UNIVERSITY OF HULL

STUDY OF NEW TECHNOLOGICAL IMPLICATIONS TO IMPROVE FOOD PRODUCTIVITY AND SECURITY IN GHANA: CASE INSIGHTS INTO THE USE OF DRONES IN COCOA FARMING

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by

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Declaration

As Samuel Boafo Afranie, I confirm that the research paper entitled ‘An analytical study of new technological implications to improve food productivity and security in Ghana – case insights into the use of drones in cocoa farming’ is submitted to achieve the Award of Doctor of Philosophy in Management at University of Hull Business School, and is my original work.

Place: University of Hull, Hull, United Kingdom

Date: 20/06/2022

Signature of the Supervisor **Signature of the student**

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Dedications

To my parents for their enormous support and believing in my ability, as well as encouraging me to complete my studies.

To my partner and children for their greatest support during the PhD journey and helping me with stress management.

To my sisters and brother, for their enormous contributions during the data collection process.

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Abstract

Since the early 1980's, in developed countries such as Japan and the United States of America, several technological applications have been used experimentally to boost food production and enhance farming practices, especially in areas which are not geographically accessible for traditional farming practices and machineries.

One such technology which has been extensively experimented with and deployed is the Unmanned Aerial Vehicle (UAV), which is an example of technological expertise pioneered by the military. Their growing adaptation in precision agriculture means that UAV have been used on farms in developed countries for crops grown on both small- and large land acreage for the purposes of identifying nutrient deficiencies, diseases, water and soil status, weeds, damage, and plant diagnostics.

The study focuses on the adaptation and implementation of UAV in Ghana's cocoa farming and the position of stakeholders in terms of their acceptance, as the country is currently the world's second largest producer and exporter of cocoa. The study applies Disruptive Innovation theory and stakeholder theory as a joint conceptual framework by which to examine how new and long-established farms create, sustain, and continuously introduce creative and novel technology in order to maximise food production while assessing stakeholders' attitudes and roles in the implementation of innovation.

Conducted in Nkawie in the Ashanti region of Ghana, the study adopts a qualitative approach, using semi-structured interviews to elicit and collate the views of stakeholders on the implementation of UAV in cocoa farming in Ghana, ultimately analysing the resulting by use of NVivo software. The findings show that traditional practices and superstitious beliefs, lack of credit facilities can impede the acceptance of new innovation.

The study identifies a comprehensive pool of stakeholders in the supply chain whose input significantly influences the implementation of UAV. Other key stakeholders maintained that limited support for local drone innovator community, access to funding, and corrupt practices hinder the implementation of this technology, although general awareness of its benefit to cocoa farming cannot be disputed. Despite the difficult conditions that arose during data collection due to COVID restrictions in the study area, 36 participant agreed to participate in the study through interviews. This study makes a specific contribution to the body of literature and policy framework on the drivers and barriers of UAV adoption and implementation in emerging economies such as Ghana in the cocoa farming industry.

Keywords: Precision agriculture, UAV, stakeholders, cocoa farming, Disruptive Innovation.

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List of abbreviation

Abbreviation	Meaning
AICAD	African Institute for Capacity Development
CMC	Cocoa Marketing Company
CDL	Common Data Link
SADC	Southern African Development Community
CRIG	Cocoa Research Institute of Ghana
CPC	Cocoa Processing Company
CHED	Cocoa Health and Extension Division
CSIR	Council for Scientific and Industrial Research
CSSV	Control Swollen Shoot Virus
EC	Extension Community
FAO	Food and Agriculture Organization
FAA	Federal Aviation Administration
FASDEP	Food and Agriculture Sector Development Policy
GDP	Gross Domestic Product
GCCSFA	Ghana Cocoa, Coffee, and Sheanut Farmers’ Association
GCAP	Ghana Commercial Agricultural Project
IITA	International Institute for Tropical Agriculture
IPM	Integrated Pest Management
ICM-FFS	Integrated Crop Management Farmer Field School
LARS	Low Altitude Remote Sensing
MoFA	Ministry of Food and Agriculture
NGO	Non-Governmental Organization
NDVI	Normalized Dimensionless Vegetation Index

NASA	National Aeronautics Space Administration
PLBC	Private Licensed Buying Company
PA	Precision Agriculture
QCCL	Quality Control Ltd
RF	Radio Frequency
RS	Remote Sensing
SMC	Sliding Mode Control
SME	Small and Medium-Sized Enterprise
SPU	Seed Production Unit
SRI	Stanford Research Institute
TCAS	Traffic Collision Avoidance System
UNICEF	United Nations Children’s Fund,
UAV	UAV
WHO	World Health Organization

Chapter 1 Introduction

1.1 Introduction

This study examines the implications of the use of UAV on farms in Ghana to maximise food production and increase food security, particularly in the cocoa production industry. The empirical investigation focuses on farmers in Ghana's Ashanti Region's Nkawie Cocoa District. This chapter presents the research context and existing literature on UAV in order to set the scene. The current research gaps, the study's conceptual framework, research aim, objectives and questions are also presented. This section includes a summary of the research techniques, the study's research contribution, and the full thesis structure.

1.2 Research background

Few African nations employ technological applications in agriculture to increase food production and/or food security, compared to their widespread usage in affluent nations (Mvumi and Stathers, 2015; Adenle et al., 2019). Food security is dependent on a physical and cost-effective approach to the provision of sufficient, secure, and nutritious food to sustainably meet the dietary needs and food preferences of a nation's people (Webb et al., 2006; Coates et al., 2006). Consequently, the accessibility, availability, and quality of the food produced in a nation are important aspects of food security.

Many academics, including Beveridge et al. (2013) and Wirsenius et al. (2010), have addressed the fundamental issue of the maximisation of food production. Many researchers, such as Mandujano et al. (2017), have demonstrated that the majority of developed nations, such as Japan and the United Kingdom, are currently employing new technological applications such as UAV also known as ‘drones’, to improve food security and production (Reger et al., 2020; Hovhannisyan et al., 2018).

Despite breakthroughs in food delivery systems and international agreements designed to decrease hunger, inadequate food production in the majority of African nations persists (FAO, 2018; Bjornlund et al., 2020). It is not a surprise that the vulnerability of the global food ecosystem is impacted by the increasing demand for food and its decreasing availability (Okoye and Oni, 2017). Clearly, climate change, traditional agricultural practices, population growth, land degradation, and urbanisation have also contributed to this development (Wheeler and Von Braun, 2013). Thus, the United Nations Intergovernmental Panel on Climate Change has warned that the world’s food supply is in extreme peril (FAO, 2018).

Even more disturbing is the fact that more than 100 million children under the age of five in developing countries suffer from childhood malnutrition, which resulted in 5.6 million deaths in 2016 alone (World Health Organization (WHO), 2016; UNICEF, 2018). Drammeh et al. (2019) and Wambogo et al. (2018) hold that Sub-Saharan Africa is the largest hunger block in the world, with 240 million people lacking sufficient food (Smith et al., 2017). The World Bank (2018) reported that approximately 11% of the world’s 7.42 billion population is impoverished, residing primarily in rural parts of Southern Asia and Sub-Saharan African nations, where 78% of the population relies heavily on agriculture for a living. According to the World Bank (2018), agricultural GDP growth is at least twice as effective as GDP growth in other sectors in facilitating the reduction of poverty.

The inadequate use of appropriate high-tech applications in agriculture to maximise output has widened the poverty and hunger divide from 2015 to the present day (Pearson, 2018). Undoubtedly, food production in developing and/or rising nations such as Ghana has not kept pace with population expansion (Killick, 2010; Tignor, 2020). Meanwhile Africa, including Ghana, witnessed a much faster population increase than any other major geographical region from 1950 to 2016, although the continent's per capita food output decreased by over 30% between 1980 and 2016 (Killick, 2010; Frelat et al., 2016). Additionally, feasibility studies by researchers such as Bhagwati and Panagariya (2013) demonstrate that, due to rapid population expansion in African nations such as Ghana, landholdings have continuously decreased in size, with 80% of the country's farms currently occupying less than two hectares (Nyantakyi-Frimpong, 2020; Chapoto et al., 2013).

Ironically, smallholder farmers, who produce more than 90% of Ghana's food, account for more than half of the nation's food insecure population (Kansanga et al., 2019). Given the substantial population growth projected for Ghana, from 21.54 million in 2005 to 50 million in 2050 (Black et al. 2008), and the fact that the country has one of the Africa's fastest-growing populations, the future does not bode well for the maximisation of food production in the country unless decision-makers adopt policies which can close the gap between food supply and demand (Diao et al., 2014).

Numerous projects, including the Food Africa Project and the African Emergency Food Production Facility (AFDB, 2022) have been established in recent years to promote and improve food production in Africa through the introduction and deployment of technological advancements on farms (McDonald et al., 2016).

On cashew farms in India, UAVs have been used to assess field gaps, water levels and irrigation problems, differences in the soil, the presence of pesticides, and the physical traits of these crops. High agricultural productivity has been achieved as a result of this, which gives farmers a more precise ground perspective of their fields (Chider and Ryley, 2015). The use of UAVs to monitor crops, such as cocoa plantations in the Republic of

Côte d'Ivoire, the world's largest cocoa producer, has shown that UAVs have a tremendous potential to record field data in a way that is easy, swift, and more affordable than traditional methods (Tsouros et al., 2019). In developed countries such as Japan and the Germany, UAV use in agriculture has recently increased dramatically (Chider and Ryley, 2015); hence, the purpose of this study is to examine the consequences of their use on farms in Ghana to maximise food production and/or food security. In most regions of Africa, the usage of UAV to boost agricultural production remains low, despite their widespread acceptance in industrialised nations (Muggeridge, 2017; Joshi et al., 2020; Doddamani et al., 2020).

1.3 Existing relevant research

Technological adoption such as that of UAV, has been the focus of current research into agricultural development and growth in Africa, particularly Ghana. The rate of adoption of UAV for agricultural growth has remained low in most of these countries, particularly in Ghana, due to concerns about its effective implementation, as the need for drones is becoming inevitable in African farming (Muggeridge, 2017; Hailu, 2022).

1.3.1 Adaptation of UAVs in agriculture

Climate change has a significant effect on food security. More than 815 million people are suffering from chronic hunger, of which 64% reside in Asia and Africa (Shah et al., 2008). According to a 2018 FAO report, global food production needs to increase by over 50% by 2050 to feed a world population of nine billion. However, resources such as new technological applications, land, and water are becoming increasingly scarce (Grafton et al., 2015). Food production is generally categorised as part of the agricultural sector, and is identified as constituting a significant proportion the GDP of the majority of developing countries' GDP and employment (Abor and Quarter, 2010; Enu, 2014; Banson et al., 2016). The agricultural sector has recently attracted great interest from economists interested studying its growth and development processes. The importance of considering this sector originated from Schultz's (1953) characterisation of the 'Food Problem'; the author explains that, until sufficient food is produced in a country, labour is trapped within agriculture and the process of modern development and growth cannot commence.

Studies indicate that productivity in agriculture is essential to the economic growth of sub-Saharan Africa (Eberhardt and Vollrath, 2018; Golan, 2010; McMillan et al., 2014). Jayne and Rashid (2013) contend that the implementation of modern technologies for agricultural productivity within sub-Saharan Africa remains low and inadequate compared to other continents and regions within the entire world (Kalantari et al., 2017).

One of the reasons behind the slow implementation of these innovative technologies, especially UAV, for agricultural productivity is the lack of sufficient support from sub-Saharan governments (FAO, 2018). Farmers remain at a disadvantage due to their failure to adopt and implement these new technological applications on their farms to improve productivity (Valuate et al., 2014; Muzangwa et al., 2017). It is clear from numerous studies (Naraka 2011; Masan and Miles 2004; Adekoya and Babaleye, 2009; Ali 2014; McDonald et al., 2015) that blame has previously been attributed to farms' locations, land tenure, security, lack of incentives, limited education, household income levels, socio-economic status, simplicity, and the usefulness of technology, as reasons for farmers' failure to adopt appropriate technological applications such as UAV to improve productivity. Further studies (Katungi et al., 2006; Rijn et al., 2012; Isham 2002; Abdulai and Huffman, 2014) include issues such as social learning, social networks, and sociological considerations for reluctance to engage with the technology adoption process.

1.3.2 Current implementation of UAV in agriculture

Agriculture is a sector in which UAV have been introduced effectively; they are progressively achieving extraordinary success (Maddikunta et al., 2021). UAV, otherwise referred to as ‘drones’, are typically associated with military applications (Weimar et al., 2014), although they also offer exciting potential improvements to the field of agriculture (Jeanneret and Rambaldi, 2016). An Unmanned Aerial Vehicle is essentially an aeroplane which can fly without a physical pilot, which is radio-controlled. Faical et al. (2014) report that Yamaha was the first company to produce the Yamaha RMAX unmanned helicopter, which was designed for spraying and crop monitoring. The Yamaha RMAX was created in 1990 for usage in Japanese rice paddies; it was equipped with a four-gallon payload for spraying a five-acre rice field. Currently, Yamaha RMAX machines are used as agricultural drones in Napa Valley, California, and Floridian wineries for outside airborne pesticide spraying (Olejnik et al., 2019).

Table 1.1 displays how widely these technologies have been adapted by various countries around the world.

Table 1-1 Technologies that have been adapted by various countries around the world

Types of technologies	Countries of use	Feasibility	Success rates
Ebee SQ – SenseFly	Switzerland France Australia Finland Canada Germany USA South Africa	Can cover hundreds of acres in a single flight for extremely efficient crop monitoring and analysis.	80%
Agras MG-1- DJI	China and Korea	4,000-6,000 m² in just ten minutes	99%
Lancaster – Precision Hawk	UK	4.35 mi (7 km)	60%
DJI T600 Inspire 1	China, France	Range of approximately 2km or 1.2 miles	60%

Source: Puri et al. (2017).

Various academics have developed different types and models of UAV for precision agriculture in order to increase productivity. In the current era, UAV have become widespread and are being utilised to improve food productivity on large-scale farms in developed countries such as United State and Japan. Their deployment rates are increasing compared to their implementation on farms in developing African countries (Negrete, 2017). It is evident from research studies (Fraser and Congalton, 2018; Mogili and Deepak, 2018) that developed countries, as illustrated in Table 1.1, are already using some forms of UAV in their precision agriculture (Qasim et al., 2017; Fraser and Congalton, 2018). Additionally, there is evidence to suggest that some studies have been conducted in this area, as shown in Table 1.2.

Table 1-2 Some collated past studies of models of UAV in agriculture

Types of UAV	**Countries of implementation**	**Studies by author/s**
Single rotor helicopter	China	(Xue et al., 2016; Huang et al., 2014; Huang, 2009)
Fixed wing	South American	(Mogili and Deepak, 2018; Herwitz et al., 2004; Herwitz et al., 2002)
Quadcopter	Germany	(Mogili and Deepak, 2018; Kwon et al., 2017; Cornett, 2013)
Hexacopter	South Africa	(Yallappa et al., 2017; Anthony et al., 2014; Primicerio et al., 2012)
Octocopter	China	(Qing et al., 2017; Bendig et al., 2012)

Source : El Hoummaidi et al. (2021).

In the majority of countries, the installation of technological applications such as UAV on farms is increasingly regarded as an essential route out of poverty (Kern, 2015). As an example, Negrete (2017) reports that the People's Republic of China employed NASA's solar-powered Pathfinder-Plus UAV to assess a coffee crop in 2016. The results provided farmers with precise area measurements of land usage in order to predict yields based on the precise area of a coffee plantation. The use of ground-based surveyors would have been enormously expensive and time-consuming because the property was located in a hilly area with limited road access. In the past, a heavyweight NASA solar-powered Pathfinder Plus was employed as a picture-gathering platform to depict a 3500-hectare coffee plantation in Hawaii (Herwitz et al., 2004). This method proved beneficial in comparison.

Existing research on the technical study of UAV in precision agriculture examines their application in agricultural activities such crop monitoring, insect spraying, and soil and field analysis (Primicerio et al., 2012). In 2014, Ebee SQ SenseFly UAV were used on vineyard operations in the Republic of South Africa to determine the efficacy of imaging in the evaluation of grape plant health before and after the administration of organic feed (Muraru et al., 2019; Primicerio et al., 2012). In this instance, mapping flights were carried out, after which nutrients were distributed using traditional techniques. Before and after the crops were sprayed with nutrients, high-resolution images of farms and vineyards were captured for mapping purposes. This information was shared between farmers, agronomists, and soil scientists; imaging revealed that treated rows outperformed untreated rows (Primicerio et al., 2012; Herwitz et al., 2004).

In addition, it is evident from the current practices of farms in countries such as the Philippines that the implementation of agricultural technologies such as UAV has increased food production (Reger et al., 2018). In the Philippines, for example, UAV are fitted with photogrammetric and navigation equipment with a ground resolution of up to three centimetres, and are programmed to detect details such as Normalized Difference Vegetation Index (NDVI), water stress, and nutrient deficiencies in crops (Muggeridge, 2017). UAV are also equipped with high-definition thermal cameras for tracking, inspecting, and remotely monitoring animals on farms.

Additionally, new research indicates that the use of UAV to spray pesticides onto fields in wealthy nations can enhance agricultural output (De Rango et al., 2017). It is documented that the spray system is installed unto the Unmanned Aerial Vehicle for the application of pesticides, which provides a platform for vector control. According to research (Boursianis et al., 2022; Hafsal, 2016; Faithful, 2021; Torres-Sánchez, 2015), large and robust UAV are required to spray vast areas, such as pesticide treatment in Asian rice fields (Negrete, 2016; Schueller, 2014). Nolan (2015) contends that the use of

UAV in spraying operations is increasing in industrialised nations due to its speed and precision in comparison to conventional approaches in Africa (Rotte, 2016). Soesilo and Rambaldi (2018) conclude that farmers spray pesticides using UAV as part of a control loop of an algorithm for their agricultural business; this is so indisputable that Kaiser et al. (2010) reaffirm that the installation of these vehicles has had various positive ramifications, thus can be considered to have played a significant role in the success of the 'Asian green revolution'.

Failure to embrace or engage with technological applications may result in social and economic stagnation, which potentially leads to destitution (Jain et al., 2009). Smith (2015) argues that, although UAV improve agricultural yields, as maintained by the proponents and technocrats who advocate this approach, they may have a positive short-term impact on some farming practices and yields, but in the long run, they significantly change the socio-cultural relationships between farmers, their environments, and their ability to understand the constraints on their capacity to develop their own autonomous solutions (Haula and Agbozo, 2020; Yonah et al., 2018). Current study of this issue fails to explore the potential influence of Disruptive Technologies on the economic model of small to medium-sized farms and the way in which UAV might be used to map Disruptive Processes to enhance food productivity in Ghana, notably cocoa cultivation.

1.4 Research gap

The frequency of publication of relevant articles in peer-reviewed journals on the use of UAV has increased successively between 2000 and 2022 (Ahmed et al., 2022).

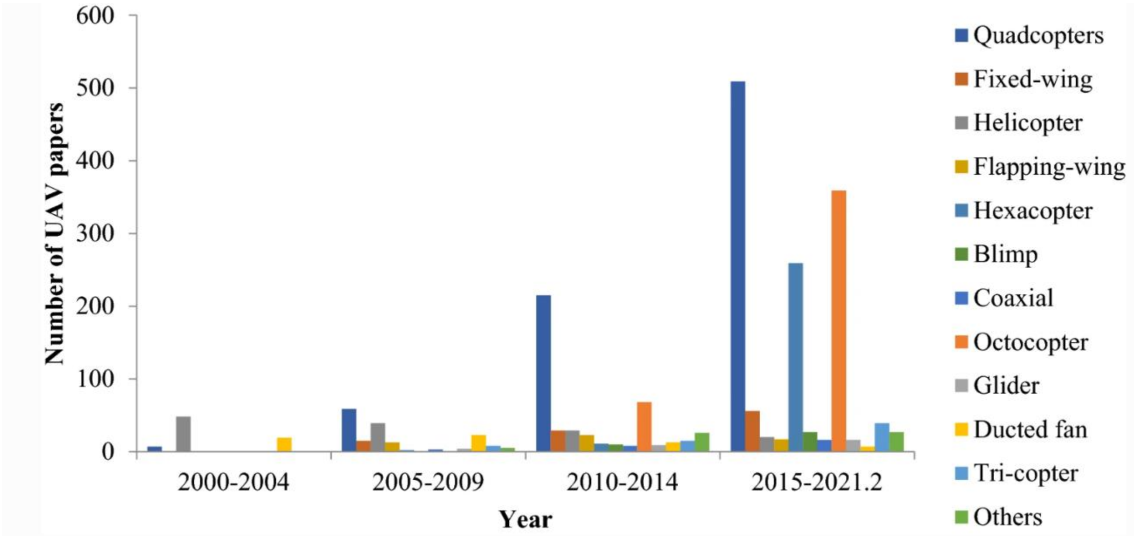


Figure 1.1 Research on drones or UAV reported in peer-reviewed journals from (Ahmed et al., 2022).

Figure 1.1 demonstrates that the number of papers published in leading research areas relating to the use of precise UAV between 2000 and 2022 has significantly increased.

In contrast to other fields like engineering, computer science, and robotics, the agricultural sector has seen increases in publication of less than 5%, and it also does not fall into the top ten categories, indicating the urgent need for research in this area given the significance of the use of technology in agriculture (Chabot, 2018). Research in this domain can be grouped into two areas, i.e.,, systematic literature reviews and pilot studies examining the missions of UAV. The majority of the pilot studies concentrate on the application of UAV on crops within a specific region; for example, the production of a preliminary assessment of UAV technology for precision agriculture focusing on the macadamia industry in Australia (Nolan, 2015). Nolan (2015) argues that remote sensing (RS) payload mounted on UAV is clearly the most common analysis in this context, used to explore or evaluate crop and/or soil conditions. This includes spatial and temporal patterns of soil properties, which utilises UAV' technologies in precision agriculture for the monitoring of crop pests and surveys to inform weed mapping.

Additional previous research studies have addressed the use of UAV for crop dusting and fertiliser application in agriculture (Soesilo and Rambaldi, 2018). Significantly, Tetteh Kwasi Nuer et al., (2018), Carlier and Desloovere (2018), and Muggeridge (2017) all identify the need for additional research into the potential use of UAV for non-crop-dusting missions, such as pest control, as elements of food productivity mechanisms. Clearly, the employment of technological applications such as UAV (UAVs) to increase food production is a new development, as indicated by the vast majority of literature evaluations. Globally, the majority of assessments in this sector focus on missions and surveys of specific types.

Notwithstanding the growing body of research on UAV, existing research identifies significant gaps in knowledge and understanding of the potential agricultural implications of this technology. It is not surprising that existing research focuses on remote sensing (RS; the procurement of data about an entity or phenomenon without making physical interaction), but only to a lesser extent on delivery and aerial application missions (Shrestha et al., 2021).

