteristics influence farmers' willingness to pay for drone services. The selection of socioeconomic characteristics for the analysis was based on literature in the area of willingness to pay. The model diagnostic test shows that the model was significant at 5% alpha value. This shows that the variables of the logistic regression are well fitted to the model. The model revealed that gender, access to input, access to information status in the household and contact with Extension agent were significant in influencing willingness to pay of maize farmers for drone services.

From Table 13, it was revealed that as female maize farmers prefer drone service, the log-odd of willingness to pay increased by 0.263. The general predictive power of gender on willingness to pay for drone service was -.251, which shows that gender predictive power is low. This agrees with Buzby et al. (1998) who also revealed that female's farmers were more willing to pay for new technologies than males. It was also evident from Table 13 that maize farmers who were heads of the household, were more likely to be willing to pay for drone service. This led to the log-odd of willingness to pay for drone services to increase by 2.563 with a predictive power of .177.

Again Table 13, revealed that when maize farmers have access to input, the log-odd of them being willing to pay for drone services increased by 2.472 with a positive low (.170) predictive power. Similarly. It was also revealed from the Table 13 that when farmers have access to information, the log-odds of them being willing to pay increased by .590 with a negative low predictive (-.099) power. The findings with regard to access to input and information in this study is consistent with Chai et al. (2020) that consumer willingness to pay for new technologies is influenced by access to input.

Lastly, from Table 13 as maize farmers get into contact with extension agents, the log-odd of being willing to pay for drone services increased by 1.188. Contact with extension agent predicted willingness to pay for drone service by .032, showing low predictive power. The findings of this study is consistent with Mersha (2018) and Mahieu et al. (2012) who also revealed that contact with extension agent was not significant to influencing farmers willingness to pay for new technologies.

The results on willingness to pay confirms the theory of UTAUT and theory of planned behavior which shows that socio-economic characteristics of the farmer influences his decision to pay for drone services or not. For a farmer to be willing to pay for a technology, the socio-economics characteristics in the form of social influencing factors and personal factors will influence the farmer decision to pay or not for drone services.

Table 13: Binary Logistic Regression for Willingness to pay for drone services

Variables	Odds ratio	dy/dx	Robust Std. Err.	Z	P>|Z|	[95% Conf. Interval]	
Gender	0.263**	-0.251	0.133	-2.650	0.008	0.098	0.707
Marital Status	1.314	0.051	0.279	1.280	0.199	0.866	1.994
Access to Credit	2.199	0.148	1.137	1.520	0.128	0.798	6.060
Access to Input	2.472**	0.170	0.932	2.400	0.016	1.180	5.175
Access to Information	0.590**	-0.099	0.118	-2.640	0.008	0.399	0.872
Status	2.563**	0.177	0.998	2.420	0.016	1.195	5.498
Control option	0.851	-0.030	0.092	-1.490	0.137	0.688	1.053
Farm size	1.345	0.056	0.938	0.420	0.671	0.343	5.275
Contact with Extension Agents	1.188**	0.032	0.087	2.350	0.019	1.029	1.371
Household size	0.985	-0.003	0.020	-0.780	0.438	0.947	1.024
Landholding	0.848	-0.031	0.285	-0.490	0.624	0.439	1.638
Age	1.381	0.061	0.422	1.060	0.290	0.759	2.515
Farming Experience	1.005	0.001	0.016	0.290	0.771	0.974	1.036
Education	1.356	0.057	0.470	0.880	0.379	0.688	2.675
Number of observation				152			
Wald Chi2(14)				29.70			
Prob> Chi2				.0008			
Log Pseudo Likelihood				-69.46			

Source: Omega (2019), n= 152, *** significant at 1%, ** at 5%. * at 10%.

H_0: Socioeconomic characteristic does not have a significant relationship with farmers' willing to pay for drone services in the control of fall armyworm

The result of the hypothesis testing obtained by comparing willingness to pay and socioeconomic characteristics revealed that some of the variables had a significant influence. Some variables with a strong significant influence on willingness to pay included; access to information, access to input, status in the household and contact with extension agents. Overall education, landholding, age, farming experience, household size, marital status, control option and farm size had no significant relationship with farmer's willingness to pay for drone services in maize farming activities in the study area. Since all the socioeconomic characteristic variables did not influence willingness to pay, the null hypothesis will be accepted. The findings agree with Alimi et al. (2016), Shin (2018), and Emukule, Ngigi and Guliye (2011) that although socioeconomic characteristics have a significant relationship with willingness to pay for services, some factors like education, income, and land size as in the case of Shin (2018) were not significant.

Factors that influence the acceptance of drone services for the control of FAW

From Table 14 below, the model looks at maize farmers' market acceptance of drone service and factors which influence their acceptance. The factors that influence their market acceptance were their socio-economic characteristics according to literature. Willingness to pay indicators were also added to find out their level of influence on the farmer's acceptance of drone service. The model diagnostic test shows that the model is significant. The independent variables made up with willingness to pay and socio-economic characteristics variable was well fitted in the model. However, the variability of the variables of the model was low (.341). The model shows that content, accessibility and status in the household were found to be significant in influencing the acceptance of drone services for the control of FAW.

From Table 14, it was revealed that if packages are added onto drone services, the log-odd of maize farmer's acceptance increased by 2.709. Access to content predicted acceptance by -.053. Which shows that farmers are attracted to new services like drone not solely by the services but packages in bedded in it. The result on content in this study is consistent with Barelka, Jeyaraj and Walinski (2013), who also revealed that end users (farmers) are more drawn to technologies that offer them add-on such as after services, and warrant because these packages are seen as a substitute for technology worthiness. Again, it was revealed in Table 14 that accessibility of drone services led to an increase in the log-odd of acceptance by 2.325 with a low predictive power of -.045. This implies that technology or services accessibility to end users (farmers) influence their acceptance. Silva and Dias (2007) also reported that accessibility of a service is crucial to influencing acceptance of that services. Lastly, maize farmers who were head of household had the log-odd of them accepting drone service increase by .293 with a low predictive power of .065. This is consistent with Brown and Venkatesh (2005) who reported that the decision of the head of the household influence the tendency of that particular household accepting a technology (service).

The results of the study under the factors influencing acceptance as depicted in the conceptual framework is evident as the UTAUT revealed that the acceptance decision of a farmer is influence by socioeconomic characteristics of the farmer and the willingness to pay of the farmer. The socioeconomic characteristics of the farmer and the willingness to pay lead to a change in the attitude of the farmer given positive social influence and facilitating conditions which ends up influencing the acceptance decision of a farmer.

Table 14: Factors influencing farmers´ acceptance of drone services

market1	Odds Ratio	dy/dx	Std. Err.	z	P>z	[95% Conf. Interval]	
Farm size	.458	.042	.260	-1.380	.169	.150	1.393
Income source	1.181	-.009	.298	.660	.509	.721	1.936
Status	.293**	.065	.125	-2.880	.004	.127	.676
Household size	.992	.000	.021	-.390	.698	.953	1.033
Reliability	1.453	-.020	.632	.860	.390	.620	3.407
Content	2.707**	-.053	1.193	2.260	.024	1.141	6.420
Cost	.839	.009	.351	-.420	.675	.370	1.905
Accessibility	2.325**	-.045	.662	2.960	.003	1.330	4.063
Responsiveness	1.416	-.018	.736	.670	.503	.511	3.922
Primary occupation	.672	.021	.514	-.520	.603	.150	3.005
Access to information	1.129	-.006	.233	.590	.557	.754	1.690
Access to input	.764	.014	.298	-.690	.489	.356	1.639
Access to credit	.935	.004	.186	-.340	.736	.633	1.381
Marital status	.910	.005	.194	-.440	.657	.599	1.381
Level of education	1.149	-.007	.467	.340	.733	.518	2.548
Contact with AEA	1.869	-.033	.747	1.560	.118	.853	4.091
Farming experience	1.117	-.006	.235	.530	.598	.740	1.687
Control option	.910	.005	.156	-.550	.581	.649	1.274
Age	.684	.020	.190	-1.370	.170	.397	1.177
Number of observation	152						
LR Chi2(19)	77.70						
Prob> Chi2	.000						
Log Pseudo Likelihood	-75.14						
Pseudo R2	.341						
/cut2	3.410		5.30			-6.98	13.80

Source: Omega (2019), n= 152, * significant at 1%, ** significant at 5%, *significant 10%.**

H_0: Socioeconomic characteristic does not influence farmers' acceptance of drone services in the control of FAW

From Table 14, revealed that not all socio-economic characteristics have significant relationship with farmer's acceptance. It was revealed that only status in the household was significant. Generally, all socioeconomic characteristics did not have a significant relationship on farmer's acceptance, hence the null hypothesis was accepted that "Socioeconomic characteristics do not influence farmers' market acceptance of drone services in the control of fall armyworm". This agrees with Ullah et al. (2018) and Kinyangi (2014).

H_0: Farmers' willingness to pay does not influence farmers' acceptance of drone services in the control of fall armyworm

From Table 14, it was revealed that out of the five willingness to pay variables used in the ordered logistic regression, only two (content and accessibility) were significant to influencing farmer's acceptance. Overall the null hypothesis of Farmers' willingness to pay does not influence farmers' acceptance of drone services in the control of fall armyworm was accepted.

Chapter Summary

This chapter presented the results and discussed the findings of the study. The chapter was introduced to reflect the content of the chapter. The socioeconomic characteristics of maize farmers' in the study areas were presented base on the various districts they belong to. The control measures adopted by farmers' were then presented as well as the results of the field experiment conducted. Enterprise analysis of the field experiment was displayed to show the input and returns farmers' were making. The last part of the chapter then looked at the willingness to pay and acceptance of farmers for drone services.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter presents the summary, conclusion and recommendations of the study. The summary and conclusion of the study were done based on the specific objectives. The chapter also presented a recommendation based on the conclusion in conformity with the specific objectives and also suggested further areas for research.