Significantly, existing research clearly indicates that this focus on UAV' applications is largely implemented in industrialised countries, primarily the United States, Australia, Japan, Israel and others, as illustrated in Appendix 1**.** Furthermore, this existing research typically focuses only on technical aspects of agricultural UAV technology, despite the fact that evidence suggests that they constitute only a small element of the potential obstacles to their implementation (Krishna, 2018). Rather, multiple factors, and their complex inter-relationships determine whether and how innovative technology applications such as UAV' technology will be implemented on farms to increase food productivity (Krishna, 2018).

There is limited discussion on how the unique characteristics of Africa, specifically Ghana, may benefit from the use of UAV for pest control on farms in order to increase production. There is also a clear knowledge gap to address in this area, as current research lacks in-depth analysis of how non-technical barriers and drivers of the implementation of UAV technology will benefit African farmers, more particularly the use of UAV for pest control, for example to control swollen shoot virus (CSSV) on cocoa farms in Ghana, in accordance with the propositions of Tetteh Kwasi Nuer et al., (2018).

Studies have also focused on its usage on large-scale or plantation-based agricultural activities including, but not limited to, dairy farming (McDonald et al., 2016), rice production (Chosa et al., 2010; Xiongkui et al., 2017), coffee cultivation (Marin et al., 2021; da Cunha et al., 2019) and cotton crop harvest (Meng et al., 2019; Xin et al., 2018). Apart from Tee et al., (2018) whose study shows a positive impact of UAV in cocoa production in Malaysia, there are limited or no studies on the implementation of UAV on cocoa production activities in Sub-Saharan Africa, specifically Ghana, which is currently the world's second-largest producer of cocoa (Bangmarigu and Qineti, 2018). This research study thus aims to conduct an analytical study of the implications of new technologies to improve food productivity and security in Ghana.

To begin to fill the gaps in existing research, this study, using the theoretical framework of Disruptive Innovation and stakeholder theory, proposes the use of technological application for agricultural use i.e., the deployment of UAV in response to Ghana's most pressing agricultural challenge, i.e., pest control in cocoa farming in order to maximise production, underpinned by the perception and roles played by stakeholders in its implementation. This research study investigates the implications of the implementation of UAV' technology in Ghana to maximise cocoa production in multiple ways, focusing on how this is likely to increase production output and alleviate hunger in the country. Underscoring this from a stakeholder position will identify the forces which come to play in the acceptance and implementation of Disruptive Innovation. The study identifies the drivers and barriers to implementation processes, suggesting steps that policymakers and the ecosystem's whole stakeholder community can take to overcome barriers and promote the implementation of UAV' technology in Ghana's cocoa sector, in order to increase production and farming practices.

1.5 Conceptual framework of the study

In view of the previous research, this study applies Disruptive Innovation and stakeholder theory to underscore how stakeholders' perceptions and roles influence the implementation of technologies such as UAV in cocoa farming at the location of study. To date, there are no studies in the African context or from emerging countries mapping processes which are disruptive and hence unsettle existing farming practices whilst considering the role of stakeholders in this collaborative process. Therefore, this study uses UAV as Disruptive Innovation to disrupt the exiting practices of farming activities in the study area (Raynor, 2011) and stakeholder theory (Freeman, 1984) as a conceptual framework to examine how stakeholders perceive precision farming and the critical role they play in influencing decisions about whether or not to implement UAV for food optimization and the improvement of farm management and practices.

1.6 Research aims and objectives

The purpose of this study is to evaluate how the use of UAV can increase food production and agricultural practices in Ghana. Due to its numerous characteristics, this technology is being promoted as a suitable platform for data collection on the health status of agricultural plots and individual crops, among other benefits. This information can then be used to target and control pests, manage diseases, boost food output, and deliver production supplies precisely and on time to the locations in which they are most needed.

This study's single purpose is to examine a new technological application, specifically the adoption of UAV' technology in agriculture to increase food output, notably cocoa growing in the Nkawie District of Ghana.

Therefore, this research is governed by the following four primary objectives:

1. **To critically evaluate the use of UAV as a Disruptive Innovation phenomenon and the impact of their use on farm efficiency in the Nkawie Cocoa farming sector (i.e., optimizing/improving productivity and farming practices).**
2. **To theorise key actors' roles, knowledge and awareness of UAV through the conceptual lens of stakeholder theory and Disruptive Innovation**
3. **To identify potential barriers and opportunities within the context of the implementation of UAV in cocoa farming and their impact on farm management practices in the Nkawie Cocoa farming sector**
4. **To present practical recommendations and a feasible framework for the maximization of productivity through the implementation of UAV.**

1.7 Research questions

Taking into consideration the knowledge gap and research objectives, the principal research question of this study focuses on cocoa farming in Ghana, investigating how the use of UAV' applications can improve productivity and farming practices and management.

The research addresses the following sub-questions:

Question 1:

A. *How can UAV add value to cocoa farming production?*

Question 2:

A. *Who are the stakeholders in the value chain with the capacity to influence the implementation of UAV for cocoa farming in the Nkawie Cocoa District?*

Question 3:

A. *What key drivers and barriers are likely to promote or hinder the implementation of UAV for cocoa farming in Nkawie Cocoa District?*

Question 4:

A. *How can a policy framework offer support for the implementation of technology to improve productivity in the cocoa farming sector?*
B. *How critical are stakeholder relationships relevant to the implementation of technology, specifically UAV for cocoa farming?*

1.8 Methodology

To answer these questions, the study employs a qualitative methodology, utilising in-depth, semi-structured interviews with key stakeholders such as the Ghana Farmers' Association and smallholder farmers in Ghana. Broadly, the sample comprised individuals from the Agricultural Ministerial Department, Ghana's Farmer's Association, and engineering departments, because they are the ones most likely to possess the necessary expertise. Data were analysed using NVIVO software application. This is a software solely built for qualitative analysis.

Eriksson and Kovalainen (2015) argue that the qualitative research approach is generally used to assess the behaviours of customers or stakeholders in a given setting, whereas the quantitative approach is more appropriate for the measurement of phenomena which can be described or quantified in precise amounts. Because the purpose of this study is to investigate the influence of technological interventions such as UAV on food productivity in Ghana from the perspective of many actor groups, a qualitative methodology is applied.

Supplementary sources, such as policy papers, publications, media reports, journals, and documents are utilised in order to triangulate data.

1.9 Research contribution

The study explores the implementation of UAV on cocoa farms in the Ashanti Region of Ghana; it provide an original contribution in an important way in that it proposes the use of Unmanned Aerial Vehicle technologies in an untapped area, i.e., farming in Ghana, to maximise production and food security on cocoa farms. The inclusion of stakeholders' perceptions and roles will be integral for policy formulation while also providing evidence for further academic research on the strategic roles played by stakeholders in the implementation of new Disruptive Innovation in cocoa farming. The results obtained from the analysed interviews will contribute to the extant literature which is currently deficient in the matter of Disruptive Technology in cocoa farming management and practices.

This research is likely to enhance current practices of farm management on cocoa farms to increase productivity, as it is clear from current studies that farmers operating on these farms continue to use traditional methods of farming which decrease the level of productivity and effective farm management practices. In addition, this study reviews current policy on the adaptation of UAV for agricultural use, particularly in cocoa farming; it offers potential management guidelines on the implementation of UAV in this area to encourage the development of a coordinated and holistic government support package for cocoa farming. The study's findings contribute to steps that policymakers can take to overcome obstacles to the successful and effective implementation of the application of UAV to increase cocoa production.

1.10 Thesis structure

This research comprises seven parts, representing a seven-chapter study.

Chapter 1 is the introduction to the research topic. This chapter's sub-topics include explanation of the study's significance and the existing relevant research on the implementation of the UAV in agriculture in various countries. The knowledge gap is then established from the existing research; through this, four objective research areas are outlined. Chapter 1 elaborates on the background of UAV and their purposes in agriculture, providing background information on UAV' technology both in general terms, and as new technological agricultural applications. The main purposes of this technology in farming practice are also discussed in this chapter. The benefits and disadvantages of the use of UAV in various agricultural practices are also considered.

Chapter 2 is one of the most important elements of this entire research study; it provides a complete foundation and understanding of prior research on the field of enquiry, which helps to answer the research question. This chapter examines relevant published literature, identifying knowledge gaps in the matter of UAV in agriculture. Specifically, the use of Unmanned Vehicles for surveillance is investigated, considering their usage as sensors for the early detection of crops and soil stress situations; their use for the aerial delivery of pesticide and fertiliser to increase food production is also discussed. In addition, this chapter investigates how UAV can collect timely and reliable agricultural data to boost food production and/or food security.

Chapter 3 discusses the theories adopted in the conduct of this research; recent studies show that Disruptive Innovation is emerging as strategically essential in practice in all areas of extractive and manufacturing industry (Spanaki et al., 2021). The chapter elaborates on how the use of UAV technology will disrupt existing farming practices in Ghana and secure improved sector development.

Chapter 4 discussed the methodology of the study, with an introduction to the methods used in the research process. This chapter also address the ways in which UAV technology is likely to increase food production in Ghana; it elaborates on the methods used in the assessment to achieve the study's results. The methodology chapter elicits others' views and attitudes on how UAV can be operated on farms in Ghana by use of in-depth interviews conducted with farmers and other associated agencies and stakeholders.

Chapter 5 considers in detail the content of the interviews and the research findings against the research objectives and research questions, exploring the attitudes of farmers towards the implementation of UAV in cocoa farming.

Chapter 6 identifies and summarises the stakeholders involved in the cocoa supply and value chain in the place of study. This section also details their perceptions of UAV in cocoa farming and other forms of agriculture and farming practices while explaining the roles they play in the implementation of this technology for cocoa farming in the Nkawie Cocoa District.

Chapter 7 provides a summary of the study’s findings and answers to the topics covered in the preceding chapters; it addresses field research and information provided by farmers in the Nkawie Cocoa District of Ghana, in addition to interviews with other stakeholders including government officials, NGO staff, and additional farmers. This chapter examines the technological, economic, political, and cultural factors which are likely to influence the introduction of UAV in Ghana to improve agricultural production and food security.

Additionally, both the theoretical and practical ramifications of their technical application are discussed; relevant contributions to the entire research study are discussed in Chapter 7. Various limitations encountered during the research process are also discussed, after which the study presents recommendations such as steps that policymakers can take to overcome obstacles to the successful implementation of the UAV’ applications on farms in Ghana in order to increase food production or food security.

Chapter 2 Literature Review

2.1 Introduction

This chapter reviews the literature which underpins innovation and technological advances in the domain of agriculture and food production. The review of pertinent literatures involves using keywords searches on databases like Google Scholar and Science Direct to identified relevant articles on topics like "UAV," "Agriculture UAVs," "Precision Agriculture," and "cocoa production in Ghana”. This chapter comprises thirteen sections, of which the second considers the justification of cocoa plantation in Ghana. Third sections explain the concept of adopting a new technological application which, in the context of this study, is UAV. Sections four and five discuss in detail the cost benefit paradox of the acquisition of UAV and it use as a new technology.

Section six considers the use of UAVs in agriculture and section seven discuss the key challenges and benefits using Remote System (RS) in developed and emerging economies, also highlighting the reality of the challenges in agriculture in Ghana. Section eight discuss the use UAV in sustainable agriculture. The prospect UAVs and its current issues are also discussed in section nine. Section ten considers the data link challenges associated with the deployment of UAV and their impact on the farming experience. Section eleven discusses the way in which non-technological drivers and barriers may promote or hinder the implementation processes of the UAV’ applications in farms in Ghana. Also included is assessment of the innovative capacity of the agricultural sector, i.e., examining whether Ghana has a forward-looking innovative orientation and the necessary capacity to support the implementation of UAV applications. An analysis of whether Ghanaian farmers are technically literate to effectively implement UAV applications on their farms in order to increase food production or food security is further presented. Section twelve identified gaps within the literature and section thirteen as the final part, summarises the literature review chapter.

2.2 Plantation of cocoa in Ghana

Cocoa is the world's third most valuable agricultural export commodity, behind coffee and sugar, and is a significant source of foreign revenue for nations such as Côte d'Ivoire and Ghana which dominate production. Despite its Amazonian origins, cocoa is the most important agricultural commodity crop in West African lowland forests, where some 60% of the world's cocoa is produced (Rice and Greenberg, 2000).

Historically and up to the present day, the continent of Africa is undeniably the highest producer and exporter of cocoa globally, with the Côte D'Ivoire and Ghana occupying the first and second position on the international listings respectively (Aneani et al., 2018). The top position and 'bragging rights' of being the largest producer and exporter has always been a battle between these two neighbouring West African countries, with the former taking the lead due to the country's advances in embracing technology to boost production; meanwhile the latter is noted for the high quality of its cocoa beans due to the country's favourable climatic conditions and geographical topography (Aneani et al., 2018).

After the introduction of cocoa to the then Gold Coast, which was a former British colony now renamed as Ghana (Kolavalli and Vigneri, 2011), cocoa production has been a rural agricultural activity due to the significance of cocoa to the country's economy (MASDAR, 1998) and the livelihood of the population, which is sandwiched in between rural areas. Cocoa production was rapid, with the first export having been made in 1885. Cocoa production peaked in 1965 at 568,000 tonnes, and then began to decrease until 1983/84, as a result of severe drought and forest fires (Figure 2.4) (MASDAR, 1998).

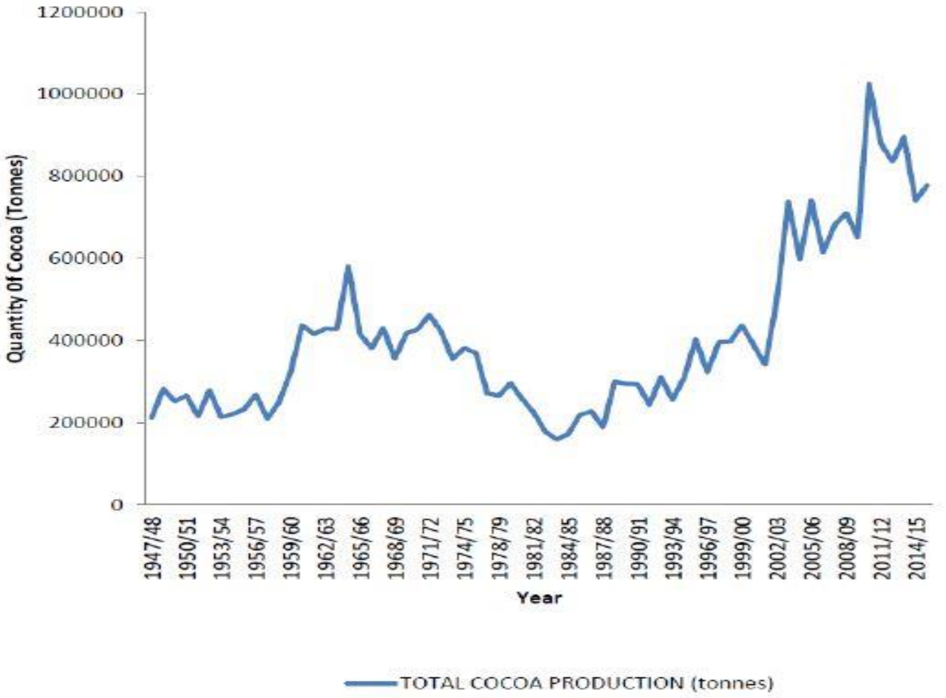


Figure 2.1 Chart of annual cocoa production trend from Ghana Cocoa Board (COCOBOD, 2013).

As clearly evidenced in Figure 2.1, the decrease in cocoa production has had a significant effect on the cocoa supply chain; these reductions in cocoa production, which diminished export quantities (Figure 2.2) and income, were ascribed to the cocoa sector's various internal issues, some of which harmed the economy as a whole in terms of GDP output, coupled with other significant fiscal consequences.

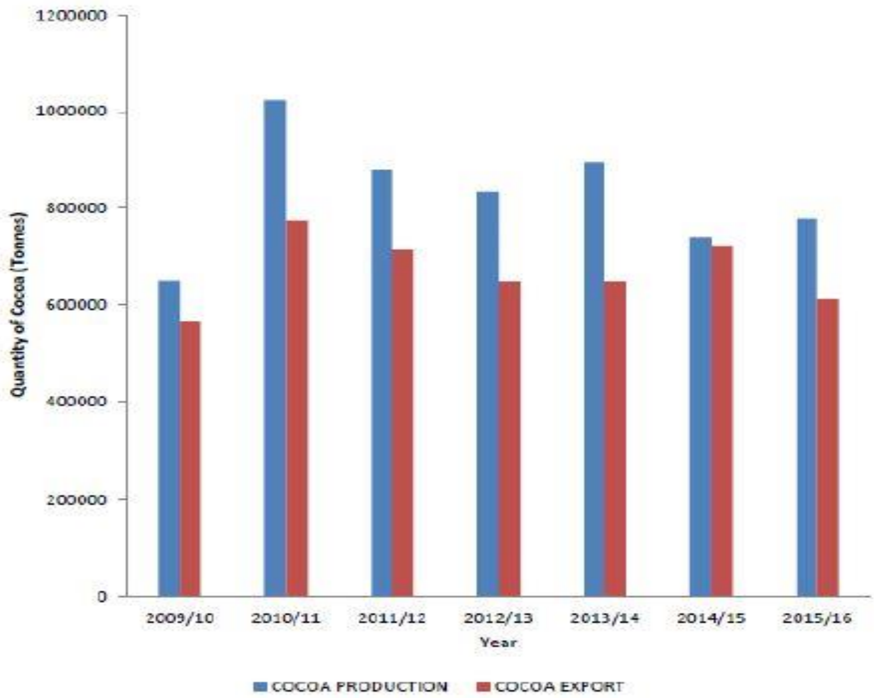


Figure 2.2 Annual values of cocoa production and export from Source: Ghana Cocoa Board (COCOBOD, 2013).

These internal issues identified included the increasing disease problems exacerbated by a lack of chemicals and application equipment; an ageing tree stock; successive droughts during the late 1970s and early 1980s; a rapidly deteriorating transport infrastructure which contributed to the inefficiencies of an overstaffed marketing organisation, and low producer prices which increased the allure of essential food crops and other perennial crops. Prior to the destabilization of the sector by the abovementioned issues, cocoa growers received global market prices minus deductions for processing, freight, and merchant margins (Ofosu, 1995).

The cocoa industry is an integral element of Ghana's agricultural business; it holds a vital position in terms of foreign exchange receipts and domestic earnings, and is the primary revenue source for the supply of socioeconomic infrastructure (Asante, 2005). There are an estimated 2,988,395 acres of cocoa-growing land in Ghana, and around 445,145 farmers in rural areas depend on cocoa production for their livelihoods (Asante, 2005). Ghana's cocoa exports account for almost 40% of its overall exports, with cocoa being the country's top source of export earnings in 2004 (Asante, 2005). Using foreign money and tax revenues acquired by the government, as well as the incomes received by cocoa farmers and other workers in the cocoa sector, the cocoa industry has contributed significantly to the country's socioeconomic growth up to the present day, where Ghana remains the second highest producer and exporter of this high-demand global crop.

According to MASDAR's 1998 research, cocoa farming is affected by several variables including power dynamics by the diversity of stakeholders, from public to private, who exercise varying degrees of influence in the decision-making processes of this ecosystem. Kolavalli and Vigneri (2011) conclude this, with their results reiterated by the findings of Adu-Acheampong et al., (2021), to the effect that currently Ghana is the leading country which comes to mind when cocoa is mentioned; it is difficult to talk about Ghana without mentioning the cocoa sector. The global recognition and local identification of Ghana to cocoa and cocoa to Ghana highlights the importance of this crop and offers a strong justification for its choice by the researcher for the purposes of this study.

Recent marginal increases in cocoa production in Ghana have resulted in a lower output per unit area (400 kg/ha) than other cocoa-producing nations, such as Côte d'Ivoire (1000 kg/ha) and Malaysia (800 kg/ha) (Adu-Acheampong et al., 2021). In response to the limited acceptance of the Cocoa Research Institute of Ghana (CRIG)'s technologies by cocoa farmers and other stakeholders, the Ghana Cocoa Board (COCOBOD) implemented the Cocoa Disease and Pest Control (CODAPEC) and Cocoa High Technology (Hi-tech) initiatives (Henderson and Jones, 1990; Donkor et al., 1991; MASDAR, 1998; Aneani et al., 2007) as a strategy to boost production and improve farming practices. According to the findings of Henderson and Jones (1990) and Donkor et al., (1991), low adoption of technologies was attributable to the linear transfer of technologies to farmers, i.e.,, the modified 'training and visit' system of technology and information transfer incorporating the 'research-extension-farmer' relationship. Thus, stakeholders in the supply chain, mainly comprising farmers, perceived the introduction of these technologies as an imposition without prior consultation from a group of players within the cocoa farming ecosystem.

This approach placed an excessive focus on technological advancements, with stakeholder consultation or engagement in its implementation and overall acceptance of the purposes of boosting cocoa production and farming management and practices (Asenso-Okyere et al., 2008; Hounkonnou et al., 2012; Aneani et al., 2018). Thus, this clarion call for the intersection of technology and stakeholders' roles in the optimization of cocoa farming provides again a strong justification for the choice of cocoa for the purposes of this study.

2.2.1 The evolution of cocoa farming in Nkawie in the Ashanti region

Cocoa farming within the Nkawie district and its adjacent communities has grown over time. This has contributed significantly to the overall trend in cocoa production in Ghana, creating a vigorous supply chain as a result of the robust activities in this area. Cocoa is the most important cash crop in Ghana; it accounts for approximately 25% of the country's yearly foreign exchange revenue (Breisinger et al., 2008; David, 2013). It is the main source of income for many rural farmers, including those in the Nkawie cocoa area (Kolavalli and Vigneri, 2011). Nkawie is one of the major cocoa districts within the Ashanti region of Ghana. It has a high cocoa contribution impact on Ghana's overall GDP and has continued to increase in both human and acquisition capacity over the years (Vigneri and Kolavalli, 2017; Enu, 2014; Teye and Nikoi, 2021).

Prior to the mid-1950s, cocoa production was minimal and there were significant problems with defective and inferior cocoa beans in and around the Nkawie cocoa district (Afoakwa et al., 2010). This defect was generally caused by the widespread diseases ‘swollen shoot virus’ and ‘vascular streak dieback virus’ which were observed on cocoa farms; these threatened the fundamental framework of farmers’ resilient practices in exploiting disease control mechanisms (Andres et al., 2017). These defects in cocoa beans tend to reduce the quality of cocoa production which exerts a ‘ripple down’ effect on overall production and market value, negatively impacting both consumption and export (Baah and Anchirinah, 2011; Oduro et al., 2020). Duguma et al. (2001) report that cocoa beans must be of good quality and must meet national standard requirements before they can be sold.

However, the cocoa beans found in the Nkawie cocoa district were generally affected by swollen shoot virus and vascular streak dieback virus, meaning that they were significantly below the national standard requirement for purchase. These caused farmers losses in terms of time, space, logistics, and labour costs, with a ‘ripple effect’ on the rural cocoa district’s economy, as well as on their households (Duguma et al., 2001).

There are examples where cocoa beans found and tested in the Nkawie district were changed from their original grade to sub-standard classification, due mainly to the presence of defective cocoa seeds (Amoa-Awua et al., 2007). The table below provides examples of defective cocoa beans found within the Ashanti Region of which Nkawie district forms part.

Table 2-1 Major defects of cocoa beans identified by COCOBOD

Cocoa districts	Defect of cocoa beans	Explanation	Implications for the region, farmers, and contribution to national GDP
Antoakrom	Not thoroughly dry (NTD)	Cocoa beans with excessive moisture content	Rejected for re-drying and purchase at a late date.
Ashanti Bekwai	Admixture, also known as average tolerance level (ATL)	A mixture of cocoa beans of different sizes or a mixture of uneven/unusual beans	Rejection at the regional office. Mostly destroyed by local authority. Not counted as part of national GDP.
Nsokote	Mould	Cocoa beans which become mouldy, taste bitter, and lack flavour	Rejection at the regional office. Mostly destroyed by local authority. Not counted as part of national GDP.
Nkawie	Swollen shoot virus Vascular streak dieback virus	This is a viral disease transmitted to the plant by mealybugs. It decreases cocoa yield within the first year of infection, and usually kills the tree within several years.	Rejection at the regional office. Most crops are destroyed by the local authority, and are not counted as part of national GDP.
Nyinahin	Weevil	Cocoa beans are infested with weevils and cocoons, causing damage to them.	Rejection at the regional office. Most crops are destroyed by the local authority, and are not counted as part of national GDP.
Konongo	Purple colour	Cocoa beans are purple in colour and taste bitter or are flavourless.	Crops are not accepted and are destroyed.
Adansi North	Foreign material	Cocoa beans are mixed with debris, stones, cow dung or other contaminants.	Rejected for repurchase at a later date.
Offinso Ejisu Juaben	Smoky beans	Cocoa beans are contaminated by smoke.	Crops are destroyed by the local authority, and are not counted as part of national GDP.

Source: Owusu Ansah et al. (2018).

As shown in Table 2.1, there is evidence to suggest cocoa bean defects within the Nkawie district contributed to the percentage of cocoa defect cases within the Ashanti region. Figure 2.3 below illustrates the regional defects of cocoa beans affected by swollen shoot virus alone, spread across cocoa producing regions.

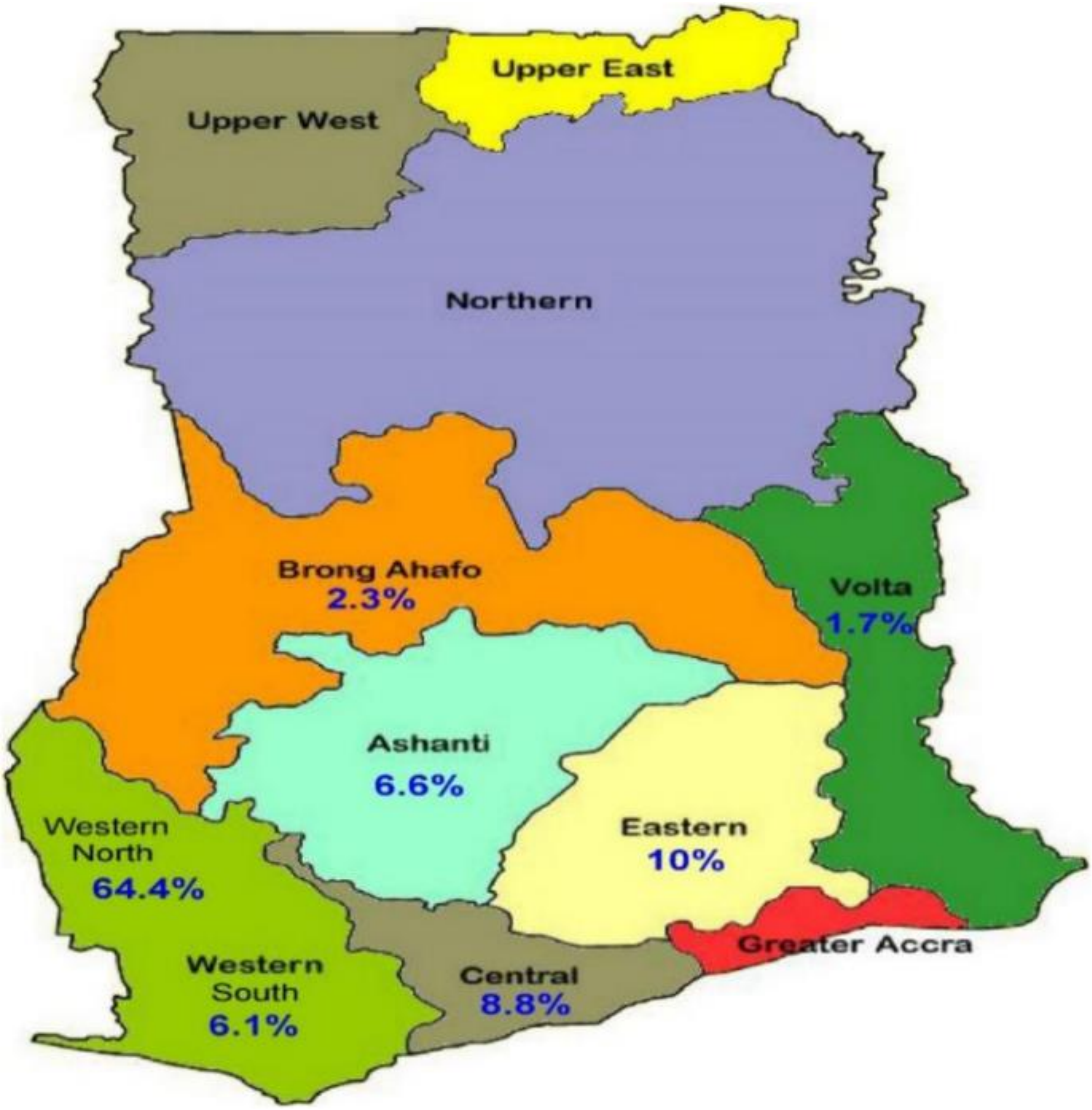


Figure 2.3 Regional defects of cocoa beans affected by swollen shoot virus (COCOBOD, 1959).

Figure 2.3 presents a map of Ghana by administrative region, to illustrate cocoa bean defects within all six cocoa production regions of the country. This research takes place within the Ashanti region, where the Nkawia cocoa direct is located. As the map suggests, the Ashanti region contributes 6.6 % to the total number of cocoa defect cases in the country. Although this is noted as not being the highest, its impact on national GDP is significant and should not be underestimated (COCOBOD, 2011).

2.3 Adoption of new technology

'Techne', the Greek term for 'art' or 'skill', is typically related to technology (Skrbina 2015). Different authors define technology in various ways, with definitions varying from the means and methods of producing goods and services (Loevinsohn et al., 2013) to a human-created system which uses knowledge and organisation to achieve specific goals (Volti, 2009), migration from analogue to digital systems (Murakami, 2010), an operational and ideological shift (Wong et al., 2014), and a disruptor of normality (Andriole, 2012), among others.

Technology is the knowledge or information which enables certain jobs to be performed more easily and effectively, improve a given condition or change the status quo (Vaughan, 2013). In the context of agriculture, it helps farmers to accomplish tasks more easily than they would have done without the technology, hence saving time and labour (Kirinya et al., 2013; Bonabana-Wabbi) (2002).

The context of technology adoption, defined by Loevinsohn et al. (2013) as the incorporation of a new technology into existing practice, typically starting with a trial phase, has been examined from distinct perspectives. Ugochukwu and Phillips (2018) and Bonabana-Wabbi (2002) describe adoption as the mental process experienced by an individual from the first time they learn about an invention, to the time they use it. Adoption comprises two categories: adoption rate and adoption intensity. The former concerns the relative speed at which farmers adopt an invention, and includes 'time' as one of its pillars, while the latter refers to the amount of utilisation of a certain technology during any given time period (Bonabana-Wabbi, 2002; Kalaitzandonakes et al., 2018).

Defining the adoption of technology is a challenge because it varies depending on the individual technology; for example, Doss (2003) concludes that farmers were classed as users of improved seed in the International Maize and Wheat Improvement Centre

(CIMMYT) survey if they used seeds that had been recycled for several generations from hybrid ancestors. In other research, adoption has been associated with extension service instructions to use only new certified seed (Doss, 2003; Bisanda, 1998; Ouma 2002; Mwangi and Kariuki, 2015). Therefore, the first consideration in the definition of agricultural technology adoption by farmers is whether adoption is a discrete state with binary response variables or not (Doss, 2003). As demonstrated by the research of Challa (2013), the concept of adoptability is dependent on whether the farmer is an adopter or non-adopter of the technology, with zero and one as potential responses.

The appropriateness of each strategy is context-dependent (Doss, 2003). Many academics employ a simple dichotomous variable technique to evaluate the adoption decisions of new technologies by farmers (Mwangi and Kariuki, 2015). Jain et al. (2009) argue that this technique is important but insufficient because the dichotomous response represents knowledge of enhanced technology rather than genuine adoption, as should be the case. This requires a precise explanation of the premise of the phrase 'technology adoption' to enable the development of a suitable assessment tool.

In the process of adopting a new technology, farm size is a key factor. Many academics regard farm size as a significant factor influencing the adoption of technology (Mwangi and Kariuki, 2015; Gude, 2016; Nyariki, 2011; Suvedi, et al., 2017). Lavison (2013) notes that farm size may influence, and be influenced by, other factors determining adoption. Some technologies are dubbed 'scale-dependent' because farm size is so important to their uptake (Bonabana-Wabbi, 2002). Several studies identify an association between farm size and agricultural technology usage (Kasenge, 1998; Gabre-Madhin and Haggblade, 2001 Ahmed, 2004; Uaiene et al., 2009; Mignouna et al, 2011). Unlike farmers with smaller farms, those with larger ones are more likely to accept a new technology because they can afford to devote a portion of their land to testing it (Uaiene et al., 2009).

Further, 'lumpy' technologies such as mechanical equipment or animal traction require economies of scale to be profitable (Zeder et al., 1985). Some research studies (Vandercasteelen et al., 2020; Ainembabazi and Mugisha, 2014) identify a negative link between small farm size and technology adoption, particularly in the case of input-intensive innovations such as labour-intensive or land-saving technologies. As an alternative to increasing agricultural productivity, small-acreage farmers may employ land-saving technologies such as zero grazing and greenhouse technology (Muzari et al., 2012; Mekonnen et al., 2010; Yaron et al., 1992; Harper et al., 1990).

Other studies demonstrate adoption having a negligible or neutral effect; for example, Waller et al. (1998), Bonabana-Wabbi (2002), Samiee et al. (2009), and Allahyari et al. (2016) conclude that the size of a farm did not influence the adoption of Integrated Pest Management (IPM), meaning that IPM diffusion may occur regardless of the size of a farm's operation. Integrated Crop Management Farmer Field School (ICM-FFS) adoption likelihood was unaffected by the expansion of land holdings, according to Kariyasa and Dewi (2011). As a primary factor, these studies emphasise overall farm size rather than crop acres on which the new technology is utilised. Because total farm size has an impact on overall adoption, crop acreage with the new technology is potentially a more accurate predictor of the rate and degree of technology adoption (Muchangi, 2016; Lowenberg-DeBoer, 2000). In terms of farm size, technology adoption can be best explained by the fraction of total land area which is appropriate for the new technology (Hu et al., 2019; Uaiene, 2011; Bonabana- Wabbi, 2002).

2.4 The cost-benefit paradox of the acquisition of new technology

A crucial factor of the adoption of a new technology is its net benefit to the farmer, including all expenditures associated with its utilisation (Awotide and Awoyemi, 2016;

Abdullah and Samah, 2013; Foster and Rosenzweig, 1995). It has been demonstrated that the expenses involved with the implementation of agricultural technology are a barrier to its adoption. For example, the withdrawal of seed and fertiliser price subsidies in sub-Saharan Africa since the 1990s as a result of structural adjustment initiatives financed by the World Bank has exacerbated this limitation (Muzari et al., 2013).

Prior research on the factors influencing technology adoption has also identified high technology implementation costs as a barrier to adoption. Makokha et al. (2001) conducted a study on the determinants of fertiliser and manure use in maize production in Kiambu County, Kenya. They conclude that the high cost of labour and other inputs, the unavailability of requested packages, and untimely delivery were the most significant barriers to fertiliser use. In Embu County, Kenya, Ouma et al. (2002) cite the cost of hired labour as one of the main issues inhibiting the use of fertiliser and hybrid seed.

Wekesa et al. (2003), in their analysis of the drivers of the adoption of improved maize varieties in Kenya's coastal lowlands, conclude that the high cost and non-availability of seeds was one of the causes of the low adoption rate. Off-farm income is found to positively influence the adoption of technology (Ghobakhloo et al., 2012), because this revenue is crucial for rural households in many developing nations, to overcome credit limitations (Lien et al., 2010; Reardon et al., 2007). Off-farm income is described as providing a replacement for borrowed capital in rural economies where credit markets are absent or ineffective (Sekabira and Qaim, 2017; Ellis and Freeman, 2004; Diiro, 2013).

Diiro (2013), and Khanal and Mishra (2014) contend that off-farm income is anticipated to provide farmers with liquid funds for the acquisition of productivity-enhancing inputs such as new technological applications, better seeds, and fertilisers. In her analysis of the effect of off-farm earnings on the intensity of adoption of improved maize varieties and the productivity of maize farming in Uganda, Diiro (2013) reports that households with off-farm income had significantly higher adoption intensity and expenditure on purchased inputs than those without it.

However, not all technologies demonstrate a positive correlation between adoption and off-farm revenue; some research studies focusing on labour-intensive technology demonstrate a negative correlation between off-farm income and adoption. Goodwin and Mishra (2004) hold that farmers' pursuit of off-farm revenue potentially impedes their adoption of contemporary technologies such as Unmanned Aircraft Systems (UAS), by limiting the amount of family labour committed to farming operations.

2.4.1 Affordability and economic viability for investment in UAV' technology

Consumers' preferences for one technology over another are inherently influenced by the price of a product, making cost and financing schemes the most important aspect of the technology adoption process (Long et al., 2016). Cost may be evaluated on a net basis, covering procurement, staff, and maintenance of a technology, or the potential cost savings created by the technology's adoption can be taken into account. UAV, for example, can be 'net expensive', potentially more so than human-piloted aircraft (Pérez et al., 2013). Since the introduction of platforms for on-board sensors which offer precise and timely information, however, the implementation of technology of this kind may lead to a more judicious use of water, fertiliser, and pesticides, as the cost-benefit ratio of UAV extends beyond their net impacts (Yinka-Banjo and Ajayi, 2019).

In addition to the monetary costs, irresponsible use of agricultural inputs can create significant ecological costs, in terms of environmental pollution, soil deterioration, water waste, and wildlife destruction, that are difficult to quantify. Consequently, despite its significance, the estimation of potential cost reductions is not simple; cost is also variable and dependent on local circumstances, particularly when comparing poor and wealthy nations. A technology which is too expensive for one nation may be more affordable for another (Apazhev et al., 2019).

The extent to which Ghana's workforce is technically competent to effectively deploy UAV has long been the subject of controversy; there are also doubts as to whether Ghanaian farmers have the financial resources to invest in and/or purchase UAV (Raheem et al., 2021). The limited popularity of UAV in underdeveloped nations is a result of their constrained affordability and accessibility (Kumi et al., 2021).

Clearly, although not the only one, the cost of UAV has received much attention in research literature as a key barrier to their access. This emphasis on cost makes sense when considering access to these innovations for some of the world's poorest people, who cannot afford technology and whose poverty is compounded by the high prices they frequently face, especially for new equipment of this kind (Chen et al., 2019). Governments in poor countries such as Ghana, are unable to invest in and acquire technology such as UAV for farmers due to their limited economic resources.

Thus, lack of affordability is an issue in developing nations, including Ghana, at both national and family level. The debate over access to antiretroviral medicines (ARVs) for the treatment of HIV/AIDS in the world's poorer countries in the late 1990s drew the most attention to the problem of affordable technology (Long et al., 2010; Chigwedere et al., 2008). This discussion, and the efforts of the United Nations and activist organisations such as the William J. Clinton Foundation, resulted to a 98% decrease in the price of triple drug AIDS therapy between 1999 and 2003, from USD$12,000 to less than USD$200 annually (Ramiah and Reich, 2005). The affordability of a technology such as UAV depends on its price, the cost of maintenance, and the availability of cash for their purchase (Reich and Bery, 2005).

In the case of UAV, the purchase price varies significantly based on the mission type and the number of systems available. Again, it is essential to consider the cost of their maintenance; this includes servicing, storage, operating fees, batteries, chargers, and generators (Mohammed, et al., 2014; Negash et al., 2019). These expenses also vary according to context, such as whether or not the location of interest is linked to the electrical grid, and has storage facilities (Suresh and Ghose, 2012). In addition, the pricing of these items can vary substantially between nations and between the public and commercial sectors within a country (Reich and Bery, 2005). This is likely to be the result of diverse company objectives, governmental intervention, tariffs, currency rates, and bargaining circumstances (Reich and Bery, 2005).

Undoubtedly, UAV are a costly technology; this explains why the majority of the world's governments, particularly those with emerging economies, have yet to adopt them. However, whether a country such as Ghana can afford this technology depends on its national income, which is only one aspect of the affordability conundrum (Yinka-Banjo and Ajayi, 2019). Research demonstrates that the government is not the sole consumer of technology in emerging nations; private investors seeking to expand operations are also involved (Stokenberga and Ochoa, 2021).

In view of this, the acceptance or implementation of Unmanned Aerial Vehicle technology is potentially influenced by the involvement of agricultural stakeholders, as it is noted that their interventions play a crucial role in the entire agricultural farming ecosystem (García-Nieto et al., 2015).

2.5 The use of UAVs as new technology

As a novel technology, UAV are related to the current artillery utilised internationally in military operations. This technology is often used for military air strikes, in addition to exploration and observation determinations (Mostafa et al., 2018; Udeanu et al., 2016; Ma'Sum et al., 2013; Bunker, 2015; Hsu et al., 2013; Alimpiev et al., 2013). Maekeler (2017) defines 'drone' colloquially as an Unmanned Aerial Vehicle (UAV), whereas Bischof (2017) refers to them as: 'Unmanned Aircraft System (UAS)' or 'Unmanned Aircraft (UA)' which are small, ecological, and sometimes silent aerial platforms without on-board pilots, being controlled from ground-based stations (Yao et al., 2019).

The first attempt at the use of UAV for aerial application occurred in 1983 in Japan when the Yamaha Motor Corporation developed the Remote-Controlled Aerial Spraying System (RCASS) (Sato, 2003). This company is a pioneer in the development and modification of non-military UAV for agricultural uses, beginning in Japan with insect pest control for rice paddies, soybeans, and wheat. UAV systems can be used for a variety of applications, as seen by the systems' expansion into new domains throughout time.

Table 2-2 The development of different proposed UAV and their numbers between 2004 and 2007 from Van Blyenburgh (2007)

	2004	**2005**	**2006**	**2007**
Civil/commercial	33	55	47	61
Military	362	397	413	491
Dual purpose	39	44	77	117
Research	43	35	31	46
Developmental		**219**	**217**	**269**

As noted from various academics such as Van Blyenburgh (2007), UAV were initially introduced for military purposes, but due to their potential use for multi-faceted purposes, they are used as an alternative or a supplementary solution to satellites for coverage of inaccessible areas. As indicated by the above table, there are growing numbers of UAV' systems, with the majority being used for military purposes. It is interesting to note the marked incremental increase in the other purposes of the UAV's itemized in the table.

It is noteworthy that UAV appear to attract more favourable connotations as a result of their rising civilian use and positive responses to their adoption. Longwell (2017) reports that hobbyists now employ UAV for recreational purposes. The Quadrocopter, for example, is a popular model for private usage that is frequently utilised in film or photography projects. Its prospective applications, including as parcel delivery, captivate global attention and contribute significantly to the e-commerce sector (Desjardings, 2018; Donath, 2016).

UAV have the potential to gain information from other acquisition systems, such as satellites, with extremely high picture spatial resolution. It is an ingenious and cost-effective gadget for completing many survey tasks, including environmental monitoring and the examination of large industrial facilities (Li et al., 2020; Jiang et al., 2020; Jawhar et al., 2014). In addition, UAV have demonstrated precision and speed in data collection; the development of this technology is one of the primary objectives of several research centres (Pnika et al., 2019). Its capacity to instantly acquire information when required, without risk to human life, is sets it apart.

In the relevant body of literature, the adoption of UAV is widely-documented. Farmers' decisions on the implementation of this technology are primarily dependent on the category of UAV and their myriad factors and circumstances (Loevinsohn et al., 2012). Early academics such as Kohli and Singh (1997), Feder et al. (1985), Uaiene (2009), Foster and Rosenzweig (1996), Delle Fave et al., (2012), and Koppel (1994) demonstrate that the adoption of technologies such as UAV, in the context of a fiscal investigation, does exhibit peculiar endowments and idiosyncrasies, such as input availability, risk, infrastructure behaviours, uncertainty, and institutional constraints. In addition, a number of studies indicate that the adoption of UAV by farmers can be impacted by a range of economic, social, and institutional variables (Akudugu et al., 2012), which account for the awareness, adoption, and implementation effects.

As such, Wu and Babcock (1998) classify these features as agricultural structures, institutional characteristics, and management structures. Importantly, there are no identifying characteristics between the variables in each category, yet they are all used to accommodate the examined technology, the region, the researcher's wishes, or even the farmer's objectives (Bonabana-Wabbi, 2002). Notably, some researchers consider the level of education of farmers as human capital, while others describe it as a household-specific feature (Akudugu et al., 2012), rendering it difficult to establish a unified standard of evaluation.

2.5.1 Innovative capacity and technical literacy of Ghana's farmers

The introduction of agricultural extension education, as stated by Bown and Okedara (1981), is intended to support farmers and families in the development of their knowledge, skills and attitudes which in return will enable them to benefit from technology with the aim of achieving higher standards of living (Simpson and Owens, 2002). Asiedu-Darko (2013) holds that this extension is described as the process of engaging farmers' understanding of the need and/or reasons for change; it does describe the outcome of change and the uncertainties inherent in change (Moayedi and Azizi, 2011). Similarly, agricultural extension education serves as the means by which farmers become aware of alternative resources, while providing them with the opportunity to select from the variety of approaches or methods available for carrying out their farming activities (Anderson and Feder, 2007).

The creation of the International Institute for Tropical Agriculture (IITA), Ibadan, and the Council for Scientific and Industrial Research (CSIR) have led to the production and development of the most efficient methods in the cultivation and management of crops such as oil palm, maize, cowpeas, cassava, and yams for high yield.

These organisations, among others, have served, and continue to serve, as high-profile research and knowledge hubs providing support to the agricultural economy or ecosystem (Oluyinka, 2020; Bugyei et al., 2019; Asare and Essegbey, 2016). In a nutshell, agricultural extension education provides a system of service which assists farmers through educational procedures, improving farming methods and techniques, aimed at increasing production efficiency and income, improving both farmers' standards of living and the social and educational standard of rural life (Asiedu-Darko, 2013; Feder et al., 2011).