Summary

Overview of the Study

As the world population grows over time, the desire to increase food production has become more than just a necessity. This has informed the decision of agriculture experts and other stakeholders in the agriculture industry to think about improved and innovative ways to apply agriculture chemicals like pesticides. It is believed that more than 50% of agriculture losses are from the activities of pests and diseases. To apply pesticides effectively, time is important. As the application of pesticides at one point of the farm will mean the pest or disease feeding on unapplied areas. Therefore, there is the need to find a more time-efficient means of applying a pesticide to give the desired results at a time. This has led experts to come out with technologies such as drones for spraying pesticides. Its usage has not yet been popularized in Africa as compared to Europe, America, and parts of Asia. The use of drones in these places has shown drones to be environmentally friendly to human health and crops. However, it is deemed expensive relative to other traditional approaches of pesticide application. Research has shown that the challenge is mostly associated with the purchase and the starting period of its usage. A farmer who uses it is likely to gain more than twice the initial amount invested in the purchase or its services. This study was designed to determine whether maize farmers are willing to accept drone services as pest and disease like FAW infestation control measure over other traditional methods of control of the infestation, thus the following specific objectives were specified for the study; a) To describe the socio-economic characteristics of maize farmers in the districts, b) To examine preferred options by maize farmers for control of FAW in the districts, c) To assess and compare the total effect of the field usage of various spraying methods of pesticide, d) To assess and compare the economic efficiency of experimental plots for the application of pesticides for the control of FAW, e) To ascertain farmers' willingness to pay for drone services for the control of FAW and f) To determine factors that influence the acceptance of drone services for the control of FAW.

The study was conducted in the North-east region and the Northern region of Ghana. The areas selected are maize farming areas in the North-east and Northern regions of Ghana. The location was West Mamprusi district in the North-east region, whiles Tolon and Mion districts were taken for the Northern region. These areas were also among some of the most affected areas of the FAW invasion. The research employed a quantitative research approach and design through the use of a cross-sectional survey design. The target population was made up of maize farmers who lived in the above mention study areas. The research made use of a multi-stage sampling technique to obtain the desired sample of 152 respondents from the sample frame of 301 respondents. The research used a questionnaire as the data collection tool for the study with different sections of the questionnaire soliciting for response based on the specific objectives of the study. The data was analysed using analytical tools such as descriptive statistics, Friedman rank test, and the Wilcoxon sign rank test, enterprise analysis, binary logistic regression, and ordered logistic regression. The summary of the findings of the research are as follows;

Socio-Economic Characteristics of the Respondent

The study revealed that maize farmers in West Mamprusi (17-32(33.0%)) were relatively young compared to the other two districts. This was partly the reason for the farming experience of farmers being 1-15 years across all the three districts. Tolon results on gender (52.0%) deviated from the normal literature findings of male dominance as females formed the majority. Also, in Tolon it was observed that widowed (6.0%) were more likely to go into maize farming than single, although the majority of the respondents were married. FBO activities were more among maize farmers in Tolon (69.0%) that the other districts of the study. With the number of contact with extension with AEA, it was revealed that visit by AEA was low in all the three districts but fairly encouraging in Mion (Less than 3(63.0%)) and Tolon (Less than 3 (62.0%)) than West Mamprusi (Less than 3 (94.0%)). Results on access to the information revealed that maize farmers in Tolon (50.9%) had more access to information that the other districts.

Preferred Options by Farmers for Control of FAW

The majority of the farmers had controlled FAW in the past, using either agro-chemicals (synthetic pesticide), local mixtures, or bio-pesticides. It emerged that the farmers have not used much of IPM practices to control FAW in the past. Farmers in the study area showed a preference for synthetic pesticides as a means of controlling FAW, as against other options. Out of the total number of 301 respondents, it was revealed that the majority of them used synthetic control in their fight against FAW infestation. The results indicate that majority of the farmers prefer the synthetic control option (57.90%) while the rest preferred cultural control (28.30%), bio-pesticides(3.90%), biological (4.60%), Cocktail/mixtures (3.30%), and IPM (2.00%). A further test of rank using the Friedman rank test also revealed that farmers were more likely to use synthetic control measures compared to other alternatives control methods. The ranking was highly significant at a 5% alpha value. The Wilcoxon signed-rank test also revealed that at all times farmers will prefer the use of synthetic control for FAW infestation to others.

Total Perceived Effect of the field Application of Drone in Spraying of Pesticide

On the total effect of the field application of spraying methods of pesticide, the effect was divided into three namely the social effect, environmental effect, and economic or financial effect. The analysis was done on district bases. With social effect, it was revealed that the overall social effect of knapsack usage (S.D= 1.192) was higher compared to that of drone (SD= 1.216) and there was a significant difference between the social effect of using drone and knapsack as a means of spraying pesticide at the alpha value of 5%. It was observed that knapsack was risky to the health of the sprayer, it was also revealed that the difference in drone and knapsack in Tolon and Mion was statistically significant. Farmers also agreed that the use of drone spraying methods was consistent with the practice of controlling FAW in the study areas. Tolon and West Mamprusi showed a significant difference in drone and knapsack. It was also revealed that there was labour available to use knapsack and easy to operate a drone. However, Maize farmers reported that knapsack needed more energy to exert during application and there were support systems for the use of knapsack than a drone.

On the environmental effect, farmers in all three districts revealed that drones had a high effect on the environment and this was significantly different. The individual component of the results also shows that knapsack was more likely to lead to drift during spraying in all the districts. Whiles, spillage of pesticides during spraying was more likely from a Knapsack than a drone. The duration of time in pesticide application per plot also showed that drone was more likely to spray faster than knapsack. The knapsack was seen to be affected by weather than the drone for all the districts.

The Economic effect of using the two methods of spraying revealed that the overall financial effect of the drone had a financial implication for the farmer than a knapsack. The availability of the equipment showed that knapsack was available compared to a drone. The cost of service in pesticide applications revealed that it was much expensive to use a drone in all the districts. The result of the performance of the two methods revealed that the drone performed well than a knapsack. Lastly, on the amount of capital for the acquisition of equipment, it was revealed that farmers needed more capital to acquire drones compared to knapsack in all three districts.

Enterprise Analysis of Experimental Plots

The efficiency measure of the plots revealed that the Total variable cost varies in the maize production cycle from one location to the other. The fixed cost being land was GHc 16.02 for West Mamprusi, GHc 20.03 for Tolon, and GHc 17.62 for Mion. As the cost for the control plot was the same for the districts, whiles the cost associated with the drone was greater in all districts than a knapsack and the control plots. Per the demonstrational field, the drone plot had the highest returns followed by the knapsack and control plot. But in the case of Mion, the control plot of the drone outweighed that of the two treatment plot. This was attributed to poor agronomic practices. The results reveal that drones allowed labour to be more productive. Despite the cost associated with the drone plot being high, the benefit attached to its calculated in terms of the revenue margin is equally high. This implies that the cost of drone associated with maize production is compensated by the returns.

Farmers' Willingness to pay for Drone Services for the Control of FAW.

The findings on willingness to pay revealed that farmers in all the three district were willing to pay for drone services (West Mamprusi = 45, Tolon= 51 and Mion= 32) as against knapsack willingness to pay (West Mamprusi = 22, Tolon= 30 and Mion= 37). The maximum amount that farmers were willing to pay for drone services for the three districts was between GHc 33.00-43.00 for Tolon, GHc 11.00- GHc 21.00 for Mion, and GHc 11.00- GHc32.00 for West Mamprusi.

The result of the binary logistic regression of 13 variables of the socio-economic characteristics of maize farmers only 4 variables, thus, access to input, access to information, status in the household and contact with extension agents were statistically significant. The predictive powers of the significant variables access to input, access to information, status in the household and contact with extension agents were .170, -.099, .177 and .032 respectively. The test of the hypothesis between willingness to pay against socio-economic characteristics showed that there was no significant relationship between willingness to pay for drone and that of socio-economic characteristics of farmers.

Factors that Influence the Acceptance of Drone Services for the Control of FAW

Maize farmer's acceptance was analyzed using the ordered logistic regression. It revealed that the model was significant. The significant variables of the analysis was status of the farmers in the household, content of the drone package and accessibility of drone services. The results that status of the farmer in household was positively related to maize farmer's acceptance and predicted acceptance by .065. The content of drone service predicted acceptance by -.045, despite it increasing farmer's acceptance by 2.707. Also, accessibility of drone service was revealed to predict acceptance by -.045 with an associated log-odd of 2.325.

Conclusions

The findings of the study satisfy the objective and hypothesis of the study. Each objective was treated as an individual concept to the study and the interrelationship was analyzed through the hypothesis tested and concluded to establish the relationship that exists among the variables.

The socio-economic characteristics of the study were introduced into the study to find out the individual characteristics of farmers for the study. The study revealed that the various study areas (West Mamprusi, Tolon, and Mion) through descriptive statistics had high experience in maize farming and have witnessed the invasion of FAW on their farm. Farming was revealed as the main occupation of respondents and maize farming was dominated by the young aged. The trend of male dominance was inconsistent for all the study areas but formal education continues to be low for farmers in the study areas as the majority turn to marriage for labour on the farm. The majority of farmers are still small scale farmers with their only source of capital coming from farming.

The study also concluded that synthetic pesticide was the most used method by farmers in the control of the FAW infestation. Framers also acknowledge other methods of FAW control available to them. The least used method was that of IPM, despite, the high level of education on its usage. This is because farmers felt synthetic pesticide meet their FAW control needs.

It was concluded on total perceived effect that drone technology met the needs of farmers in the control of FAW. This showed that farmers were not satisfied with the use of knapsack sprayers as a means of pesticide application. However, drone technology also had some disadvantages according to farmers' for their farming activities. Drone technology was reported to be expensive in terms of purchase, service, and maintenance. The availability of support systems to help farmers with its usage was existing but the drone itself was unavailable.

The study further concluded that the claims by farmers that drone services were expensive were true through an enterprise analysis. It was concluded that the initial cost of an enterprise that uses a drone was more likely to incur more cost. However, the returns associated with drone service were reported to outweigh that of the other control method. Indicating that it is expensive to use the drone as a method of pesticide application but the return associated with its use was worth its purchase.

It was also concluded from the research that maize farmers in all the study areas were willing to pay for drone services but were also limited by resources. This indicates that farmers have the desire for drone services due to the performance and efficiency offered them. On the determinant of willingness to pay, it was revealed that farmer access to input, access to information, status in the household and contact with extension agents influenced willingness to pay positively by the log-odd of 2.472, .590, 2.563 and 1.188 respectively.

Lastly, it was also concluded that a farmer’s decision to accept drone service is influenced by status in the household, content of drone services and accessibility of drone services. Status in the household was found to increase log-odd of acceptance by .293 while content of drone service and accessibility of drone services increased by 2.707 and 2.325 respectively.

Recommendations

Based on the results of the study, it is recommended that:

Firstly, the Ministry of Food and Agriculture, Center for Scientific and Industrial Research, Environmental Protection Agency, and Non-governmental Organisations in agriculture should eduacte maize farmers in the Northern and North-east Regions on the need to use other alternative control methods like integrated pest management practices to control FAW rather than the use of synthetic control method which sometimes has residue effect on consumers. This will both ensure the protection of the farmer, consumers, and also the environment.