Although it is abundantly clear that extension education is primarily aimed at providing farmers with opportunities to learn and implement practical knowledge, addressing daily activities and issues on their farms, there remains the need for farmers to recognise and appreciate why there should be changes to their farming practices (Asiedu-Darko, 2013). However, farmers stand no chance of benefiting from these services if information, and/or newly-developed knowledge or techniques, are not made available in the area of the farmers' operations by use of the appropriate channels (Anang et al., 2020). This inadequacy of exposure to alternative approaches for farmers continuing with their daily activities on their farms does prevent them from shifting from their traditional practices of engagement in their contexts.

The significance of extension initiatives for Ghana's agricultural sector cannot be overstated. In his presentation of the 2006 budget, the then Minister of Finance and Economic Planning, Kwadwo Baah Wiredu, acknowledged the inadequacy of funding allocated to extension services in Ghana, recommending the channelling of adequate resources to the sector in order to address the numerous challenges facing it (Akpotosu, 2015). Extension education plays a critical role in the effective implementation of agricultural technologies, which is a crucial intervention in agricultural development (Asiedu-Darko, 2013). The effective implementation of innovative technologies such as

UAV require measures which ensure that farmers acquire the necessary awareness, exposure, knowledge, and competencies from extension education officers to improve their effectiveness.

2.5.2 The multi-functionality of UAV

The combination of the spray system with UAV provides an autonomous spray system for pest- and vector control. Spray UAV helicopters, which were originally designed for aerial application, have been converted for agricultural RS (Messina and Modica, 2020; Xiang and Tian, 2011; Yin et al., 2019). Compared to the lightweight UAV' platforms that have been utilised exclusively for LARS to date, customised unmanned helicopters are more costly, larger, and capable of carrying heavier payloads such as high-performance cameras (Moon and Shim, 2009). In 1994, for example, a Yanmar YH300 spray unmanned helicopter was outfitted with a high-definition digital multispectral camera to scan agricultural fields (Sugiura et al., 2005). The same aircraft was used to monitor crop conditions for precision agricultural operations (Sugiura et al., 2002).

In some situations, the spraying equipment (chemical tank and nozzles) was removed, with an adapter for the installation of imaging equipment being added. In 2016, a Yanmar AYH3 spray unmanned aircraft was equipped with a hyperspectral imaging sensor for estimating maize production and feed quality (He et al., 2016). The information supplied confirmed the accuracy of crop forecast, particularly nutritional crop properties. In the context of agriculture, it is important to emphasise that Remote Sense detects changes in crop growth and soil condition through differences in spectral responses (Warren and Metternicht, 2005). This data can then be utilised to determine nutritional deficits, diseases, water status, weeds, damage, and plant populations.

As farmers on the one hand seek to adopt modern technologies such as UAV to increase crop yields and meet growing demand for food, while on the other hand supply is dwindling, the advantages of Remote Sensing (RS) as a non-disruptive means by which to collect systematic, accurate, and timely information have become increasingly advantageous (de Luna et al., 2021; Zhang and Zhao, 2010). General agricultural applications supported by RS include the monitoring and mapping of soil parameters, categorization of crop species, crop pest control, detection of plant water stress, and monitoring of weed control (Gutiérrez et al., 2008).

Satellites, aircraft, balloons, helicopters, and UAV are typical RS platforms. On these platforms a range of sensors are mounted, including optical and near-infrared sensors and RADAR (Stafford, 2000; Zhang et al., 2002). In recent years, satellite pictures have been used to monitor crop growth and stress, and to forecast agricultural production. However, their usage has been hampered by short return durations, restricted spatial resolutions, and, on occasion, cloud cover (Stafford, 2000; Srinivasan, 2006; Stafford, 2006).

RS equipment deployed on piloted aircraft platforms has proven beneficial for a number of agricultural operations, despite their considerable operational complexity, expense, and safety risks (Rango et al., 2009). The advantages of UAV over other technologies are significant. Primarily, unlike satellites, they enable the independent timing of aerial flights, hence avoiding insufficient frequency of satellite surveys and/or cloud cover-related interruptions (Zhang et al., 2014).

In addition, they can deliver ultrahigh spatial resolution at centimetre level. UAV are safer at low altitudes, particularly under adverse weather conditions. As a result of flight plan scheduling, piloted aircraft often incur higher operational expenses and offer lower schedule flexibility (Primicerio et al., 2012). Additionally, in distant places where piloted aircraft are scarce, UAV can be helpful because they are less expensive than ground-based surveillance missions. Low Altitude Remote Sensing (LARS), which uses UAV to gather photographs of the Earth's surface at low altitudes, is now being marketed as a possible alternative platform for Remote Sensing (RS) (Zhang et al., 2006).

UAV utilised for agricultural remote sensing (RS) have primarily comprised low-cost model aeroplanes with limited payload capacity and other versions, which have become progressively more accessible to farmers and scientists (Swain et al., 2010; Swain and Zaman, 2012). These aircraft generally have limited flight endurance, typically less than one hour, and fly at low ground speeds to carry affordable multispectral cameras (often less than USD$5,000) to perform LARS at altitudes below 1,000 feet over agriculture fields (Huang et al., 2013).

Images acquired by UAV have been successfully used in agriculture to detect small weed patches in rangelands, document water stress in crops, monitor crop biomass, map vineyard vigour, assess the effects of various nitrogen treatments on crops, and detect agricultural disease agents (Villa et al., 2016).

UAV have been used to collect data from rice, wheat, maize, grapes (in vineyards), and coffee fields in industrialised nations (Johnson, 2004). In addition to spray helicopters, multi rotor micro-UAV equipped with multispectral cameras have been employed for weed control and disease diagnosis, as previously discussed (Garcia-Ruiz et al., 2013). UAV have been used for agricultural missions, such as NASA's Pathfinder Plus models, which can carry two complementary high-definition digital cameras for agricultural surveillance, with one collecting high-resolution colour images for the qualitative interpretation and mapping of agricultural fields, and the other high-resolution CIR images for quantitative analysis of canopy spectral response (Herwitz et al., 2004). In 2004, these UAV hovered for lengthy periods at an altitude of roughly 7,000 metres to provide high resolution photos for a coffee maturity study and harvest time determination

(Johnson, 2004; Herwitz et al., 2004). There are several lightweight multispectral cameras that can be added to obtain the desired outcome. This provides the operator with several options for aerial images; these photos are analysed and processed for future use.

Methods of utilising UAV in agriculture are diverse and reliant on both the region and the intended objective. UAV play a crucial role in the early detection, prevention, and control of weeds, insects, and plant disease infestations on farms. This is especially important in the agricultural sector, particularly in the domain of food security, enhancing best farming practices, pest- and disease control, and the management of post-harvest losses, among other uses. These risks are widespread in Ghana's cocoa growing sector.

2.5.3 Infestations of weeds, insects, and plant diseases

The infestation of agricultural fields with weeds, insects, and plant diseases may be catastrophic for a farmer. A monoculture agricultural area will always be exposed to, and endangered by, the natural systems which surround it (Capinera, 2005). Pesticides in agriculture have been extensively studied by scientists for several decades (Thorp and Tian, 2004). Typically, genetically engineered organisms, insecticides, and herbicides are utilised to eliminate invasive species. Plant diseases are occupational dangers that every farmer must contend with, whether on a small or large scale (Van Bruggen and Finckh, 2016). Fungicides are often employed to prevent plant diseases, and their efficacy has been repeatedly demonstrated (Seelan et al., 2003).

It should be noted that some plant and insect species might develop resistance to pesticides and herbicides via repeated application, resulting in an increase in pesticide use on farms (Nayak and Solanki, 2021; Dabrowski et al., 2014). Typically, pesticides are applied at standard or variable rates, as opposed to the specific weed locations provided by UAV (Wandiga, 2001). There are a number of advantages to the remote sensing of weeds and plant diseases, such as the near-immediate generation of field status maps (Lamb and Brown, 2001; Torres-Sanchez et al., 2013).

In addition to favourable climatic circumstances for vegetable cultivation, Ghana as a large agricultural society (Darfour and Rosentrater, 2016) lacks the advanced technological facilities and inventive prowess required for market economy competitiveness. Therefore, any solution which enables farmers to cut production costs while preserving product quality and integrity is of the greatest importance and profitability to the industry participants (Damba et al., 2020; Dzanku et al., 2022). Over the years, developed nations such as Japan have utilised UAV in precision agriculture for a variety of missions, including image capture for analysis of individual plant leaves' culture, obtaining information on soil water holding capacity, and management of irrigation systems for large agricultural producers cultivating in regions with dispersed areas (Yun et al., 2017; Pederi and Cheporniuk, 2015; Takeshima and Joshi, 2019). Sugiura et al. (2003), for example, utilised an image sensor and laser range finder mounted on an unmanned aircraft to produce maps of field information such as crop conditions and topographical land features. In this area of technology, several innovations have emerged. Archer et al. (2004), for example, construct a microwave autonomous copter system for monitoring the temporal variations in soil moisture as a function of depth, despite the presence of vegetation cover. Khan et al. (2017) demonstrate that UAV' sensors can be utilised for satellite validation in the atmospheric boundary layer, horizontal and vertical mapping of local pollutants and greenhouse gases, and comprehension of carbon absorption in a forest canopy. Patel et al. (2013) created a revolutionary quadcopter equipped with an infrared camera to examine an agricultural field in order to distinguish between infected or diseased- and mature crop. In addition, Verbeke et al. (2014) evaluated a unique compound multicopter for checking fruit orchards and vineyards in outdoor situations while flying between tree rows.

In Germany, there is already evidence of the use of commercial agricultural drones. For example, they are utilised prior to meadow mowing to safeguard young wildlife, such as fawn identification (Bauerdick, 2016), in the estimation of yield losses, such as damage by wild boars (Allbach and Leiner, 2016), and in the distribution of beneficial insects across crops (FarmFacts GmbH n.d.).

UAV are frequently associated with intelligent or precise agriculture. The combination of terrestrial and satellite-based applications enables the processing, mapping, and recording of agricultural land in specified, and potentially discrete, locations (Bansod et al., 2017). Each country and its own unique history of the usage of UAV in agriculture. Japan, where commercial drone technology has been available since the late 1970s, might be regarded as the cradle of the usage of agricultural UAV, namely for the application of PPP (plant protection, products, and pesticides) (Scherer et al. 2017).

In addition, Japan's small-scale land usage has had a favourable impact. Due to the inaccessible nature of the terrain and heavy reliance on physical labour, the potential for enhancing agricultural productivity is great (Scherer et al., 2017), but the most prevalent applications remain the application of PPP and sowing. Due to these factors, the adoption and utilisation of UAV' technology in Japan is over 70%, which is far greater than in the United States, which is also extremely tech-friendly, at approximately 40% (Scherer et al. 2017; Stehr, 2015). Due to the wide geographical area and often easily-accessible topography, agricultural land in the United States is relatively expansive and organised.

UAVs can attain the size of human aircraft such as the Boeing Condor (Yenne, 2010). The Condor belongs to the category of 'fixed-wing', aircraft and its wingspan of 60.96 metres exceeds that of the Boeing 747. In the majority of civilian uses, such as agriculture, UAV are of similar size to conventional model aircraft (Reinhard, 2013) or are somewhat larger, for example the Agronator. The Agronator octocopter, with a payload of 35 kg, is suitable for the application of crop protection, seed, and fertiliser (Reger et al., 2018; Koch, 2017). The most prevalent UAV (UAVs) are rotorcraft with a diameter of up to one metre and four to eight propellers (also called ‘multicopters’). The term ‘multicopter’ refers to the number of propellers, and hence encompasses all rotorcrafts having two or more propellers at the same level (Pittu and Gorantla, 2020; Schroder, 2017).

It is impossible to overstate the evidence and significance of the extensive deployment and application of UAV in agriculture in many industrialised nations in order to boost production and implement effective pest and disease management systems; its long-term application in agriculture is now essential for food security.

2.6 UAV applications in agriculture

The application of Unmanned Airborne Vehicles in agriculture can be categorised into two basic areas: the aerial administration of pesticides and fertilisers over farms, and the use of remote sensing (aerial photography) to support agricultural field mapping and growth monitoring (Kim et al., 2019; Urbahs and Jonaite, 2013; del Cerro et al., 2021). The majority of agricultural UAV are MAVs, fixed-wing or rotary-winged helicopters with low cost, low speed, low ceiling altitude, light weight, poor play load weight capabilities, and short endurance.

2.7 Key challenges and benefits of UAV using Remote System (RS)

The advantages of UAV over other prevalent technologies in terms of their flexibility and mobility, lower cost of operation, precision, and safety have attracted significant interest in their development and use for aerial application activities (Huang, 2009; Pederi and Cheporniuk, 2015). In 1983, the Yamaha Motor Corporation developed the Remote-

Controlled Aerial Spraying System (RCASS) in Japan, marking the first application of UAV (Shim et al., 2007).

This company is a leader in the development and transformation of non-military UAV for agricultural applications, such as rice paddies, soybeans, and wheat, and is rapidly expanding into additional sectors and uses (Johnson, 2001). In 1990, Yamaha's R50, an Unmanned Aerial Vehicle helicopter with a payload capacity of 20kg, was introduced; subsequently, in 1997, the RMAX was developed (Kaitlin, 2018). UAV of the Yamaha RMAX type were outfitted with an azimuth and Differential Global Positioning System (DGPS) sensor system in 2000 (Theodore et al., 2006).

In 2005, an experiment was conducted in the United States to investigate the effectiveness of the employment of UAV for the distribution of insecticides to minimise human disease caused by insects (Puri, 2005). UAV furnished with both liquid and granular pesticide dispersion devices were evaluated via a series of experiments; the Yamaha RMAX was equipped with both liquid and granular pesticide dispersal systems. Overall, the UAV' pesticide dispersal system demonstrated commendable performance, and was proven to be reliable (Puri, 2005).

Japan now utilises more than 2,300 tiny, unmanned aircraft to spray and check the crop health of inaccessible rice fields (Nonami, 2007; Enderle, 2002; Freeman and Freeland, 2015; Xiongkui et al., 2017). Over 90% of crop protection in Japan is performed by the Yamaha RMAX (Kaitlin, 2018). Japan is an important case study for Africa because the average Japanese farm size is 1.5 hectares, similar to the average size of African farms, which are approximately 1 hectare (Yun et al., 2017).

In comparison, the typical farm area in the United States is 441 acres, rendering the use of UAV (UAVs) for aerial application less effective (Shakhatreh et al., 2019). Agricultural UAV such as the RMAX have a chemical capacity of 19 litres of liquid, compared to 1364+ litre for human agricultural aircraft currently employed on US fields (Shokirov et al., 2020).

In addition, the Yamaha RMAX operates at 15 miles per hour (mph), whereas human piloted agricultural planes travel at 160 mph (Eisenbeiss, 2004). In addition, the quantity of air forced down to the crop canopy by a rotor or a fixed-wing is proportionate to the weight of the aircraft that the air is supporting; a tiny aircraft, whether manned or unmanned, does not displace a great deal of air (Nonami, 2017). This quantity of air is what renders crop protection by aerial spraying efficient. In view of these obstacles, it is doubtful that UAV will be deployed in the United States for widespread aerial applications in the foreseeable future. However, similar uses are acceptable in the United States under 'niche' conditions, such as small-scale vineyards and speciality crop scenarios, as well as sensory applications (Freeman and Freeland, 2014).

However, vineyards in California's wine area have already started to experiment with Unmanned Airborne Vehicles' technology for the aerial delivery of fertiliser, herbicides, and irrigation (Johnson et al., 2003; Gago et al., 2015). The region's small rows and mountainous terrain provide challenges for tractors and other farm equipment, but not for UAV. As part of the studies conducted by the University of California, the Yamaha RMAX was evaluated for the application of water, herbicides, and fertilisers (Saripalli et al., 2003). In the context of this study, the RMAX cannot be compared to manned aircraft, but rather to tractors or manual labour, which are the prevalent methods used on Ghanaian cocoa fields. According to the above-mentioned research, UAV are more cost-effective than seeking to drive a tractor up slopes, or employing humans with backpack sprayers on cocoa fields in Ghana (Besseah and Kim, 2014; Danso-Abbeam and Baiyegunhi, 2018).

Additionally, the RMAX is approximately ten times faster than a tractor, despite the fact that it flies quite slowly, at 12 mph; this demonstrates the fact that UAV can be used for insecticide application in aerial spraying, particularly for mosquitoes on Ghana cocoa farms, for example. Huang et al. (2013) developed a specialised spray system for use on fully autonomous UAV; the team designed low-volume spray equipment for the Roto motion SR200, a VTOL unmanned helicopter with a two-stroke gasoline engine with a maximum payload of 23kg and a primary rotor diameter of 118 inches. Their research demonstrates that a spray system for UAV' application platforms was effectively constructed.

Table 2-3 Summary of key benefits and challengers of UAVs

Benefits of UAVs	**Challenges of UAVs**	**Explanations**	**Sources**
Flexibility and mobility access	UAV are subject to problems, including possible security and privacy threats and public safety,	Although there is a dread of the technology invading people's beliefs, which makes it difficult for it to adapt, it is incredibly simple to operate because it is not static in nature. UAVs are known for devastation and for terget missions in the military.	Shakhatreh et al., 2019).
lower cost of operation,	UAV are subject to problems, including High cost for its initial purchase	Although the initial purchase price of a UAV is very high, it is more cost-effective than trying to push a tractor up a hill or hiring people to use backpack sprayers.	Pederi and Cheporniuk, 2015).
Effective farm management especially for crop spraying	Low play load on large farmlands be a problem for effective farm management.	With its bird's-eye perspective and increased efficiency, UAVs can cover more ground and reduce labour costs significantly.	Velusamy et al., 2021).

Source: Author (2022)

2.8 UAV for sustainable agriculture

Even if sustainability is a widely disseminated and utilised phrase, its significance in human and natural ecosystems should be taken seriously. Humans are one of many species which have a symbiotic relationship with nature on Earth, despite the fact that most individuals feel completely disconnected from it (Williams and Parkman, 2003). Polluting and harming the world around humans, as if they were a virus, depletes the resources on which the human species depends. As agriculture is a significant factor in the escalating environmental devastation, it is essential for humans to transition to more sustainable farming methods (Olanipekun et al., 2019). Demand for soil resources is at an all-time high and will continue to rise due to a growing world population and increased demand for higher-quality diets and improved living standards, as more people emerge from poverty (Lal, 2009).

The agriculture sector is responsible for a significant amount of environmental damage to the global environment (Leontief, 1970). Several species of wild plants and animals rely on cultivated land and water as their essential habitats. When these are maintained sustainably, they support the preservation and restoration of vital ecosystems, the protection of watersheds, and the improvement of soil health and water quality (Harwood, 2020). Agriculture poses a significant danger to these species and ecosystems when humans disregard the sustainability and management of land by use of conventional methods. Multiple factors contribute to the advancement of sustainable agriculture, such as increased awareness of the significance of a healthy and functioning environment. Brodt et al. (2011) and Gomiero et al. (2011) contend that the ability to produce food year after year with minimal or no intervention from nature is crucial to human civilization. To avoid destroying the ecosystems on which humankind relies, it is essential that relevant activities are geared toward sustainability.

Technological improvements and developments have evolved, and continue to change techniques of farming and land management. Precision Agriculture (PA) is the final paradigm shift in contemporary agriculture (McBratney et al., 2005). PA can be developed with the aim of providing customised treatment as near to individual plant level as feasible (Zhang et al., 2002; Gebbers and Adamchuk, 2010). UAV and other current- and cutting-edge technologies are vital and necessary for the achievement of this.

As agricultural UAV will revolutionise spatial ecology (Anderson and Gaston, 2013), some academics are of the belief that the dawn of UAV technology has arrived, with agriculture as its initial objective (Koh and Wich, 2012; Getzin et al., 2012). Despite the fact that technology does not yet have the capacity to treat each plant individually and particularly, significant progress has been achieved over the past decade (Mulla, 2013). PA is shifting from the uniform treatment of a field to a more varied range of treatments according to the requirements of the plants and soils (Bongiovanni and Lowenberg-DeBoer, 2004). Sensor technology, machine-learning software, multispectral sensors on UAV' satellite photos, and ground-based data are among the various technologies being utilised to estimate soil moisture (Aubert et al., 2012).

Agriculture is, and has always been, a relationship between humans and natural processes, with the former exerting control over the latter to steer them towards any desired aim. In so doing, humans also disrupt the natural condition of the surrounding and interconnected ecosystems, which has unfortunately exerted harmful effects on the ecosystem. Therefore, it is essential to implement an agricultural practice which takes into account the protection and preservation of nature, hence the support for the use of UAV as an essential tool. Mineral fertilisers, organic amendments, microbial inoculants, and pesticides have a significant impact on soil organisms (Bünemann et al., 2006).

A careful and exact application of inputs has the potential to mitigate the detrimental effects on soil organisms. In this study, Abdullahi et al. (2015) conclude that remote sensing technology is crucial to the achievement of precision agriculture. Zhang et al. (2014) proved that the implementation of UAV in agricultural operations will alleviate concerns related to the post-processing of pictures, cost, and training in terms of operation and analysis. Reducing field inputs through more accurate and varied use of artificial fertilisers and pesticides will increase food production and assure sustainability. To achieve this, the divide between researchers, end-users, and various technical breakthroughs must narrow; Anderson and Gaston (2013) contend that the potential afforded by current technology advancements were almost inconceivable just a few years ago.

There are several manufacturers of UAV; their products vary significantly, with limited number of developing devices for the agricultural industry. UAV can save a significant amount of labour by providing a bird’s-eye view, cover more hectares with greater efficiency (Velusamy et al., 2021). The rapid development of new UAV is supporting the improvement of agricultural-sector technologies; these and sensors both incorporate these innovations (Delavarpour et al., 2021). The size, weight, and cost of sensors and cameras are decreasing, while their precision and pixel quality are increasing, creating a wider range of applications. In the agricultural industry, the use of UAV may be defined into two categories: commercial usage and research application (Radoglou-Grammatikis et al., 2020).

UAV are mainly used commercially for irrigation management of fields, crop and yield estimations, and plant chemical content measurement by various methods (Yinka-Banjo and Ajayi, 2019). The quality and content of soil are the first parameters with which plants interact, and are crucial for the achievement of best results. Using UAV (UAVs) to build a map of Sigmoid Sliding Mode (SMC) control, and incorporating this new knowledge into management choices has been proven as both useful and dependable in agricultural productivity (Hassan-Esfahani et al., 2015).

Chen et al. (2015) demonstrate in their study that combining SMC monitoring with an integrated geospatial sensor web may significantly improve the efficiency of farm operations. Fernández-Gálvez et al. (2008) assert that the inaccuracies produced by uncertainties in the effective soil dielectric constant can be reduced over time, despite the fact that there are areas in which improvement is required for more accurate calculations. Other disadvantages of UAV include their initial cost, platform dependability, sensor capabilities, and the absence of a standardised system for the processing of massive amounts of data (Zhang and Kovacs, 2012). Fortunately, these limitations have diminished significantly over the past decade as a result of market evolution and the introduction of new competitors (Wu et al., 2020; Ren et al., 2019).