Secondly, drone technology companies like Drone hub Ghana Limited, Aglon IT and Aero Data Drone services, and Acquahmeyer Drone Technology Limited in collaboration with the Ministry of Food and Agriculture, Center for Scientific and Industrial Research, and Environmental Protection Agency should conduct more research into the effect of the drone as a method of pesticide application in agriculture in the Northern and North-east Regions. This will help to improve the performance of the current drone's services available to farmers in the Northern and North-east Regions. Also, MoFA should educate maize farmers on the use of drones and its importance to their farming activities.

Thirdly, the Ministry of Food and Agriculture and Non-governmental Organisations into agriculture should encourage maize farmers in the Northern and North-east Regions to form co-operative societies by providing motivational packages to farmers who are willing to join such groups. This will allow them to put resources together to achieve benefits that come from alternative technology like a drone at a lesser cost since the returns from such technologies are greater than the initial cost involved.

Fourthly, with maize farmers being willing to pay for drone services in the Northern and North-east Regions, there is the need for MoFA, Ministry of communication, NGOs, and other government agencies into agriculture to promote and create awareness in other farming areas of the country to also realize the benefits drone technology can offer them.

Fifthly, the government should have a clear cut policy on the usage of drones in agriculture and also subsidy the price of drone services for maize farmers in the Northern and North-east Regions (drone companies should charge around Tolon- GH₵ 22.00-32.00, Mion and West Mamprusi- GH₵11.00-21.00) and its related services to make it affordable to farmers to patronize it.

Sixthly, drone companies like Drone hub Ghana Limited, Aglon IT and Aero Data Drone services, and Acquahmeyer Drone Technology Limited should develop strategies like offering after service package, consultation services and discount to attract heads of households to purchase drone services. Since the income spending decision in the Northern and North-east Regions depends mostly on the family head.

Also, drone companies like Drone hub Ghana Limited, Aglon IT and Aero Data Drone services, and Acquahmeyer Drone Technology Limited should make drone services accessible to famers in all maize farmers in the Northern and North-east Regions to increase their acceptance of drone services.

Lastly, MoFA and NGOs related to agricultural activities should support maize farmers in the Northern and North-east Regions with credit to be able to purchase basic input for maize farming.

Suggestions for Future Research

The research paid attention to a few areas of drone technology like the effect, the economic efficiency, willingness to pay, and market acceptance by farmers in the northern part of Ghana. Owing to this reason future studies should endeavor to extend the research to other parts of the country like the middle belt and southern belt to find out if the result will be the same as the northern belt. Further studies could also pay attention to the various design of the drone used and how the design can also impact the performance of the drone.

The research also considered only one crop (maize) and only FAW at the expense of other crops grown in Ghana and pests that attacks them. Studies should be done to ascertain the efficiency of drone given other crop varieties and different pests that attacks them.

Lastly, the estimation methods used like logistic regression, descriptive statistics and enterprise analysis for this study, this can be improved upon by using other estimation methods.

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APPENDICES

APPENDIX A

Total Effect of the field application of spraying methods of pesticide

	Districts							
	Tolon		**Mion**		**West Mamprusi**		**Overall/ Total**	
Effects	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Social Effect								
Effect of weight of the equipment on the sprayer								
Drone	2.588	2.418	2.898	2.266	3.391	2.463	5.551	1.216
Knapsack	8.314	1.568	8.755	1.762	7.826	2.153	6.099	1.192
χ^2	.000***		.001***		.001***		.001***	
Riskiness (safety) to the health of the sprayer								
Drone	2.490	2.378	3.694	2.952	3.804	2.964		
Knapsack	8.216	2.157	7.816	2.811	8.261	1.555		
χ^2	.000***		.000***		.116			
Availability of labour to use the technology								
Drone	3.628	3.194	2.612	1.998	4.370	2.653		
Knapsack	6.490	3.126	8.041	2.500	7.000	2.675		
χ^2	.002***		.000***		.000***			
Consistency with practice of control of FAW								

Drone	7.922	2.959	8.286	2.010	7.826	2.425
Knapsack	4.471	3.145	5.367	2.949	5.783	2.898
χ^2	.000***		.230		.020***	
Ease of use of the equipment						
Drone	8.392	2.654	8.286	2.723	8.283	2.596
Knapsack	3.608	2.079	4.143	2.654	3.957	2.065
χ^2	.190		.039***		.020***	
Flexibility in the manipulation of the equipment						
Drone	8.157	2.656	7.469	3.000	7.761	2.378
Knapsack	4.137	2.779	4.694	2.434	4.413	2.146
χ^2	.029***		.199		.116	
Bulkiness of the equipment						
Drone	3.294	2.886	4.776	2.988	6.391	2.560
Knapsack	6.980	3.050	7.408	3.027	5.044	2.624
χ^2	.000***		.027***		.052**	
Reliability of the equipment						
Drone	7.196	3.188	6.694	3.124	7.500	2.519
Knapsack	4.647	2.777	5.020	2.735	4.957	2.494
χ^2	.000***		.013***		.002***	
Knowledge operating the equipment						
Drone	5.255	3.328	5.674	3.436	6.674	2.860
Knapsack	5.118	3.147	5.163	3.255	5.087	2.731