2.9 UAV prospects and current issues

Agricultural field activities require the use of large, energy-intensive machinery. By introducing UAV, a technology which is light, compact, and energy-efficient, another step is being taken towards more sustainable and ecologically friendly farming practice. Further research is required in order to develop better and more adaptable UAV for the agricultural sector, with less human intervention, by improving flight time and payload on their application, as this could expand and become more appropriate for agricultural purposes (Abdullahi et al., 2015). Utilizing a variety of sensors, including as thermal and multispectral sensors, in conjunction with the extraordinarily high spatial resolution of UAV imaging, enables the development of crop-specific solutions. By focusing on certain problems or facts, such as soil moisture or crop disease, all farmers can benefit from this technology, becoming better managers of their production techniques (Almalki et al., 2021).

Zhang et al. (2017) provide a comprehensive overview of the use of UAV for precision agriculture. In particular, they illustrate the diversity of potential applications and available sensors and platforms. Using heat and micro-hyperspectral sensors, these scientists have determined the water capacity of the units; using thermal aerial imaging, Gonzalez-Dugo et al. (2019) report the geographical variability of crop water status within a commercial orchard containing five distinct fruit tree species. Popovic and Djukanovic (2017) developed an architecture for spraying pesticides on crops which combines UAV with a wireless sensor network (WSN).

The path of UAV is determined by a network on the ground based on air conditions and the amount of chemicals already sprayed. UAV are subject to a variety of problems, including possible security and privacy threats, public safety, public opinion, costs, and other factors (Shakhatreh et al., 2019). These several illustrative examples of some of the technological challenges which potentially limit the widespread use of UAV in civilian airspace; thus, they are of paramount relevance when contemplating their adoption. The 'sense-and-avoid' phenomenon is one of the most significant obstacles to the widespread usage of unmanned aircraft in civilian airspace (Smith et al., 2014)

'Sense-and-avoid' is the basic technique by which piloted aircraft in manned civil aviation avoid collisions (Oztekin and Wever, 2012). This is obviously unfeasible for the widespread deployment of unmanned vehicles, which must thus reach the same degree of safety as 23 manned aircraft operations. UAV' 'sense and avoid' is now the subject of extensive study. Active options include the use of radar or the Traffic Collision Avoidance System (TCAS) to identify collision dangers; however, such systems demand a significant amount of electrical power and are large and heavy, at over 44 lbs (Zhahir et al., 2016). Passive options include the use of machine vision, which minimises power consumption, but necessitates substantial processing capacity (Chen et al., 2015). Although features such as 'lost connection procedures' in UAV must be provided with a method of automated recovery in the case of a lost link, further data link difficulties remain a barrier to their usage for the management and coordination of deployed aircraft (Sahingoz, 2013).

2.10 Data links challenges

Designing aeronautical wireless data networks is challenging due to the vast distances they need to travel, and the aircrafts' rapid speed. These factors, together with the restricted availability of Radio Frequency (RF) spectrum, impact data links' performance. Before commercial and civilian UAV are able to use non-segregated airspace, new data linkages require establishment in order to meet the above-mentioned difficulties (Zeng et al., 2016).

UAV differ from regular aircraft in that, unlike standard aircraft, there is a data link between the pilot at the ground control station and the aircraft. Both the data connection and the ATC are vulnerable to security attacks like as spoofing, hijacking, and jamming (Erdos et al., 2013). Theoretically, a hacker can generate bogus UAV' signals, jam the data link, or even hijack the data link, seizing control of the unit.

This issue is crucial because data linkages are essential for the safety and flawless operation of UAV. Several security elements can now be incorporated into their systems, such as designing the aircraft's system to acknowledge all instructions it receives (Nex and Remondino, 2014). Although the military employs secure data lines such as Common Data Link (CDL) and has other built-in security capabilities, there is currently no permanent solution available to the civilian sector (Nex and Remondino, 2014). The combination of the mission's range and altitude requirements, and notably the communication range, are factors which determine whether UAV of a certain class can or cannot execute a task (Sharma et al., 2020). In brief, the shorter this range becomes, the lower the aeroplane flies.

While agriculture is the largest contributor to Ghana's GDP (Kyei-Mensah et al., 2019), the lack of money to promote innovation and system transformation is one of the sector's greatest challenges (Daum and Birner, 2017). The assumption is that adopting new technologies such as UAV on farms is expensive, and cannot be fully implemented due to a lack of training for farmers and their participation. Inadequate finance and the unwillingness of farmers to use technology constitute obstacles for the majority of farmers in Ghana. This has had an effect on the adoption rate of new technology applications in agriculture throughout Ghana (Banson et al., 2016).

Importantly, Ghanaian farmers believe that modern applications lack certain characteristics associated with traditional farming methods, representing a challenge to their smooth adaptation. Van de Ban and Hawkin (1988) note that perception has an influence on the psychological awareness of a product as a result of the processing of environmental information. In accordance with the decision-making model of Norton and Mumford (1993), there is evidence that, based on perception of a given situation, a farmer develops an evaluation with anticipated results. The farmer's action will be determined by his judgement of all potential outcomes, from his own perspective. In conclusion, Chilonda and Huylenbroeck (2001) assert that: *"farmers' attitudes impact the adoption of new technologies since attitudes are evaluative reactions to the technology and are established when farmers acquire knowledge about it"*. Therefore, it is essential to understand how farmers view this technology in order to better comprehend their decisions regarding its adoption.

Farmers' reluctance to accept certain technologies is attributable to their unattractiveness; the inadequate husk cover of obatanpa, which renders this maize variety unappealing, is a classic example of this (Sahabi, 2016). The adoption of farming technology requires adequate consultation with, and the engagement of, farmers in the initial planning and development of technologies. Kenyon and Fowler (2000) conclude that inadequate communication between researchers and farmers was recognised as a barrier to effective research and development in the 1994 National Agriculture Research Strategy and the 1998-2000 Agriculture Services Sector Investment Programme.

Farmers' expertise and experience are essential to the introduction and uptake of new technology. According to Cohen and Levinthal's (2000) notion of absorptive capacity, scientists must be willing to incorporate farmers' local inventions into their research operations, while local farmers must be eager to share their local expertise. This facilitates the deployment of innovations, hence increasing their rate of acceptance.

Deshler and Merrill (1995) underline the fact that the researcher should assume new responsibilities as instructors, facilitators, and coalition builders, leveraging the demonstrated success of traditional knowledge, local institutional resources, and political commitment as points of reference (Hoffmann et al., 2007). The importance of incorporating local knowledge into policy and programme design and implementation cannot be overstated; inherent to such an orientation is the increased likelihood of forming a closer, more meaningful, and more relevant partnership between communities and researchers, producing research that can be applied to achieve social change (Crane, 2014).

Thus:

- Sustainable agriculture is possible with the intervention of technologies like UAV and the active involvement of all stakeholders.

- UAV provide enormous benefits which outweigh their disadvantages.
- UAV have developed over time, rectifying challenges including data link and speed, showing greater prospects for the further development of the agricultural industry.
- The place of policy and collective action is critical to the future of technological implementation in agriculture.

To support the conclusions of Desher and Merrill (1995), it is generally acknowledged that the use of new strategies in technological development and transfer not only incorporates the perspectives of all key stakeholders, but also increases the likelihood that research findings will be accepted as community property (Stuiver et al., 2004). From the issues highlighted above, it is evident that farmers must be actively involved in the development and implementation of agricultural technology, and that traditional knowledge should be incorporated (Sumner et al., 2010). Chi and Yamada (2002) note that the personal characteristics of the researcher, such as credibility, positive relationships with farmers, intelligence, empathic ability, sincerity, resourcefulness, the capacity to communicate with farmers, and a clear development orientation, are essential for the successful implementation and adoption of new farming technologies such as UAV.

Because geographical settings and spatial ecologies vary from region to region and continent to continent, as do the socio-cultural considerations of farmers, it would be improper to generalise with regard to the drivers and barriers to the implementation and knowledge awareness of UAV, because no two situations are identical.

2.11 Drivers and barriers in implementation processes of the applications of UAV

Drivers are the incentives or factors which enable policymakers and individual users to select a technology to satisfy a particular need, and gain the ability to maintain the technology's deployment (Battistella and Nonino, 2012). In contrast to drivers, barriers are impediments to the adoption and deployment of technology. Frequently, both drivers and obstacles derive from the same origins; their primary distinction is whether the source is present or absent. For example, whether financing is available for the acquisition or development of the technology or not, whether the populace is technologically competent, whether the public favours the technology, and whether it is legal are all key considerations (Silberglitt et al., 2002).

Some constraints and motivations to technology adoption, such as 'trialability' and 'observability'," relate to the technology itself. For example, the performance of the technology may be unpredictable if it has not yet been validated, or if it has intricate connections to other systems which are difficult to evaluate and predict. In this sense, agricultural applications of UAV are a new concept, hence there is insufficient evidence to conclusively demonstrate their additional value (Huang et al., 2013).

Additional technical drivers and obstacles, such as cloud cover and winds, potentially encourage or impede the functioning of a technology; other motivators and obstacles may arise from institutional, economic, cultural, legal, and social variables (Lalani et al., 2016). For example, for a technology to be officially accepted, it must be lawful. National airspaces are governed by rules and regulations which vary between countries. The Federal Aviation Administration (FAA) in the United States, for example, was ordered to change regulations by September 2014 to enable the safe integration of civil UAV (UAVS) into the national airspace system, but this has not yet been delivered in a comprehensive manner (Farber, 2014).

The FAA proposed safety regulations for small UAV undertaking non-recreational missions in February 2015. These rules restrict the flights of small UAV to daylight and visual-line-of-sight operations, defining additional height constraints, operating limits, operator- and aircraft registration requirements, and other factors (Canis, 2015). In the near future, the development of more flexible regulations for 'micro' UAV is possible under the proposed rule (DOT and FAA, 2015). As with all other kinds of UAV, the law currently prevents their commercial use in US airspace at altitudes of over 400 feet, although their operators who have earned a Special Airworthiness Certificate in an experimental category may be granted an exemption. This is a common practice among research colleges which develop UAV, payloads, and novel applications (DOT and FAA, 2015).

Other countries including Japan, Australia, and Canada, have enacted legislation permitting the use of UAV in agriculture on a large scale (Sheets, 2018; Bolman, 2015). While there is limited information regarding airspace rules and regulations in African nations such as Ghana, there is a possibility of these countries adopting certain versions of legal systems currently in force in other nations. In Kenya, for instance, a government official from the Ministry of Transportation in charge of the national airspace stated that efforts are presently underway to replicate the United States' approach to UAV (Rodgers, 2020). In addition, the following characteristics must be met in order for a technology to obtain social acceptance: "societal worry is not excessive, pros and disadvantages have been sufficiently articulated so that informed decisions can be made, and the new product is really used" (Jasper Deuten et al., 1997).

In the context of UAV, because these are deemed a 'stigmatised' technology, social acceptability of this is an intriguing topic of debate (Kamaruzzaman et al., 2019). Frequently, the public's impression of such contentious technology is confused and incorrect, leading to stigmatisation. This is due to a number of variables, such as perceptions of particularly high risk, mistrust in management and government, and the impression of broken promises (Kamaruzzaman et al., 2019). UAV are not the only technology with a negative reputation; examples of this phenomenon include genetically-modified organisms and nuclear energy (Zhang, 2018; Nam-Speers et al., 2020).

In the 1950s, nuclear energy was viewed as an affordable and secure form of energy generation. However, following the 1986 Chernobyl accident in the Ukraine and the 2011 Fukushima Daiichi nuclear disaster in Japan, the public's perception of the safety of this source of energy has become more negative (Ochiai et al., 2014). The stigma associated with UAV largely results from debates about 'drones' and US military strikes in Afghanistan and Pakistan; this features questions of efficiency, i.e., unmanned versus manned missions, ethics such as desensitised killing, and precision, as it relates to collateral damage and indiscriminate civilian deaths (McKinnon, 2014; Koras, 2016). Moreover, UAV raise privacy issues among individuals and organisations which fear that this technology will be used to spy on them (Lee, 2016). The stigmatisation of technology can pose substantial obstacles to its social acceptability and incorporation into society.

In Ghana, the deployment of UAV' applications is potentially affected by the factors listed in the table 2.2

Table 2-4 Comparison of the drivers and barriers to the adoption of UAVs technology based upon Ali and Aboelmaged (2021).

Drivers	**Barriers**	**source**
Severity of the problem	Imperfect mission fit	Lee (2016).
Lack of effective and/or acceptable solutions	Cost of production	Guo et al., (2016)
Interest in innovative, mechanized methods	Technical feasibility, in view of undeveloped infrastructure and technical illiteracy	Bhagwati and Panagariya (2013)
Multipurpose nature of solution UAV for pest control and remote sensing	Security issues	Annor-Frempong and Akaba (2020)
Support from strong stakeholders	Privacy concerns	Shakhatreh et al., (2019).
Ability of UAV to recruit young people into agricultural work	Legal, and possibly political, restrictions	Shakhatreh et al., (2019).

Other researchers, such as Ephron (2015) and Moran (2016), claim that the use of UAV in agriculture is a further step towards an increased reliance on technology, thereby removing the competence of farmers as direct farm managers. The usage of UAV in agriculture is therefore “a seductive but deceptive solution that would gradually expand the disappearance of peasants to the benefit of technocrats.”

Burchfield (2014) demonstrates without any doubt that the African Institute for Capacity Development has frequently discussed UAV in agriculture to increase productivity (AICAD). AICAD has disseminated information about UAV’ applications on farms through training courses, generally aimed at small-scale farmers in South Africa and Tanzania (Nato et al., 2016). According to the data, this initiative has already benefited around 700 small-scale farmers in several African nations, apart from West African nations such as Ghana, who have not signed up for it (Ipate et al., 2015).

According to Burkart et al. (2018), the introduction of UAV (UAVs) in poor nations such as Ghana has recently been a focal point of attention for agricultural policy (Raheem et al., 2021; Quaye-Ballard et al., 2020; Haula and Agbozo, 2020). Despite current agricultural technology, such as the use of axial-flow pumps and new approaches to management, Ghanaian farmers continue to struggle to increase their food output (Emmanuel et al., 2016; Darfour and Rosentrater, 2016; Banson et al., 2016). The deployment of UAV to improve food productivity is therefore at the heart of agricultural growth to support the alleviation of rural poverty if correctly implemented; however, Pierpaoli et al. (2013) assert that the implementation of UAV in agricultural growth is rarely rapid, as the process is subject to the influence of a large number of factors during its implementation process.

Despite this, agriculture plays a significant role in economic growth, boosting food security, reducing poverty, and fostering rural development. It is the primary source of income for over 2.5 billion individuals in poor countries (Saint Ville et al., 2019; FAO, 2018). The installation of UAV to maximise food production in Ghana remains behind schedule. Although Ghana is well-known for its small-scale farming, it is also widely observed that Ghanaian farmers continue to rely on traditional production methods, which has lowered the country's level of food productivity and led to numerous discussions on the use of technological applications on farms in order to increase food production (Muggeridge, 2017).

According to researchers such as Carlier and Desloovere (2018), the next agricultural revolution will be driven by data derived from UAV as a result of their accuracy. This is likely to help to increase agricultural productivity whilst causing minimal environmental damage and improving livelihoods in agricultural communities.

While there have been extensive studies on the profitability and prospects of UAV in the domain of agricultural productivity and food security in developed countries and certain African countries, there is limited study and evidence of the implications of their implementation in developing West African countries, particularly Ghana, on the basis of influencing stakeholders' perceptions and roles. Ghana's agrarian prowess and position as the world's second-largest producer and exporter of cocoa beans, to the extent of 800,000 tonnes annually, render its research essential to the body of knowledge. UAV and other technologies are vital for the attainment of this objective, given their potential to expand output and become the global leader. Therefore, the purpose of this study is to investigate the implications of the implementation of UAV' technology in Ghana, in order to maximise cocoa production in multiple ways, focusing on how stakeholder perceptions and roles influence the implementation of this technology to increase production output, and improve farming management and practices in the Nkawie Cocoa District.

The study seeks to identify further drivers and barriers to their implementation processes and suggests steps that policy-makers can take to overcome barriers and promote the implementation of UAV as a disruptive technology in Ghana's cocoa sector in order to improve production and farming practices. This study is conceptually supported and philosophically framed by the theories of Disruptive Innovation and stakeholders. This is essential for measuring the influence of UAV' technology on farming methods, as well as the activity and/or inactivity of various stakeholders in the deployment process.

2.12 Key Literature Gap

The implementation of technological implications to optimise production in the agricultural sector more specifically in the cocoa farming sector in Ghana in the context of productivity, pest control, and other factors, has not yet been studied in the literature review specifically in the context of Africa and as Ghana whole. As emphasised in the previously mentioned research, there are enough empirical case studies and convincing evidence of the usage of UAV in precision agriculture, especially in industrialised nations, yet there is a substantial vacuum in addressing the issue of UAV's input of cocoa production in Ghana.

The peculiarity of this research study, the first of its kind to the author's knowledge, lies in its attempt to close this gap by concentrating on UAV for food production optimization, pest control, and other factors that have not yet been investigated.

It is stated that by taking into account the study's economic consequences at both the micro and macro levels, readers will be better able to comprehend how productivity in cocoa cultivation is attained and how it has changed (Chidi et al., 2021). The researcher argues that understanding the economic actors and their relationships, which have an impact on the entire procedure and practise, is required in order to maximise productivity in cocoa cultivation.

The identification of opportunities and challenges in the deployment of UAV in the cocoa farming ecosystem allows for the maximisation of production by understanding the economic participants, their activities, and their effects. This makes it possible to improve agricultural practises and initiatives that promote cooperation among parties involved in the cocoa-growing industry. This study looks at how farms, both new and old, develop, maintain, and keep introducing inventive and UAV to maximise output, notably in the cocoa farming sector.

2.13 Summary

Undoubtedly, there is a long historical antecedence and precedence to the use of UAV' technology in the agricultural sector for food production and pest and disease control; these dates back to their first experimentation and use in Japan and the United States of America. Other regions, including Europe, Oceania, and Asia Pacific have all extensively explored the potential of this technology, which has overcome its initial challenges with data links and automatic backups which accompany its implementation. The uptake of UAV' technology has been slow in developing in emerging economies such as Africa due to the various drivers and barriers detailed in this review. Although the process has been slow, there has been recent advocacy and a steady uptake of its implementation at different levels, designed to improve the gains created by it in the agricultural sector.

Chapter 3 Conceptual framework of the study

3.1 Introduction

In the light of the gaps identified in previous studies, there is evidence of an inadequate focus on the impact of technologies on the business model of small- and medium-scale farms. To date, there has been no study in the African context which maps processes classified as 'disruptive' and hence unsettle existing farming practices. Thus, this study applies Disruptive Innovation theory and stakeholder theory as a conceptual framework to examine how both new and long-established farms create, sustain and continuously introduce creative and novel products to maximise food production, while improving pest and disease control mechanisms. Stakeholder theory is particularly helpful, as it enables the mapping of stakeholders' attitudes and their role in the implementation of technological innovation. The application of both theories also enables the author to gain a better perspective on how farmers are likely to accept the implementation of new technologies for high optimisation on their farms as a *'sine qua non'* for the improvement of their gains.

3.2 Disruptive Innovation theory

Over the years, there have been some discrepancies in the theories and definitions which underpin the study and application of the term 'Disruptive Innovation', both in academia and practice owing to the diversity of their perspectives. The initial notion, according to Christensen et al., (2001), gained popularity among industry practitioners before the term 'disruptive' entered the business arena. During these times, the core concepts of the theory of Disruptive Innovation generally remained misinterpreted due to the different perspectives and attributes ascribed to these terms (Christensen, 2006; Raynor, 2011).

Management, as a field of study over the years, has tried to offer prescriptive guidance to industry practitioners because the area of disruptive technology and innovation is an applied field (Vermeulen, 2005; Gulati, 2007; Hambrick, 1994; Kieser and Leiner, 2009). This is based on the notion that disruption theory has the potential to become a benchmark for the assessment of technological relevance in terms of performance and efficiency in both theory and practice, especially the latter for practitioners.

Although there has been widespread citation of the foundational competencies and tenets of this term in diverse academic fields such as healthcare (Yellowlees et al., 2011; Hwang and Christensen, 2008), education (Lagace, 2008; Flynn, 2013), strategy (Lindsay and Hopkins, 2010; Petrick and Martinelli, 2012), organizational theory (Dan and Chieh, 2008; Si and Chen, 2020), marketing (Chomvilailuk, 2016; da Costa Nogami and Veloso, 2017), entrepreneurship (Si et al., 2020; Mureithi, 2017), economics (Coccia, 2020; Urbinati et al., 2022) and digitalization (Gobble, 2018; Nasiri et al., 2017), coupled with varied debates of the fundamental conceptual theories (Christensen, 2006; Dan and Chieh 2008; Markides, 2006; King and Baatartogtokh, 2015; King and Tucci, 2002; Sood and Tellis, 2007, 2011; Gans, 2016), management research into the core premise and concepts of Disruptive Innovation remains uneven.

Christensen et al. (2018) identify the uninformed abuse and overuse of the phrase: 'Disruptive Innovation/disruption' as a substitute term for any new threat or major continuous change to an existing process or system while it is used as a theoretical notion. Early authors and studies characterise Disruptive Innovation as any technology or invention, especially a start-up, which causes a dramatic upheaval in an industry by deconstructing and reconstructing competitive trends, displacing strategic players with large market shares, and driving others out of business (Christensen et al., 2001).

Due to the expansive nature of the terminology's application in both academia and industry, it is potentially problematic to evaluate its definition and understanding in only one context, namely academia or industry. The danger is that, when the core ideas of previous work are obscured by indiscriminate use of its terminology, it becomes difficult for researchers to build on and extend studies on this topic; practitioners who rely on incorrect or misleading renditions of disruptive-innovation theories may be tempted to apply flawed ideas, decreasing their chances of success (Christensen et al., 2018).

Christensen et al., (2018) conducted an extensive search initially using databases such as the Web of Science for all academic articles, citing Bower and Christensen (1995), Christensen and Bower (1996), or Christensen (1997); secondly, the Web of Science database for all academic articles on management published between 1993 and 2016 which cited Bower and Christensen (1995), Christensen and Bower (1996), or Christensen (1997) mention specific disruption terminology ('disruptive technology,' 'disruptive technologies,' or 'Disruptive Innovation'); thirdly, usage by journalists and practitioners identified by searches on Factiva and Lexis Nexis databases for all general-interest articles published between 1993 and 2016 mentioning any of these terms and finally, using a manual process to determine which academic works from which to draw in the conceptualization of Disruptive Innovation.

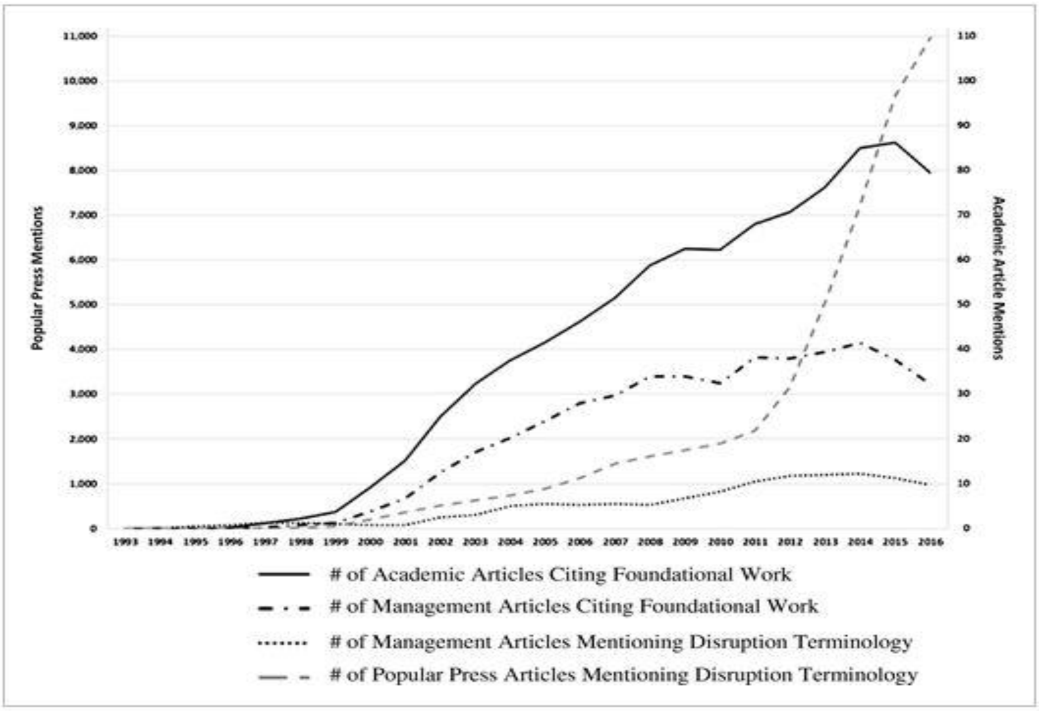


Figure 3.1 Plots of the numbers of academic and general-interest articles from (Christensen et al., 2018).

These trends, as evidenced by Figure 3.1, indicate that the concept of Disruptive Innovation has gained considerable currency among practitioners, and that its terminology has also entered the domain of management research.

Disruptive Innovation theory has been a powerful tool for the development of new markets, whilst also providing some functionality which usually disrupts existing market linkage (Adner, 2006). It is again important to reiterate the fact that Disruptive Innovation theory does not always imply that new entrants or emerging businesses will replace the incumbents, or that traditional businesses as disruptors are not necessarily start-ups.

Existing organizations in themselves can launch technologies, interventions, products and services which may exert disruptive effects on their operations, as well as the market and industry in which they operate (Adner and Kapoor, 2010). In the context of this study, the application of Disruptive Innovation theory creates room for farmers' understanding of the introduction of a new application for their farming practices, and how its deployment potentially changes the social, cultural, and economic landscape of their day-to-day business activities.

As the emergence and popularity of this terminology is attributed to Christensen, it is imperative to define its fundamental base from his work; Christensen et al., (2008) define Disruption Innovation as: *"good enough"* functionality which has a low cost. In other words, this constitutes any novelty whose performance and efficacy supersedes existing mechanisms, while promoting cost-efficiency in the entire process or operation. Disruptive Innovation theory was popularized by Christensen (1997), and has exerted an impact on management research and operational practices; the theory was developed from a series of studies of technological innovation, and has evolved since this time (Nagy et al., 2016). The figure below illustrates the timeline of the evolution of Disruptive Innovation theory, providing a summary based on the early literature relating to technology discontinuity, while also referring to Christensen's papers and books.

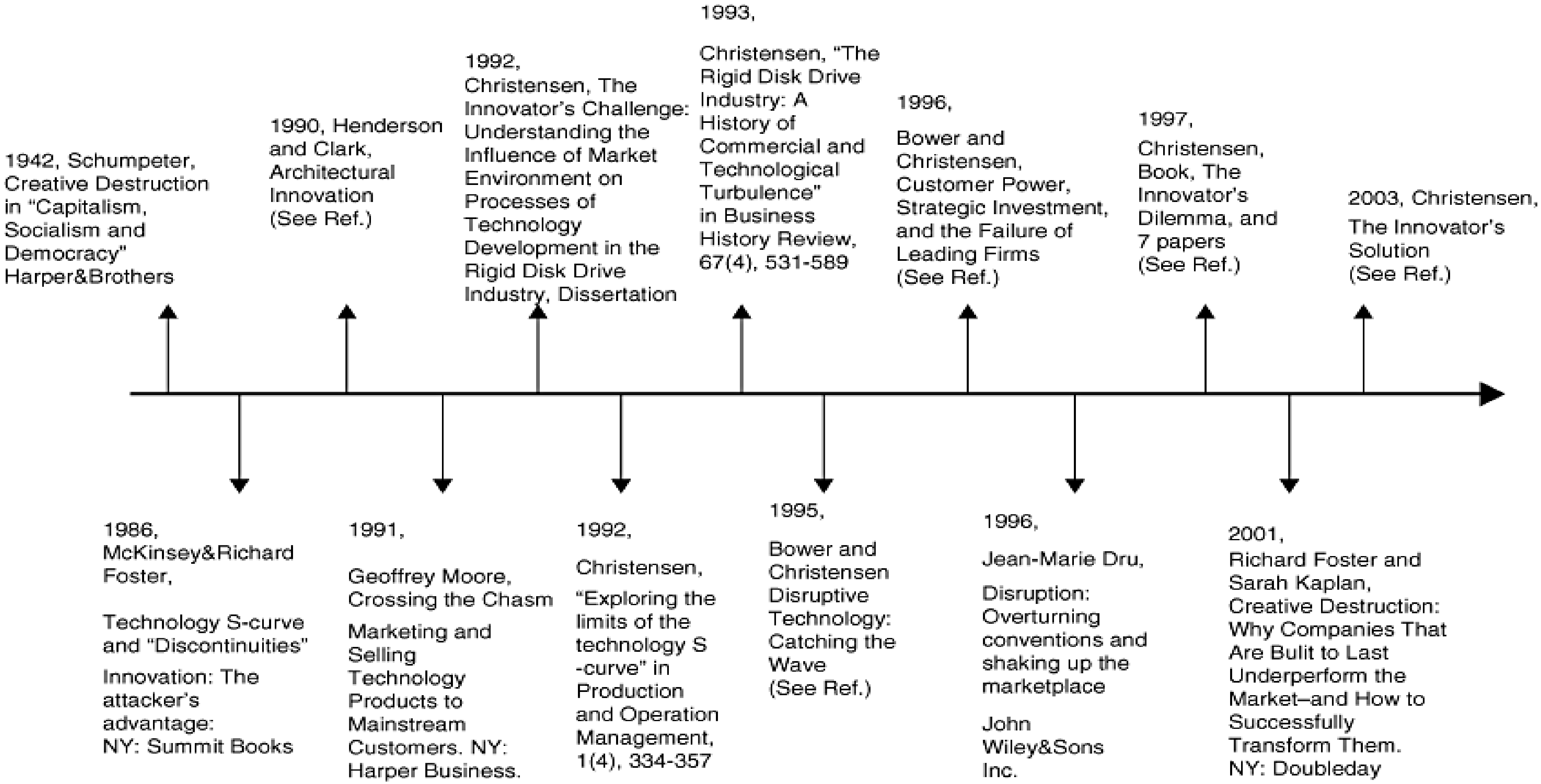


Figure 3.2 Snapshot of the timeline of the evolution of Disruptive Innovation Theory from (Christensen, 1997).

As illustrated in figure 3.2, Disruptive Innovation remained unpopular during the period 1942 to 1996, prior to the 1997 publication of Christensen's influential book entitled 'The innovator's dilemma'. Christensen became more renowned for the study of technological innovation, especially in the context of commercial enterprises. His book demonstrates a comprehensive approach to the basic theory of disruptive technology; in its time, it was one of the bestselling books in this area of study.

Christensen contends that Disruptive Innovation occurs within a process; the value proposition it provides is more efficient than mainstream technologies, while the former is inferior to mainstream technologies when considering the dimensions of performance and efficiency, which are most important considerations for customers (Sandberg, 2002). He introduces the important aspects of changing performance with time, plots the trajectories of product performance provided by companies and requested by customers for different technologies which occur when these trajectories intersect. This is illustrated in the Disruptive Innovation model in Figure 3.3 below.

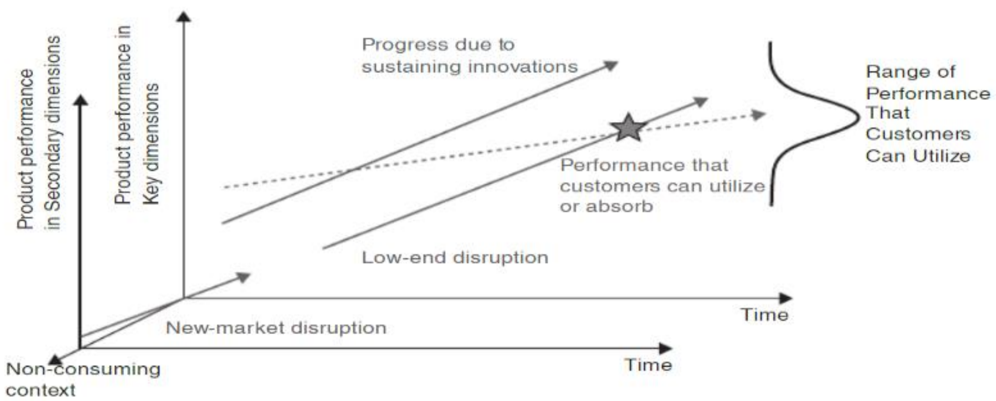


Figure 3.3 The Disruptive Innovation model (Christensen, 1997).

As illustrated in Figure 3.3 of Christensen's Disruptive Innovation model, he recognises two distinct forms of it, namely: *"New market disruptive"* and *"Low-end innovations"*, stating that many disruptions result from a combination of both (Christensen, 2006; Christensen and Raynor, 2003).

The market impact of these two types of disruptive technologies is distinct (Christensen, 1997). New market disruption is essentially the creation of a new demand for a new technology, for example when a corporation establishes a new market sector to service unserved or under-served clients. In contrast, low-end disruption offers similar attributes to current technology at a far lower cost, for example when a company utilises a low-cost business plan to join a market at its base, and claiming a sector (Lin et al., 2015; Guo et al., 2016). Low-end disruption provides products or services for over-satisfied customers at the low-end of the original value network, whereas new market disruption provides products or services with some features valued by new consumers who have never purchased or used the existing mainstream product; it creates a new network by changing the existing competition base of performance (Christensen and Raynor, 2003).

This research is aligned to new market disruption in terms of its aim to create a new market by means of the introduction of new technological applications to optimise productivity in Ghana's agricultural sector, specifically cocoa farming. This research fills a gap because no study of UAV in the African context maps processes which are disruptive and hence unsettle existing farming practices, specifically with high-value crops that are grown on both small- and large scale by small- and medium-scale farmers.

The following section discusses the philosophical foundation of Disruptive Innovation, and how it has evolved to date. This provides an understanding of why this approach is used as a conceptual framework for the purposes of this research study.

3.3 Philosophical foundation of Disruptive Innovation theory

In the early development of this theory, disruptive technology could only serve niche segments which placed a value on their non-standard performance attributes. Due to the fact that the majority of these technologies were in their experimental or trial stages, with less awareness and knowledge of their importance and the paradigm shifts they could cause in processes and procedures, many were reserved and sceptical about their integration into organizational systems (Rigby et al., 2003).

However, further development has enabled the performance of disruptive technology on focal mainstream attributes to satisfy mainstream customers to a sufficient level. It was apparent at this stage that the performance of disruptive technology remained inferior to that offered by established mainstream technology (Dan and Chieh, 2008). It noteworthy here that technological disruption happens when inferior performance on focal attributes is valued by existing customers; this is due to not providing the value expected of the product or service. Thus, the introduction of the new technology displaces the mainstream technology from the mainstream market (Williamson et al., 2020).

Christensen and Raynor (2003) argue that disruption has two prerequisites: performance overshoot and asymmetric incentives; they gathered evidence from a variety of sources, including hard disc drives, earth-moving equipment, retail establishments, and motor controllers. The application of the technology-centric approach has expanded to embrace innovation in services and business models, in addition to technologies.

As a result, Christensen replaced the term ‘disruptive technology’ with ‘Disruptive Innovation’ (Christensen and Raynor, 2003), therefore classifying the latter as lower-end and new-market disruptive innovation (Christensen and Raynor, 2003). Christensen et al. (2013) note that the disruptive nature of Disruptive Innovation is due to its influence on business models, the current system, and society. Below is a comprehensive explanation of the concept of Disruptive Innovation (Christensen, 2013; Ross, 2009; Christensen and Raynor, 2003).

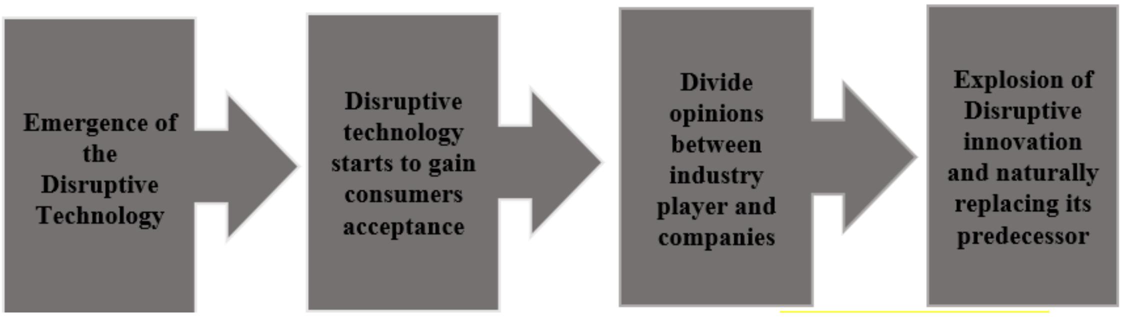


Figure 3.4 The Disruptive Innovation concept from (Christensen, 2013).

This concept, as posited by the figure 3.4, is reflective and synchronises with the contemporary concept of Disruptive Innovation which supports the aims and objectives of this research study. After the emergence of disruptive technology, the debate on the acceptance or otherwise by all the actors or players in the industry and potential concluding reception of the technology is what informs the natural replacement of existing technology or practices.

Various researchers have conducted studies on disruptive technology in previous years. Table 3.1 below evidences some examples, and their impact on the relevant fields

Table 3-1 Examples of technologies with Disruptive impact

Technology	Disruptive impact	Literature sources
Digital media store	Prior to 2003, the majority of individuals purchased their favourite music on compact disc (CD). The development of digital media stores such as iTunes resulted in a fall in the sales of physical press albums such as CDs and long-playing vinyl records (LPs). In addition, cassette tapes were discontinued as a result of continuing decline.	Adeola et al., (2020) Berinato (2010) Wlömert and Papies (2016)
Streaming video portal	With the advent of streaming video portals such as Netflix and Amazon Prime, individuals are increasingly viewing videos online. This ultimately contributes to the decline in television cable and DVD sales. The success of this innovation success is supported by the fact that Netflix shows such as ‘Stranger Things’ have a high viewer count.	Adib et al., (2021) Wayne (2017) Yu (2020)
Smartphones	Since 2013, smartphones have been widely utilised. Since then, various applications, such as Instagram, Snapchat, and WhatsApp, have been established as a result of the usage of smartphones. These items did not exist in previous decades.	Church and Oliveira (2013) Heitmayer and Lahlou (2021) Sarwar and Soomro (2013)
Internet	The availability of the Internet has led to the development of various new technologies, including e-mail, social media, mobile phones, and file sharing.	Currah (2007) Fuchs (2007) Mack and Veil (2017)
Cloud storage	The era of data storage has evolved into common usage; ‘the cloud’ is a concept referring to computer-generated data storage in which digital data is kept in logical pools. The physical environment consists of numerous servers, and is usually owned and managed by a hosting provider.	Chang and Wills (2016) Wu et al., (2010) Yang et al., (2018)

Source: Author (2021).

3.4 The use of Disruptive Innovation theory

The viability and relevance of the use of Disruptive Innovation theory has been challenged and questioned by various academics such as (Barney et al., 1997; Danneels, 2004; Tellis, 2006). According to Barney (1997): “It may simply be the case that some firms are lucky in their choice of technology”. He further maintains that these companies are subsequently scrutinized, and a retrospective rationale for their success is formed. ‘Ex ante’ arguments are also based on the performance of market demands, including other dimensions and performance level technologies which satisfies the criteria as being variable.

Sood and Tellis, (2011), for example, contend that the theory suffers from circular definitions, inadequate empirical evidence, and the lack of a predictive model. Relating to the findings of their study: ‘Demystifying disruption’, they conclude that potentially disruptive technologies are more expensive than existing ones, which rarely disrupt companies and markets as they are. The study moreover states that technological disruption is not permanent, due to the multiple overlaps in technology performance, and the coexistence of numerous rival technologies without one disrupting the other.

On the other hand, some researchers have established the importance of this theory in practice, providing strong practical evidence on companies and the market (Schmidt and Druehl, 2008). Christensen et al., (2013) after two decades’ appraisal of the theory of Disruptive Innovation as captured in their study in the Harvard Business Review, note that:

> “The theory of disruptive innovation, after its introduction in 1995, has proven to be a powerful way of thinking about innovation-driven growth. Many leaders of small, entrepreneurial companies praise it as their guiding star; so, do many

> executives of large, well-established organizations, including Intel, Southern New Hampshire University and Salesforce.com".

To debunk the assertions made by Sood and Tellis (2011) which cast doubts on the longevity of Disruptive Innovation and other issues as it applies to the theory posited by Christensen (1997) in his book: 'The Innovator's Dilemma', King and Baatartogtokh (2015) revisited the sample of the 77 Disruptive Innovations discussed in the book to conduct an expert appraisal of the theory's success and relevance to the current existence of these disruptions.

- 802.11 (Wi-Fi)
- Amazon.com
- Barnes & Noble
- Beef processing
- Bell Telephone
- Black & Decker
- Blended plastics
- Bloomberg
- Boxed beef
- Canon photocopiers
- Catalog retailing
- Charles Schwab
- Circuit City, Best Buy
- Cisco
- Community colleges
- Concord School of Law
- Credit scoring
- Dell
- Department stores
- Digital animation
- Digital printing
- Discount department stores
- Disk drives
- eBay
- ECNs
- Email
- Embraer and Canadair regional jets
- Endoscopic surgery
- Fidelity Management
- Flat panel displays (Sharp and others)
- Ford
- Galanz
- GE Capital
- Google
- Honda motorcycles
- Hydraulic excavators
- Inkjet printers
- Intel microprocessor
- Intuit's QuickBooks
- Intuit's TurboTax
- Japanese steelmakers
- JetBlue
- Kodak
- Kodak Fun Saver
- Korean auto manufacturers
- Linux
- MBNA
- McDonald's
- MCI, Sprint
- Merrill Lynch
- Microsoft DOS
- Minicomputers
- Online stockbrokers
- Online travel agencies
- Oracle
- Palm Pilot, RIM BlackBerry
- Personal computers
- Plastics
- Portable blood glucose meters
- Salesforce.com
- Seiko watches
- SonoSite
- Sony
- Southwest Airlines
- SQL database software
- Staples
- Steel mini-mills
- Sun Microsystems
- Toyota
- Toys-R-Us
- Ultrasound
- University of Phoenix
- Unmanned aircraft
- Vanguard
- Veritas and Network Appliance
- Wireless telephony
- Xerox

Figure 3.5 Sample of 77 Disruptive Innovations – 'The Innovator's Dilemma' from (King and Baatartogtokh 2015).

The sample of Disruptive Innovations shown in Figure 3.5 corresponds to the 75 cases listed in 'The Innovator's Solution' and two cases discussed at length within 'The Innovator's Dilemma' (King and Baatartogtokh, 2015). The outcome illustrates the fact that most of the case studies and companies included in them remain functional, and are often leaders in their respective sectors.

The results of the expert study also establish the relevance of this theory both to management research and practice in today's world, but acknowledge the fact that intense competition and the changing human, geographical and market environment and conditions demonstrate different motivating forces on the subject of Disruptive Innovation, which generate unexpected outcomes. These clearly provide credibility and validity to the application of Disruptive Innovation theory to this present study. The following section provides an in-depth discussion of the role of the stakeholder theory and how it has been used, together with Disruptive Innovation in this context for the implementation of UAV, specifically on cocoa farms in Ghana.

3.5 Stakeholder theory

Every organization or business ecosystem has certain individuals who have a stake or interest in its affairs of the business. From 'Persons with Significant Interest (PSIs)' to pressure groups, the pool of stakeholders in any organization varies depending on stakeholders' interest in it. This renders the study of stakeholder theory a critical component in the assessment of this interplay and the influences various individuals exert on the outcome of organizational decisions and choices. Stakeholder theory motivates stakeholders to interact to mutual advantage, because they do not work in isolation (Freeman et al., 2010; Parmar et al., 2010; Savage et al. 2010). Notably, Goodman et al. (2017) propose a dual collaborative and proactive role for stakeholders, concluding that secondary stakeholders potentially play a larger influence in innovation adoption than primary stakeholders.

3.5.1 The philosophical foundation of stakeholder theory

Gossy (2008) holds that the stakeholder approach, and the interventions of stakeholders, has been existence since the 1960s when it was initially introduced and defined by the Stanford Research Institute (SRI). Freeman and Reed (1983) note that the definition of stakeholder refers to: "… those groups without whose support the organisation would cease to exist…", with examples including societal lenders, suppliers, customers, employers, and shareowners. Notably, this definition provides a tool for the SRI which complements these early notions (Freeman and Reed, 1983). Ansoff (1965) contends that stakeholder theory was first introduced in business management by academics from a normative discipline of business such as business ethics and social issues in management, as well as from theories such as strategic management, system theory, and organisational theory.

Due to contributions from research studies concerning strategic planning, the stakeholder concept has become increasingly popular. Academics such as Rhenman (1968), among commentators on organisational theory, use the word 'stakeholder' to specifically identify the individuals or groups which rely on a company for the achievement of their own objectives, and on whom the company is dependent (Freeman, 1984).

It is additionally highlighted that the influence of system theory in the majority of research studies has significantly contributed to the development of stakeholder concept theory. The stakeholder analysis technique was established by Ackoff (1974); in this methodology, Ackoff argues that individuals and organisations are the components of larger systems in which stakeholders' interactions, participation, and support are essential for system design and the resolution of numerous social problems by reducing conflicts between levels; namely subsystems i.e., individuals, systems i.e., organisations, and super systems i.e.,, communities, society, and the environment (De Gooyert et al., 2017). Ackoff (1974) states: "...an organisation should serve its parts (individuals) and the wholes of which it is a part (environment and society) as much as it serves its own interests."