χ^2	.000***		.006***		.508	
Skills needed to use						
Drone	5.784	3.396	6.122	3.569	6.913	2.958
Knapsack	4.706	3.208	4.878	3.225	4.478	2.198
χ^2	.002***		.000***		.504	
Exertion of energy in the process of application						
Drone	2.784	2.283	2.694	1.828	3.783	2.764
Knapsack	8.431	1.836	9.143	1.768	8.326	1.967
χ^2	.003***		.000***		.028***	
Consistency with the needs of farmers to control FAW						
Drone	7.451	3.221	8.204	2.081	7.544	2.647
Knapsack	5.313	3.102	5.163	3.064	5.630	2.695
χ^2	.000***		.012***		.015***	
Availability of support systems to use the, technology						
Drone	3.667	2.847	2.388	1.382	4.391	2.687
Knapsack	6.275	3.200	8.102	2.584	6.696	3.010
χ^2	.000***		.297		.049***	

Environmental Effect								
Duration of time in pesticides application per plot								
Drone	4.118	3.064	3.776	2.939	5.217	3.313	4.2123	1.902
Knapsack	7.843	2.618	7.571	3.069	7.522	2.648	6.679	1.512
χ^2	.137		.059**		.023***		.020***	
Spillage of pesticides during spraying								
Drone	3.314	2.895	2.306	1.805	4.087	2.920		
Knapsack	7.137	2.030	8.490	1.959	7.217	2.289		
χ^2	.002***		.000***		.005***			
Quantity of pesticides used								
Drone	4.118	2.957	3.388	2.396	4.674	3.080		
Knapsack	6.412	2.570	7.327	2.340	6.304	2.674		
χ^2	.000***		.000***		.002***			
Drift (missing of targeted plants) during application								
Drone	3.647	3.019	3.571	2.901	4.522	3.325		
Knapsack	6.196	2.592	7.163	2.889	6.283	2.491		
χ^2	.000***		.018***		.224			
Effect of weather on the use of the equipment (wind & rain)								
Drone	4.765	3.374	4.551	3.195	5.587	2.956		
Knapsack	6.098	2.587	6.204	3.102	5.152	2.440		
χ^2	.000***		.385		.001***			

Landscape/terrain of the fields								
Drone	4.882	2.984	4.306	3.170	5.261	2.471		
Knapsack	5.392	2.913	6.225	3.016	5.609	2.463		
χ^2	.001***		.001***		.024***			
Economic/Financial Effect								
Availability of the equipment								
Drone	1.980	1.985	2.265	1.729	3.826	2.767	6.495	1.429
Knapsack	8.980	1.643	9.061	1.897	7.630	2.645	5.371	1.298
χ^2	.000***		.001***		.000***		.000***	
Cost of service in pesticides application								
Drone	6.255	3.249	6.367	2.949	8.022	2.071		
Knapsack	5.157	2.942	4.813	2.958	4.935	2.736		
χ^2	.000***		.034***		.383			
Performance of the equipment								
Drone	8.373	2.366	8.163	2.726	8.674	1.674		
Knapsack	3.667	2.197	4.653	2.454	4.609	2.275		
χ^2	.000***		.132		.714			
Amount of capital for acquisition of equipment								
Drone	7.980	2.956	8.429	2.102	8.000	2.160		
Knapsack	3.020	2.195	4.082	3.220	3.804	2.227		
χ^2	.005***		.107		.000***			

Cost of maintenance						
Drone	6.726	2.899	5.918	2.668	7.000	2.741
Knapsack	5.000	2.742	5.306	2.679	4.109	2.253
χ^2	.000***		.004***		.002***	
Efficiency of the equipment						
Drone	8.118	2.747	8.449	2.381	8.978	1.064
Knapsack	3.726	2.155	4.714	2.574	4.326	2.098
χ^2	.000***		.010***		.520	
Affordability of the technology						
Drone	3.431	2.737	4.469	3.076	5.348	2.885
Knapsack	7.647	2.848	7.020	3.351	6.457	2.771
χ^2	.003***		.013***		.117	

Source: Omega (2019), n = 152, Composite Mean (Knapsack= 5.993, Drone = 5.419) S.D (Knapsack= 1.145, Drone = 1.313) χ^2 = .226, *** represent significant at 5%, ** represent significant at 10

APPENDIX B
Experimental Plot Information

	West Mamprusi			Mion			Tolon		
	Drone	knapsack	Control plot	Drone	knapsack	Control plot	Drone	knapsack	Control plot
Time spent in spraying	55sec	8m 9sec	0	1m 18sec	9m	0	55 sec	8m 6sec	0
Maize planted per plot	60*22 rows	60*22 rows	60*22 rows	60*22 rows	60*22 rows	60*22 rows	60*22 rows	60*22 rows	60*22 rows
Plot size	.0801	.0801	.0801	.0801	.0801	.0801	.0801	.0801	.0801
infestation rate	17%	17%	16%	16%	17%	17%	18%	17%	17%
Water	3 litres	3 litres	0	3 litres	3 litres	0	3 litres	3 litres	0
Chemical volume	10ml	10ml	0	10ml	10ml	0	10ml	10ml	0

Source: Omega (2019), n = 152

APPENDIX C

UNIVERSITY OF CAPE COAST
DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION

MAIZE FARMERS ACCEPTANCE AND WILLINGNESS TO PAY FOR DRONE SERVICES FOR THE CONTROL OF FALL ARMYWORM IN NORTHERN GHANA

This study is designed to assess the market acceptance and willingness to pay for drone technology in the application of pesticide for the control of fall Army Worm (FAW) in the northern part of Ghana. You have been identified as individual to provide information to achieve the objectives of the study. The interaction session is expected to last for about 45 minutes. Please respond frankly to the questions on this questionnaire/Interview Schedule. Be assured that all the information that will be provided will be used for the intended objectives and will be kept confidential. Your practical recommendations will be used to improve the control of FAW. Your name and phone number have been requested to assist us reach you again for follow up questions or field trip to observe fields where drone and knapsack had been used to apply pesticide.