In 1970, the necessity of incorporating non-traditional business challenges into the strategic management process gained widespread popularity and recognition. Freeman and Reed (1983) hold that non-traditional corporate issues include governments, special interest organisations, trade associations, foreign rivals, and complex concerns including labour rights, environmental damage, consumer rights, tariffs, and government regulations. Freeman and Reed (1983) observe that stakeholder theory provides a new way of viewing the mutual relationships between those who have a stake in an issue or an enterprise.

3.5.2 The concept of stakeholder theory

Academics such as Freeman and Reed (1993) and Gibson (2000) emphasise the significance of stakeholder participation in corporate operations, contending that stakeholders have a direct interest in the organisation and the ability to influence it, with their participation potentially also affecting the business's operations (Todaro et al., 2022). Specifically, stakeholder theory has been widely applied by various management frameworks to acquire a better knowledge of the macro- and micro-settings in which a business functions, because it is believed that opportunities are more effectively exploited via the efforts of corporate stakeholders (Freeman, 1984). Effective organisations therefore focus on: "...all and only those interactions that can impact or be affected by the attainment of the organization's aims..." (Freeman, 1999).

Through the framework it proposes, stakeholder theory enables the recognition of a variety of stakeholders, managing both their interests and obligations. Caroll and Nasi (1997) assert that the theory provides managers and directors with guidance for the incorporation of an ethical component into their business activities by considering the interests and demands of stakeholders inside the organisation and "...others out there in society...".

Stakeholder theory comprises three distinct elements, namely: descriptive, instrumental, and normative (Donaldson and Preston, 1995). The descriptive element analyses the behaviours of managers, companies, and stakeholders, whereas the instrumental dimension evaluates the influence of stakeholders on the company's effectiveness, focusing on the management of stakeholder interactions. The normative dimension defines the moral responsibilities of managers with regard to their stakeholders, with the aim of outlining and recognising stakeholders' interests, even in the absence of evident advantage.

Freeman and Dmytriyev (2017) study the application of this technique in an empirical research study in which where descriptive, instrumental, and normative approaches were used to a stakeholder theory analysis disclosure model to predict and explain particular Corporate Social Responsibility (CSR) behaviours. It has also been used to analyse a company's strategic position, which reflects the responses of a company's main decision-makers to societal expectations and economic performance (Bosse et al., 2009).

Thus, it is concluded that: "given specific levels of stakeholder power and strategic stance, the bigger a company's social responsibility activities and disclosures are, the better its economic success" (Roberts, 1992).

Early academics investigated a variety of definitions and views of the stakeholder notion. In describing stakeholder theory in strategic management, Freeman (1984) asserts that stakeholders encompass "...any group or individual who may impact or is affected by the fulfilment of the organization's objectives". Freeman classifies stakeholders as: owners, consumers, competitors, workers, suppliers, governments, local community organisations, special interest groups, environmentalists, consumer advocates, journalists, unions, trade associations, the financial community, and members of political groups. Carroll (1993) describes stakeholders as "any individual or group who may influence or is influenced by an organization's actions, choices, policies, practises, or goals". To expand on the profile and influence of stakeholders, Carroll's definition emphasises the necessity of viewing an organization’s policies and practices as essential to the entire stakeholder engagement process.

Although Donaldson and Preston (1993) reaffirm the core concept of the definition of stakeholders as including “persons or groups with legitimate interests in the procedure and/or substantive aspects of corporate activity...”, many critics argue that popular definitions such as this, and those of Carroll (1993) and Freeman (1984), are too broad to identify who, or what, truly constitutes a stakeholder (Agle et al., 1999).

The incorporation of the non-human natural environment into the concept of stakeholders has received considerable attention in recent research studies (Haigh and Griffiths, 2009). It has been stated that the natural environment, its systems, and its living and non-living elements should be viewed as one or more stakeholders of businesses, because non-human nature, such as oil drilling, mining, fishing, and forestry, form part of the business ecosystem, thus enterprises should recognise their links to the availability and pricing of natural resources. The non-human natural environment is likewise a political and economic entity because nature has, and will continue to, provide economic value to all organisations. Driscoll and Starik (2004) contend that businesses have to integrate the natural environment into the process of identifying stakeholder and formulating, implementing, and evaluating plans.

Numerous academics offer stakeholder categorization systems; Goodpaster (1991) classifies stakeholders as fiduciary and non-fiduciary, which determines the distinctions between the types of ethical interactions between management and stockholders, and management and other parties such as workers, consumers, and suppliers. In contrast, Jones (1995) divides stakeholders into internal and external individuals with an interest in the organisation, distinguishing stakeholders as those within the organisation and those outside it (Richter and Dow, 2017). Clarkson (1995) distinguishes between major and secondary stakeholders; he describes the major stakeholder groups as comprising shareholders and/or business owners, staff, consumers, and suppliers who are essential for a company's survival. Secondary stakeholder groups are those which are not vital to the company's existence but have the ability to influence or impact the organisation; they are personally influenced and affected by it. Media and interest groups, for example, can be both a danger and an asset to a company (Clarkson, 1995).

Clarkson (1995) argues that the continued participation of primary stakeholders is essential to a company's survival, therefore it is argued that businesses should be fair and balanced in their interactions with their primary stakeholders, treating them adequately by acknowledging their interests, claims, and legitimacy (Benn et al., 2016; Schraeder and Self, 2010). Mitchell et al. (1997) cite legitimacy, power, and urgency as characteristics of stakeholders, suggesting that their importance is positively correlated with these three characteristics which managers regard them as possessing (Mitchell et al., 1997).

Using these criteria, the most significant stakeholders are therefore those with an urgent or time-sensitive stake in the company, the ability to influence the judgement of the company's managers, and the perception that their application of power is lawful (Chapleo and Simms, 2010). Friedman and Miles (2002) suggest a paradigm, based on a realist theory of social development and differentiation, to identify stakeholders on the basis of examination of organisation and its stakeholder interactions. In their study, stakeholders are classified as 'required' or 'contingent', and 'compatible' or 'incompatible' (Mitchell et al., 1997).

However, many of these studies and models consider stakeholder analysis from the standpoint of company operations and profitability, focusing on those stakeholders who have the potential to directly impact the company's operations and/or who hold a position of authority (Clarkson, 1995; Friedman and Miles, 2002; Goodpaster, 1991; Mitchell et al., 1997; Sheehan and Ritchie, 2005). This potentially leads to the disregard of those stakeholder groups with less influence, or those who do not immediately affect the organization's operations.

For example, Mitchell et al. (1997) asserts that the viewpoints of management determine the significance of stakeholders. An emphasis given to one stakeholder over other risks producing some bias in the context of social and environmental issues from a strictly administrative perspective (Lu and Abeysekera, 2014). These are most likely to be missed by managers because they are less salient, meaning that they have less authority, urgency, and legitimacy, than other economic stakeholders (Currie et al., 2009).

3.6 The application of stakeholder theory in agriculture, specifically cocoa farming

The application of stakeholder theory opens more avenues for other parties within the agricultural industry, specifically the cocoa farming sector, to be considered in its decision-making and for developmental planning. This theory is a very robust means of optimising productivity and meeting objectives by contributing to, and forming, collaborations (Shahbaz et al., 2018). It is important to highlight the fact that the stakeholder framework facilitates the identification of cocoa industry stakeholders while also understanding their profiles.

Freeman et al. (2010) hold that a stakeholder is: *"...any group or individual who may impact or is affected by the organization's objectives."* Thus, cocoa industry stakeholders potentially include the host community i.e., farmers in local villages and government authorities such as the Ghana Cocoa board (COCOBOD), as well as representatives from economics / rural affairs / marketing and branding and other groups which could exert an impact on, or be affected by, the sector.

Savage et al. (2010) contend that stakeholder theory requires stakeholders to work for the mutual benefit of all parties, because they do not act in isolation. Goodman et al. (2017) propose a dual collaborative and proactive role for stakeholders, arguing that secondary stakeholders play a more significant role in the adaptation to a Disruptive Innovation than key stakeholders.

After consideration of these diverse viewpoints on stakeholder categorisation, it is important to consider the other two stakeholder theories, namely traditional and modern stakeholder models, and their application to this research in the Ghanaian cocoa sector, as suggested by Donaldson and Preston (1995). The latter hold the moral responsibilities for the operation and administration of organisations, constituting the normative 'heart' of stakeholder theory. Byrd (2007) proposes that all stakeholders' interests have inherent worth and presupposes that each one has the right to be regarded as ends, rather than means. Consequently, all cocoa industry stakeholders' interests and values should be considered in the process of agricultural development planning. It is not necessary for every stakeholder to participate equally in the decision-making process, although their interests should be acknowledged and understood (Donaldson and Preston, 1995).

Numerous researchers, including Aas et al., (2005), Byrd (2007), Currie et al., (2009), and Sheehan and Richie, (2005), have conducted research within the agricultural industry, specifically the cocoa sector, to demonstrate the significance of stakeholder identification and analysis due to their substantial impact on farming optimisation and productivity.

Exploratory research undertaken by Yamoah et al. (2020) to identify the potential to increase innovation in Ghana's cocoa sector identifies the key players in the cocoa business, their roles, and how they interact with one another in the discharge of their responsibilities.

Table 3-2 Stakeholders and their functions in the cocoa industry

Number	Name of stakeholder	Function / role played in the cocoa industry	Location of head office	Relationship with other institutions
1	Ghana Cocoa Board (COCOBOD)	COCOBOD is a permanent public board, formed in 1947 by ordinance. In accordance with the government's liberalization agenda, COCOBOD currently formulates regulations, supervises, and regulates the Ghanaian cocoa business.	Accra	2;3,4;5;6,7;8;9.
2	The Cocoa Marketing Company (Ghana) Company Limited (CMC)	CMC is responsible for the external marketing of the Cocoa Processing Company Limited's cocoa beans, cocoa liquor, cocoa butter, and cocoa cake.	Tema	1;3;6
3	The Cocoa Processing Company (CPC)	CPC transforms unprocessed cocoa beans into semi-finished goods including cocoa butter, liquor, cake, and powder. In addition, Golden Tree chocolate, Couverture 'Pebbles' and the Vitaco instant chocolate drink are produced.	Tema	1;2;6;8
4	The Cocoa Research Institute of Ghana (CRIG)	CRIG investigates problems and pests of cocoa, kola, coffee, shea nut, cashew, and the tallow tree (Pentadesmabutyracea), soil fertility, and good agricultural practices, developing planting materials for use by farmers, such as cocoa seedlings/clones and coffee clones, with the goal of increasing yield and farmers' income; it also conducts research into the development of other products from cocoa waste and the associated by-products.	Accra	1;4;7;9
5	The Cocoa Swollen Shoots Virus Disease Control Unit (CSSVDCU), now renamed as the Cocoa	CSSVDCU/CHED is responsible for cocoa farming expansion and the management of cocoa swollen shoot viral disease.	Accra	1;4;7;9

	Health and Extension Division (CHED)			
6	The Quality Control Ltd (QCCL)	QCCL is in charge of inspecting, grading, and sealing cocoa, coffee, and sheanut for export, as well as fumigating and storing cocoa.	Tema	1;2;3;8
7	The Private Licensed Buying Company (LBC) and Hauliers	The LBC is responsible for domestic bean procurement and transport to the export port.	Accra and Kumasi	1;2;3;9
8	The Seed Production Unit (SPU)	The SPU is accountable for the reproduction and distribution of enhanced cocoa and coffee planting supplies.	Accra	1;4;5;9
9	The Farmers represented by Ghana Cocoa, Coffee, and Sheanut Farmers Association (GCCSFA)	At agricultural level, cocoa is produced by the farmers. The GCCSFA manages the acquisition and distribution of agrochemicals (insecticides, herbicides, and fungicides) and spraying equipment. It also serves as a nationwide voice for farmers' perspectives.	Accra	1;4;5;7;8

Source: Yamoah et al. (2020).

As illustrated in Table 3.2, Yamoah et al., (2020) study evidence of how all of these stakeholders are actively involved in the management and processes for the development of the sector; this includes planning and management i.e., education on the cocoa farming practices from the initial stage of nursing to planting, pest and disease control, to the harvesting stage. Amlalo and Oppong-Boadi (2015) note that effective collaboration and the involvement of the various cocoa industry stakeholders is essential for the implementation of any new applications or management which will have a direct impact on the optimisation of productivity within the industry.

As evidenced in Table 3.2 by Yamoah et al., (2020), the interconnected nature of the stakeholder community in the cocoa industry renders it essential for a collective consultation to take place in the case of the introduction and implementation of new technologies such as UAV. The cocoa industry's stakeholders have different attributes, which can have an impact on their involvement in forming a collaboration towards the achievement of their goals. These attributes include knowledge, skills, interest, attitude, exposure, and experience (Bitzer et al., 2012). In the light of this, and to reduce any potential conflicts of interest, it is essential that the actors, interests, and values of the cocoa industry, enable stakeholders who are normally excluded from decision-making to participate in the agricultural development process in order to facilitate effective collaboration and partnership among them.

The concept of stakeholders theory provides an analytical tool for their identification and a perspective for examining their concerns, rivalries, and conflicts of interest. To date, there is little empirical research on issues involving stakeholders in the agricultural sector, specifically in the context of cocoa management, and many studies show a lack of stakeholder views when evaluating the growth of this sector (Yamoah et al., 2020; Abbey et al., 2016).

According to the normative core of stakeholder theory, the identification of stakeholders in the cocoa business comprises individual farmers, farmer associations, district, and regional boards (Donaldson, 1999). In view of this, this study considers a wide range of cocoa industry stakeholders, including both direct and indirect cocoa industry stakeholders based on their level of involvement with cocoa production and management.

Direct cocoa industry stakeholders are those who are generally involved in the production of cocoa and the management of day-to-day business, including farmers, harvesters, and farm labourers. Indirect cocoa industry stakeholders are those who are less involved in production activities, such as governmental bodies, exporters, and buyers. These indirect cocoa industry stakeholders are also affected by, and themselves affect, the optimisation and productivity of the cocoa farming business.

Due to the significance of stakeholder collaboration, participation, and involvement, it has been suggested that additional research be conducted to increase understanding of the opportunities and challenges of stakeholder involvement and participation in this sector (Byrd, 2007; Hermans et al., 2017). The problems include stakeholder involvement and participation, including mistrust of government policies, poor administration, and operating in isolation (Jamal and Stronza, 2009; Sautter and Leisen, 1999).

Although stakeholder theory supports the identification of stakeholders' interests, concerns, attitudes, and values, it does not explain the variables which potentially impact these, nor does it explain decisions regarding their participation and engagement. In addition, stakeholder theory fails to explain the complex interrelationships between the diverse cocoa industry stakeholders, which, according to this research, are significant factors which influence the development of effective collaboration and involvement for technological implementation and knowledge-sharing.

Moreover, co-operation, in the form of relational networks, is based on common interests, shared values, mutual advantages coming from the reciprocal and complementary exchange of connections among the actors, and the degree and nature of their interdependence, trust, and power (Pavlovich, 2001; Sheikh et al., 2011). Consequently, it is essential to comprehend the nature of the interrelationships between stakeholders, as this may exert a substantial impact on growth prospects and obstacles in such collaborations. Figure 3.6 shows the stakeholders in the cocoa industry in Ghana:

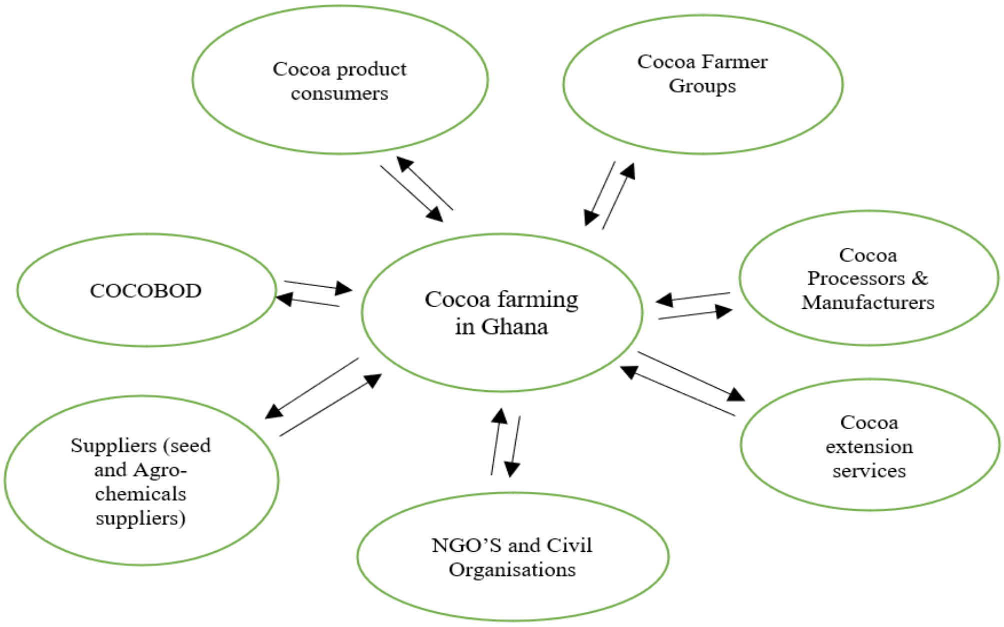


Figure 3.6 Cocoa industry stakeholder concept from Yamoah et al., (2020).

Figure 3.6 illustrate the cocoa industry stakeholder theory concept, providing a comprehensive snapshot of the stakeholder actors in Ghana; it focuses on the key cocoa farming stakeholders from the public and private sectors, NGOs, and other local groups, clearly identifying and formally recognising the actors who are involved in the farming processes, regardless of their levels of influence on farmers' decisions.

3.7 Key gaps in the relevant literature

To date, there is no study which applies the Disruptive Innovation and stakeholder theories in an analytical study of the implementation of technological implications in order to optimise production in the agricultural sector, and more specifically in the cocoa farming sector in Ghana in the context of productivity, pest control and other factors. As highlighted in the previously discussed studies, there are sufficient empirical case studies and clear evidence of the use of UAV in precision agriculture, especially in developed countries, but there is a significant gap in addressing the issue of stakeholders' input; this results in a failure to explain and address the influence of the interrelationships of farming stakeholders on the adoption of Disruptive Innovation as a collective process for decision-making.

To the author's knowledge, the novelty of this research study, which is the first of its kind, is that it aims to fill this gap by focusing on the role of the cocoa farming stakeholders and their interrelationships, and how these influence productivities by the implementation of technological application, specifically UAV for food production optimization, pest control, and other factors, which have not been previously studied. The focus on cocoa is an additional dimension of the novelty of this research, which has not been widely explored.

It is argued that this study enables readers to gain a better understanding of how productivity in the cocoa farming is achieved and how it has evolved, by considering its economic implications at micro- and macro- levels (Chidi et al., 2021). The researcher believes that, in order to maximise production in cocoa farming, it is necessary to comprehend the economic players and their interrelationships, which impact the entire process and practice.

This study's conceptual framework as discussed in sections 3.2 is based on the relational method of economic geography, which captures micro- and macro- behaviours and socio-spatial interactions among players (Boggs and Rantisi, 2003; Chidi et al., 2021). As stakeholder theory is applied in order to identify cocoa farming stakeholders, it becomes vital to comprehend their attitudes, interests, difficulties, and comprehension of cocoa farming issues such as pest control. The notion of Disruptive Innovation facilitates the introduction of this technical application, such as UAV, within a geographical region and provides the opportunities and limitations for its exploitation.

Understanding the economic players, their activities, and their repercussions enables the identification of possibilities and obstacles in the application of UAV in the cocoa farming ecosystem in order to maximise production. This allows for the enhancement of agricultural techniques and activities which encourage collaboration among cocoa growing stakeholders.

To date, the adoption of both approaches, i.e., Disruptive Innovation and stakeholder theory has yet to be established. However, the acceptance of Disruptive Innovation in the context technological adaptation has been discussed in section 3.4 and illustrated in figure 3.5 of how this theory has been implemented in other studies. This research study examines how both new and established farms create, sustain, and continuously introduce creative and novel products such as UAV to maximise productivity, particularly in the cocoa farming sector, and its interplay with stakeholders.

3.8 Summary

This chapter demonstrates how the combination of Disruptive Innovation and stakeholder theory may be utilised to analyse the interrelationships between cocoa sector stakeholders at regional level, including farmers, governmental authorities and related organisations and associations. It again demonstrates how the two theories are utilised to optimise cocoa growing sector production. It is no doubt this is distinct theoretical contribution to academic research as it is the first in the field of cocoa farming research in a country with an emerging economy to apply both stakeholder theory and Disruptive Innovation theory by investigating the implementation of UAV as a disruptive technology for cocoa farming. These two theories help the researcher to understand and provide evidence of the interplay which influences the acceptance by cocoa farmers and stakeholders within the study area of the implementation of UAV for cocoa farming.

The application of the two theories provides a holistic understanding of the cocoa farming sector, with their application providing a relational framework for a better understanding of the effective implementation of technological applications for maximising productivity in relation to stakeholders' influences on the smooth implementation of these applications, or otherwise.

The following chapter (Chapter 4) examines the reasoning for the selection of the methodological/philosophical approach, the criteria for the selection of case study locations, and the data-gathering methods used.

Chapter 4 Research methodology

4.1 Introduction

This chapter describes the data collection process, the research strategy, methodology, and procedures. It describes and examines the qualitative study strategy, the use of the philosophical basis as an interpretative perspective, research methodology, research design, study area, data collection techniques and tools, participant selection methods, data validation, data analysis procedures, and ethical issues.

Despite the increasing adoption of UAVs by developed nations such as Finland, Canada, Germany, and the United States on their farms to increase productivity, the proportional uptake of this technology in the majority of African nations, Ghana included, remains relatively low (Muggeridge, 2017). This project aims to evaluate the use of UAV to increase cocoa field output in Ghana, namely in the Ashanti Region. This is a field of research that has not been thoroughly investigated to date.

Although a number of authors, including Owusu-Amankwah et al. (2017), Curry and Kirwan (2014), Bartlett (2013), and Friedman (2015), have used qualitative research methods to investigate agricultural development in Ghana, none have incorporated the social constructivist philosophical assumption into these studies, particularly in the context of an interpretivist paradigm. This study’s central proposition is to investigate the use of UAV to increase the productivity of cocoa farms in Ghana; consequently, it employs a qualitative research approach as its primary methodology, which is underpinned by a social constructivist philosophical assumption.

A qualitative approach allows both researchers and participants to provide a thorough account of events, processes, and subjectivities within a specified framework (Al-Dajani and Marlow, 2013). Thus, this methodology provides a comprehensive set of information on the technology's acceptability in terms of its drivers and barriers on cocoa plantations in Ghana.