Part 1: Socioeconomic characteristics of farmers in the study areas.

1. Name:____
2. Phone: ____
3. Region: Northern Region [ ] North East region [ ]
4. District: Tolon [ ] Mion [ ] West Mamprusi [ ]
5. Location of Farmer Nyankpala [ ] Kpalsogu [ ] Salanpkang [ ] Kplijine [ ]
   Dijo [ ] Kukua [ ] Loagri [ ]
6. Primary occupation of respondent __________________________________
7. Age at last birthday: _______ years
8. Sex of farmer: Male [ ] Female [ ]
9. Years of farming experience: ______ years

8a. Type and Level of education of farmer:
Non Formal Education [ ] Non formal, describe___________________
Formal Education [ ] No formal education [ ]

8b. If formal indicate the highest level:
Primary [ ] MSLC/JSS/JHS [ ] SSS/SHS [ ] Tertiary [ ]

9. Marital Status of farmers: Married [ ] Cohabitation [ ] Single [ ] Divorced [ ] Widowed [ ]
10. Do you belong to a farmer group/organization/association? Yes [ ] No [ ]
11. How many times do you contact extension agents during a planting ______________

12. What is your current land holding status? Own land [ ] Family land [ ] Leasing [ ] Renting [ ] Others, specify ______________________________
13. What is the size of your farm ______________________________ (Acres)
14. What is your source of income? Farming [ ] Trading [ ]Teaching [ ] Others, specify
15. Status in the household. Head [ ] Spouse [ ] Child [ ]
16. Household size ____________
17. Do you have access to credit? Yes [ ] No [ ]
18. Do you have access to input? Yes [ ] No [ ]
19. Do you have access to Agriculture information? Yes [ ] No [ ]

Part 2: Preferred pesticide options by farmers for control of FAW in the study areas.

20. Which of the following control measures is your preferred option for the control of FAW in your farm? Rank all the options from 1, 2, 3, 4, 5, etc. with 1 as most preferred control method and so on.

Control Options	Ranking
Cultural practices (Crop rotation, Use of planting dates, Crop refuse destruction etc)	
Synthetic pesticides control	
Bio-pesticides	
Biological control	
Cocktail of chemicals mixtures	
IPM	
Others (Specify)	

Part 3: Total effect of the field application of spraying methods of pesticide.

21. Compare the effects of the use of drone to knapsack sprayers in the application of pesticides to control fall army worm by indicating a number (1 – 10) for the following indicators.

1 - · -> 10
(Very low) (Very high)

Indicate 0 if you cannot tell.

Knapsack	Indicators	Drone technology
	Cost of service in pesticides application	
	Duration of time in pesticides application per plot	
	Exertion of energy in the process of application	
	Spillage of pesticides during spraying	
	Drift (missing of targeted plants) during application	
	Quantity of pesticides used	
	Cost of maintenance	

	Bulkiness of the equipment	
	Effect of weight of the equipment on the sprayer	
	Flexibility in the manipulation of the equipment	
	Ease of use of the equipment	
	Availability of the equipment	
	Reliability of the equipment	
	Skills needed to use	
	Knowledge operating the equipment	
	Affordability of the technology	
	Performance of the equipment	
	Efficiency of the equipment	
	Consistency with practice of control of FAW	
	Consistency with the needs of farmers to control FAW	
	Riskiness (safety) to the health of the sprayer	
	Effect of weather on the use of the equipment (wind & rain)	
	Amount of capital for acquisition of equipment	
	Availability of support systems to use the technology	
	Landscape/terrain of the fields	
	Availability of labour to use the technology	

Part 4: Willingness To Pay for Drone Technology for FAW control

22. What is your preferred method of pesticide application? Knapsack [ ] Drone [ ]
23. How much do pay for the method of pesticide application? GH¢ ……………
24. Will you be willing to pay more for the conventional method of pesticide application
    Yes [ ] No [ ]

24a. If yes, how much are you willing to pay for conventional application per acre? GH¢ …

25. Will you be willing to pay for drone technology for pesticide application?
    Yes [ ] No [ ]

25a. If yes, how much are you willing to pay for drone application per acre? GH¢ ……

26. What will be the maximum amount you will be willing to pay for drone application? GH¢ ……………

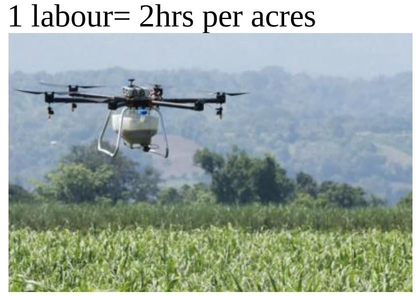
27. Why would you pay the said amount?

…………………………………………………………………………………
………………………………………………………..

Willingness to pay using choice Experiment

28. I will like you to imagine the following scenarios. A company is introducing drone technology in the application of pesticide for the control of fall army worm. We are going to show you a number of scenarios and all you have to do is to choose the one you would most prefer to purchase for your spraying activities. If you choose not to purchase any of the two options, you can opt out.

Packages:

	Knapsack sprayer	**Drone**	**Opt out**
Reliability (man-hours per acre)			
Option 1:	 1 labour = 8 hrs per acre	 1 labour =2hrs per acres	
Option 2:	 10 labour= 2hrs per acres	 1 labour= 2hrs per acres	
Option 3:	 20 labour= 1hr per acres	 1 labour =2hrs per acres	
Option 4:	 20 labour =1hr per acre	 2 labour = 0.5hrs per acre	

Cost (GHC)

Option 1:

Free= GH¢ 0

Free= GH¢ 0

Option 2:

GH¢ 10

GH¢ 20

Option 3:

GH¢ 20

GH¢ 15

Option 4:

GH¢ 25

GH¢ 30 + free maintenance

Accessibility (Renting and buying)

Option 1(Buy):

GH¢ 150 GH¢ 15000

Option 2 (Rent):

GH¢ 35 GH¢ 450

Option 3 (Free):

GH¢ 0 GH¢ 0

Option 4:

GH¢ 450 GH¢ 449

Content

Option 1:  

+free spraying | + free spraying + after services

Option 2:  

+ free spraying + after services | + free spraying

Option 3:  

No package | No package

Option 4:  

+ free spraying + after services | Refund of GH¢ 200

Responsiveness (Output per acres)

Option 1:  

GH¢ 1000 | GH¢ 1000

Option 2:  

GH¢ 2500 GH¢ 1000

Option 3:  

GH¢ 1000 GH¢ 2500

Option 4:  

GH¢ 1000 GH¢ 1001

Part 5: Acceptance of Drone Technology for the control of FAW in Northern Ghana

29. Please indicate the extent to which you are likely to accept drone technology for the control of FAW in your farm using the 10-point scale of 1 (very lowly) to 10 (very highly). 0 = not applicable/ can't tell

Perceived ease of use	**Extent**										
I understand drone usage for spraying pesticides and its clear to me	0	1	2	3	4	5	6	7	8	9	10
Drone is easy to use	0	1	2	3	4	5	6	7	8	9	10
The use of drone for the control of FAW is simple	0	1	2	3	4	5	6	7	8	9	10
Using drone technology will make control of FAW easier	0	1	2	3	4	5	6	7	8	9	10
Using drone improves effectiveness of FAW control	0	1	2	3	4	5	6	7	8	9	10
Drone technology is flexible in the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Drone technology is user friendly in the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
Drone technology for the control of FAW fits my pesticides spraying style.	0	1	2	3	4	5	6	7	8	9	10
Using drone technology for controlling FAW enables mistakes to be corrected quickly	0	1	2	3	4	5	6	7	8	9	10
I think I can use drone technology successfully every time to control FAW.	0	1	2	3	4	5	6	7	8	9	10
Perceived Usefulness	**Extent**										
Using drone technology to control FAW improves my performance in pest control	0	1	2	3	4	5	6	7	8	9	10
Using drone technology to control FAW will increase my yield	0	1	2	3	4	5	6	7	8	9	10
Using drone technology to control increases income	0	1	2	3	4	5	6	7	8	9	10
Using drone technology is useful in the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Using drone technology saves time in the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Perceptions of External Control (PEC)	**Extent**										
The right conditions has been created for the use of drone for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
I have the resources to use the drone for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Given the resources it takes to use the drone, it would be easy for me to use it for the control of FAW on my farm	0	1	2	3	4	5	6	7	8	9	10
The drone provide opportunity for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
The drone is compatible with the knapsack FAW control	0	1	2	3	4	5	6	7	8	9	10
Knowledge for using the drone is available	0	1	2	3	4	5	6	7	8	9	10
There is assistance for me to use drone technology to control FAW	0	1	2	3	4	5	6	7	8	9	10
Voluntariness (VOL)	**Extent**										

My use of the drone for the control of FAW will be voluntary	0	1	2	3	4	5	6	7	8	9	10
My AEAs will not force me to use the drone for FAW control	0	1	2	3	4	5	6	7	8	9	10
Using the drone is not compulsory for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Behavioural intention	**Extent**										
Assuming I have access to the drone, I intend to use it for the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
Given that I have access to the drone, I predict that I would use it for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
I plan to use the drone for the control of FAW in the next planting season.	0	1	2	3	4	5	6	7	8	9	10
Attitude	**Extent**										
Using drone technology for the control of FAW is good	0	1	2	3	4	5	6	7	8	9	10
Using drone technology for the control of FAW is favorable.	0	1	2	3	4	5	6	7	8	9	10
It is a positive influence for me to use drone technology for the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
Using drone technology for the control of FAW is valuable.	0	1	2	3	4	5	6	7	8	9	10
Using drone technology for the control of FAW is trendy	0	1	2	3	4	5	6	7	8	9	10
I have increase the occurrence of using drone technology for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Using drone technology for the control of FAW has enhance productivity	0	1	2	3	4	5	6	7	8	9	10
I love using drone technology for the control of FAW	0	1	2	3	4	5	6	7	8	9	10
Using drone technology provides me a multi-approach for the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
Social Influence	**Extent**										
People who influence my behaviour think that I should use drone technology for the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
People who are important to me think that I should use drone technology for the control of FAW.	0	1	2	3	4	5	6	7	8	9	10
The drone technology company has been helpful in the use of drone technology.	0	1	2	3	4	5	6	7	8	9	10
The AEAs will help me to access the drone for FAW control	0	1	2	3	4	5	6	7	8	9	10