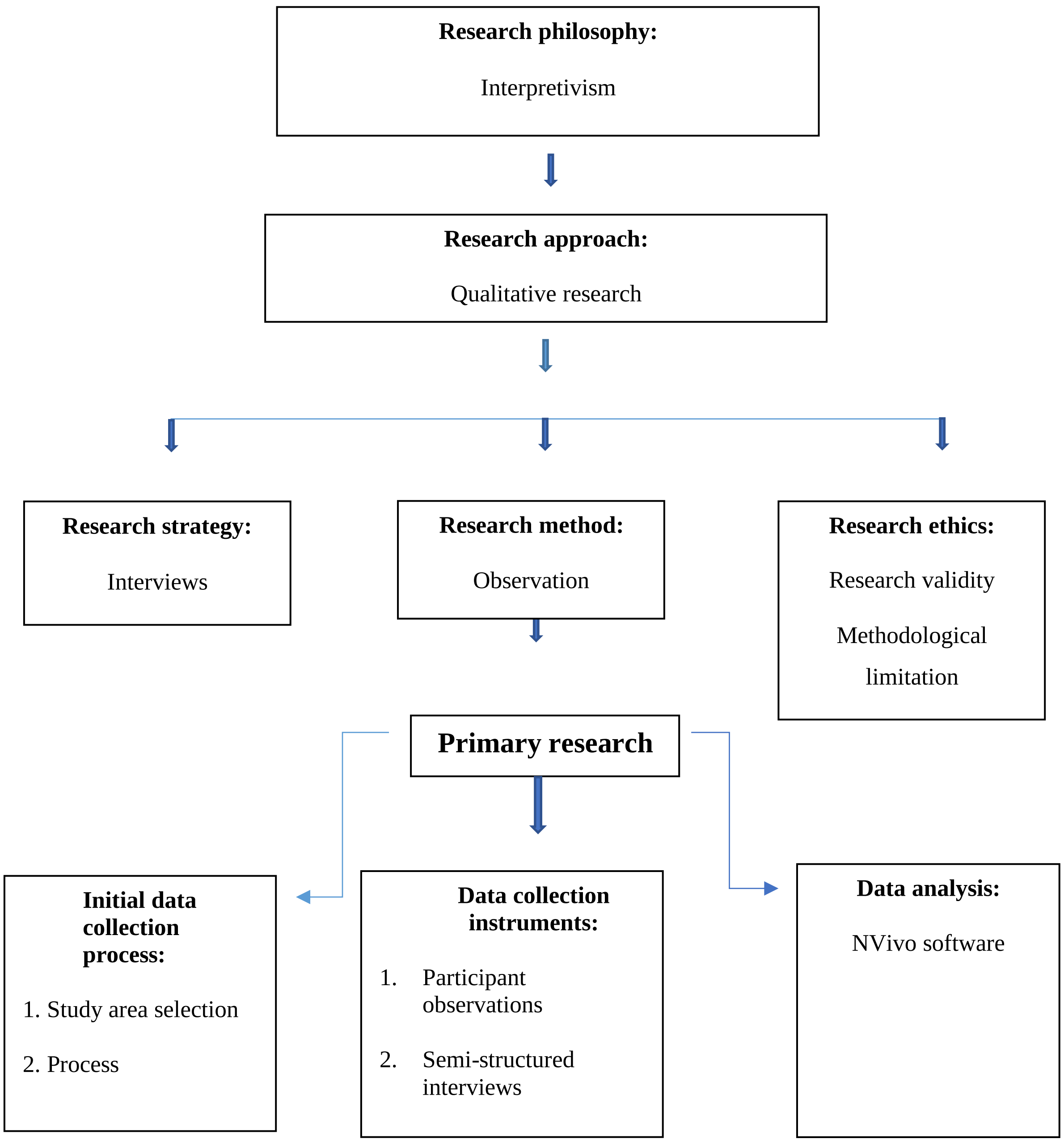


Figure 4.1 Research process framework from (Author , 2021).

Figure 4.1 demonstrates the research procedure to be followed as a guide for the study while providing a clear underpinning of the data collection process and the analysis to be carried out thereafter. It clearly shows the instruments to be employed as well as the framework to be considered in underscoring the tenets of limitation and validity that will be ascribed to the approach of this study. This leads to the choice of the philosophical foundation to be considered for this study.

4.2 Philosophical foundation of the research

The philosophical foundation of any research study is an essential feature because it guides the research process, underpinning it with a philosophical assumption defining the rationale behind the research design and methodology employed (Hunt, 1991). Thus, underpinning each methodological approach is a sequence of conventions regarding the nature of realism which, in turn, grounds and limits knowledge about what exists.

The research focuses largely on the Ghanaian cocoa farming ecosystem, such as farmers and their stakeholders, in terms of their willingness to embrace the deployment of UAV in their agricultural operations. The purpose of the study is to examines the implications of the use of UAV on farms in Ghana to maximise food production and increase food security, particularly in the cocoa production industry.

Therefore, the constructivist method is considered appropriate for addressing the research objective of this study. Marvesti (2004) holds that the constructivist approach provides a comprehensive explanation of how situational and cultural diversity affect reality. Over time, the nature and structure of connections change and evolve, arguably, in response to economic, cultural, and political factors (Marvesti, 2019). These changes are likely to have an impact on people’s worldviews, and potentially their understanding of reality.

From this perspective, the ontological premise that realities are diverse and socially constructed on the basis of individual or group experiences in a particular local context is evident (Guba and Lincoln, 2004). Guba and Lincolin (1989) contend that ontological assumptions are those which answer the questions: 'what can be known?' and 'what is the nature of reality?'. This provides an understanding of the methodological or philosophical attitude that research has utilised, thereby eliciting and compiling individual and collective understanding of social realities and their interpretations in relation to the advent of contemporary technology.

Guba and Lincoln (2004) hold that the constructivist epistemological approach posits that the data collected are the product of interactions between the researcher and the topic under investigation. According to constructivists, knowledge generation is of the utmost importance, because it is defined by the interactions and engagements between the researcher and the participants. Thus, the methodological premise of constructivism is that an individual's viewpoint may be shaped through interaction between the participant and the researcher (Manning, 1997; Lauckner et al., 2012).

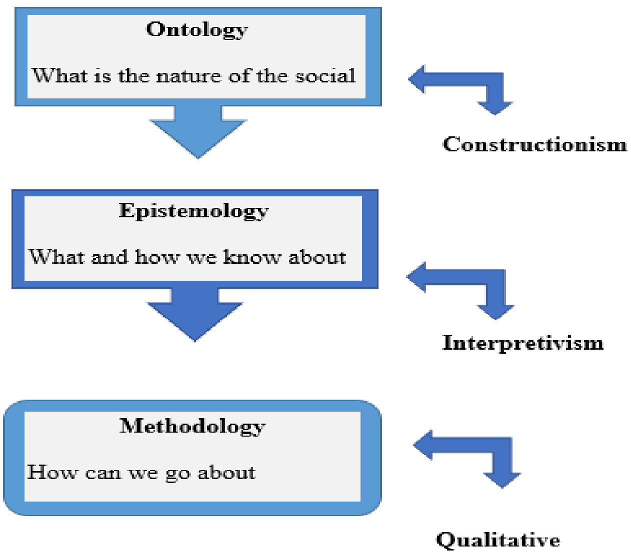


Figure 4.2 Overall philosophical stance of the research study from (Manning, 1997 and Lauckner et al. 2012).

Figure 4.2 illustrates the philosophical foundation of this research study. The social constructivist theory is adopted for the purposes of this research because it generates natural knowledge from social phenomena in order to develop ontological assumption (Sivan, 1986). In addition, the research study adapts epistemological assumptions, as it interprets the social world; this renders it interpretivist in nature. This supports the choice of methodology for this research in adopting a qualitative approach, because information collected from individual experience and viewpoints through fieldwork are essential to the establishment of the previously mentioned factors (Grix, 2004). The following section discusses the study's ontological position.

4.3 Ontological position of the research

Saunders et al. (2009) argue that: "ontology is concerned with the nature of reality...and the assumptions scholars make about how the world functions and the commitment to a specific view". Saunders et al. (2016) reaffirm that ontological assumptions are significant in research because they influence the way in which a study is carried out in order to achieve the aims of the research.

The questions, assumptions, and beliefs that the researcher brings to the study endeavour, both consciously and unconsciously, serve as a starting point for the formation of an ontological perspective. This research aligns ontologically with social construction, as its process denotes the collaborative or collective shared actions of a group regarding the acceptance of a technology which would benefit the group as a whole. Similar research studies in farming such as climate-smart agricultural production innovations (Yamoah et al., 2020), stakeholder perception of barriers and drivers in the oil palm sector (Dompreh et al., 2021) and big data in smart farming (Wolfert et al., 2017), amongst others, have all employed the similar ontology of social construction. Thus, this study adds to the body of literature on agriculture by way of contributing not just to the farming industry, but specifically to the cocoa farming sector.

4.4 Epistemological position of the research

The epistemological assumption, according to Burrell and Morgan (1979), is concerned with the transfer of information to others and what constitutes acceptable, valid, and legitimate knowledge (Becker and Niehaves, 2007). In his study, Cecez-Kecmanovic (2005) notes that this addresses the scope, origins, and nature of knowledge.

Thus, the epistemological stance of this research is an intuitive and inter-intuitive method designed to highlight and make sense of the social situations of indigenous farmers in Ghana towards the adoption of the usage of UAV, or drones. The unpredictability and dynamism of farmers' behaviour in Ghana, from the researcher's vantage point, renders researching social situations, including the present study, more feasible by use of a discursive approach, as opposed to positivism, which could easily supplant potential concealed meanings that individuals ascribe to their situation, for what is already known. Social phenomena, according to Heracleous (2004), do not possess the same integrity and consistency as natural phenomena, as the former is primarily defined by people and is best comprehended through the context-based meaning assigned by them to it.

Acceptance of views, or the lack thereof, among individuals such as Ghanaian local farmers is characterised by context, as farmers make sense of this context to determine whether or not they embrace change. Phillips and Hardy (2002) conclude that the social sphere evolves from communicative discourse, rendering it the dominant means of assessing and conforming to reality. This shows that the best means by which to handle acceptance in the research process is through dialogue with local farmers to determine the specifics of implementing a new system into their agricultural methods. This technique also enables the researcher to gain access to, and understand, the originality of information gathered from study participants.

Accordingly, this research adheres to the basic interpretivist assumption defined by Crotty (1998), i.e., that humans construct meaning when they interpret and interact with their surroundings. Additionally, individuals create meaning and make sense of the world on the basis of their social and historical views and the notion that meaning is formed in the context of human interaction. This also demonstrates the social constructionist perspective on how people and organisations together generate meaning and context (Coffman, 2011).

In addition , the researcher talked to local farmers and their stakeholders, asking pertinent questions relating to the topic and gathering information from them on their current agricultural techniques. Even though theories on acceptance and implementation provide a conceptual framework (Alvesson and Deetz, 2000; Daniel, 2006), this method allows more information to be gathered from respondents in order to inductively construct meaning about the topic (Creswell, 2009; Creswell and Zhang, 2009).

4.5 Axiological assumptions

Axiology serves a crucial role in ensuring that researchers adhere to appropriate ideals and ethics throughout the research process (Gericke, 2012). This provides researchers with explicit rules on how to interact with participants whilst respecting specific principles. Research ethics and values are of the utmost significance because exercising due diligence and adhering to them ensures the legitimacy and validity of the research (Saunders et al., 2016).

The capacity of positivism to explore complicated societal issues which cannot be simply categorised on a Likert scale is a strength which should be examined. However, the reliance of positivism on the Likert scale is a disadvantage; Cresswell (2009) holds that social phenomena are complicated, context- and person-dependent, and cannot be reduced to a small number of known factors. A relative improvement in comprehension is the result of a detailed knowledge and interpretation of actors' perspectives and intentions.

The strategy of enquiry implies that human acceptance is addressed with an open mind to allow for additional information to be requested from participants on the study focus (Creswell, 2009); in this case, to achieve a better understanding of the actual problems facing local farmers and ecosystem stakeholders.

Blumberg et al. (2014) contend that this promotes comprehensive knowledge and adds to theory. Nevertheless, the open and deductive method prevents the study from establishing a definite research parameter from the outset, because unanticipated and improbable facts may be uncovered during data collecting interactions with respondents, which potentially prolong the research process. The axiological position of this study therefore considers the varying opinions of respondents while setting the boundaries of the collected data in order to help the research to remain within the study's aims and objectives while applying ethical considerations to ensure that respondents' opinions, especially in the translated interviews, are a true representation of what was discussed.

4.6 Rationale for the choice of research philosophy

The chosen method of enquiry requires small sample sizes with a close concentration on a deeper degree of comprehension (Blumberg et al., 2014). This allowed the research to concentrate on relatively proximal farmers and their stakeholders in order to collect in-depth information for rich data and contextual analysis, hence enhancing comprehension. The originality of the research requires that the collected data capture the originality of participants' perspectives, which are essential for the establishment of the principles of this study's larger knowledge.

The investigation was undertaken in Ghana, where the researcher has resided for many years, rendering it possible to arrive at accurate interpretations and understandings. Although acquaintance with the historical, social, and anthropological context and structure of farming activities and practices provided the researcher with a solid framework, this did not pre-determine the route of the study.

Nevertheless, this creates a dilemma in terms of the appropriate use of human judgement in order to avoid preconceived notions and biased outcomes. The study was governed by the qualitative research approaches of confirmability, credibility, transferability, and dependability (Guba and Lincoln, 1994) to guarantee that the research methodology and outcomes are trustworthy, for reasons of duplicability and dependability.

Although there are some disadvantages, as with any approach, the strength of the selected paradigm is that it provides certain advantages over other research paradigms used in similar research studies in the agricultural domain; the selected paradigm allows for a more thorough examination of the complexities of human acceptance behaviour than others. Hofstede et al. (1993) contend that cultural and common ideas resulting from power distance and individuality and collectivism, particularly in the case of Ghana, may be deciphered most effectively through the chosen paradigms, as opposed to positivism.

The phenomena may be better understood as a result of the greater personal participation and exchanges characterised by interviews. This was beneficial, because study participants are active and equal sense-makers as the researcher (Alvesson and Deetz, 2000). This procedure provided a greater comprehension of the subject under investigation than a ‘fact-finding’ expedition undertaken in isolation by the researcher and under the guise of positivism. Treating researchers as autonomous of the subject under investigation (Remenyi et al., 1998) deprives positivist research of rich common meanings.

Moreover, compared to other paradigms, the selected one facilitated a more rigorous investigation of the acceptability of a new agricultural technology in the research study. Blumberg et al. (2014) hold this allows for more in-depth involvement in the data collecting process and the testing of insights than positivism, in which there is little opportunity to pose critical questions in order to determine the robustness of the initial data collection process. Again, the selected paradigms enabled the researcher to conduct the interviews as a natural dialogue process (Fontana and Frey, 1994) and to observe and interpret the material obtained (Heracleous, 2004) in order to better comprehend the phenomena.

Additionally, the implementation of the selected paradigm supported the identification and addressing of the issues of local Ghanaian farmers regarding their understanding and acceptance of Unmanned Aerial Vehicle application technology. This was achievable because, as noted by Alvesson and Deetz (2000), interpretivism allows analysis of important but concealed aspects of daily life that may be easily neglected by other paradigms.

While positivist research largely categorises people on the basis of theories (Mills and Huberman, 1994), the selected paradigm focuses on an in-depth understanding of what acceptance means to farmers in their specific contexts, as opposed to seeking to fit them into known groups which may not apply to all participants (Creswell and Roth, 2016).

This research study aims to comprehend the social phenomenon of acceptance and its repercussions and was guided by a number of ethical frameworks and concerns. The increased importance of ethical consideration is a result of technological advancements in digital photography, audio- and video- recording, and online analysis of virtual materials; data protection legislation in the United Kingdom and many other nations dictates the way in which research data is stored, reported, disposed of, or reused; and professional codes and ethics committees by various bodies require compliance (Hammersley and Traianou, 2012).

4.7 Ethical considerations

With regard to the ethical framework of this research, the study employs Hobbes' (1991) social contract theory, as described by Plotica (2017) and Muldoon (2016). According to this idea, ethics constitute an issue of social consensus or agreement between individuals or a community regarding what is good or bad (Donaldson and Dunfee, 1999; 2002). To give further context for the ethical framework adopted, deontological ethics were explored, per Clack (1999). This ethical paradigm regards the performance of the appropriate action, regardless of its consequences, as an obligation; it focuses on the activity itself, irrespective of the outcome it produces (Nuseir and Ghandour, 2019). The premise that the purpose justifies the means is thus invalidated. In the matter of technological interventions, for example, moral judgement and ethical decision-making are essential in the deployment of information technology for managers, as this has a 'ripple effect' on the type of relationships they are able to maintain and manage with the pool of stakeholders they work with, according to Shahand (2010).

Moreover, Aristotle's (384-322 BC) virtue ethics require an individual's life to be devoted to the accomplishment of the highest ideal, and to 'be good', beyond mere compliance with norms (Loriaux, 2005). It defines the optimum character traits and characteristics necessary for a happy and productive existence (Hartman et al., 2014), emphasising the cultivation of virtuous values and their interactions with society for the benefit of all members. This is viewed as an essential feature of the ethical framework for this study because the farmers' willingness to adopt and apply this new technology could improve their lives and facilitate the development of various complementary farming techniques. This is likely to benefit both their immediate recipients and surroundings, and also contribute to the growth of the sector and the country in general. This is consistent with the ideas of Owusu-Amankwah et al. (2017), who argue that qualitative research employing the above-mentioned ethical considerations is the most appropriate method for the investigation of the interrelationships between Ghanaian farmers as stakeholders in their natural setting and context, for example socio-cultural and economic aspects. This study's methodology provides a comprehensive knowledge of the farmers' and stakeholders' perspectives and interests, as well as their understanding of development in a specific setting, i.e., cocoa cultivation in Ghana.

4.8 Research design

The development of a research design is important because it illustrates the overall strategy chosen to integrate the different elements of a study in a coherent and logical manner, thereby ensuring that the research problem is effectively addressed; it serves as the blueprint for data collection, measurement, and analysis. According to Maxwell (2012), "a good design, one in which the components operate in harmony, promotes efficient and successful functioning, whereas a bad design leads to poor operation or failure".

This study's research design was established on the basis of its stated research aims and goals. The criteria and technique for data collection and analysis are defined by the research design. The table below compares the three most common research designs to that of the current study.

Table 4-1 Research design

Exploratory research	**Descriptive research**	**Causal research**
Aims to generate new ideas, and is adaptable and predominantly qualitative.	Aims to acquire precise information, evaluates hypotheses, and is predominantly quantitative.	Aims to comprehend cause and effect, is experimental and employs a control variable.
This investigation is supported by exploratory research because the focus of the research is to understand the social phenomena in a specific setting of local cocoa farmers and their stakeholders in Ghana.	This study disregarded the use of a descriptive research methodology since it does not utilise surveys to collect information about a variety of subjects with the objective of determining the degree to which certain conditions can be attained among these subjects.	This study rejected the use of a causal research design because it is not a type of conclusive research, which attempts to establish a cause-and-effect relationship between two or more variables.

Source: Shukla (2008).

As demonstrated above, the approach of this study is exploratory in nature, as the focus of the research is to understand the social phenomena in a specific setting of local cocoa farmers and their stakeholders in Ghana. This position also reiterates the choice of the qualitative approach taken by this study.

The following section describes the research methodology utilised in the study process. Within the constructivist framework, the qualitative technique was deemed most appropriate for the achievement of the study's objectives (Lueddeke, 1999).

4.9 Methodological choice of qualitative research

Qualitative research is the study of social phenomena from the perspective of the participants or people under investigation (Keady and Williams, 2007); it places a significant focus on the participants' subjective interpretations and views (Schmid, 1981 cited in Krefting, 1990). Qualitative research also enables the researcher to obtain specific information from their 'direct observation of a social occurrence, and to participate in this phenomenon.

Consequently, this study employs a qualitative approach to comprehend the interrelationship between cocoa farmers and stakeholders' attitudes towards the acceptance and implementation of a new technological application, namely the adaptation of UAV by cocoa farmers in the Asante region of Ghana, and how this is likely to impact their practices. This will aid in valuing contributions from a variety of stakeholder perspectives, from practices to policy. The focus was to collect and investigate relevant information from agricultural stakeholders, specifically the cocoa farming sector, to determine their level of technology acceptance and implementation in their cocoa farming practices and processes.

Table 4-2 Research methodology

Qualitative study	**Quantitative study**
This research is interpretivist at a philosophical level.	This research does not adhere to philosophical positivism.
The purpose of this research is to develop theory.	This research does not test any hypotheses or theories.
The research is concept-driven and uses a framework.	This research examines variables.
Inductive reasoning guides the research.	This research uses deductive reasoning.
This research is founded on empirical evidence.	This research uses statistical samples
This research aims to observe the daily lives of participants.	This research includes the investigation of both subjects and objects.
This study typically takes the form of a textual narrative.	Typically, statistical analysis is used in this research.

Source: Hillman and Radel (2018).

Table 4.2 clearly explains why qualitative, rather than quantitative research methods were used. Due to its incompatibility with the stated research aims and objectives, the mixed-methods technique was not used in this study. The subsequent subsection describes the study's data collection methodology.

4.10 Selecting the Study Areas

This research focuses on the acceptability and deployment of UAV in small-scale agriculture farming in Ghana, specifically Nkawie in the Ashanti Region. It seeks to examine the ramifications of the use of UAV in cocoa production for pest control and other management measures to maximise productivity. This research also identifies the various farming practices and individual beliefs within farming processes which directly and indirectly inform farmers' and stakeholders' decision-making.

One of the major agrarian regions in Ghana, the Ashanti Region, located in the central belt of the country, was selected due to its high cocoa contribution, prospects, and impact on the sector's gains, as well as its overall contribution to the country's GDP. The location also boasts of a multitude of stakeholders whose engagement contributes to the optimization of farming productivity in the region. The Ashanti region, with Kumasi as its capital, is located in the forest zone. According to Musah et al., (2018), the average daily temperature in the district ranges from 22 to 28 degrees Celsius, with a relative humidity between 85% and 90%, and an annual rainfall ranging between 1270mm and 1651mm. The district has a population of approximately 9,376 inhabitants, with 75% of the populace citing farming as their occupation (Musah et al., 2018). The remaining 25% of workers are also actively engaged in the farming supply chain, which makes the location for these exploratory studies ideals for obtaining information to inform the outcomes of this research. Another important fact worthy of mention here is that approximately 50% of the 75% farming population in the district are cultivators of cocoa farms (Dotse, 2019) on an area of 8720 hectares, representing about 40% of the total land area under cultivation (Musah et al., 2018).

This area (district) was chosen due to its lengthy history and its significance to Ghana's cocoa production (Otchere et al., 2013). The execution of the Ashanti Region Cocoa Project in the study area between 1970 and 1979 led in the repair of cocoa plantations and the training of farmers in improved cocoa production methods, which contributed to the selection of this district (Amoah, 1998).

Following initial visits to six villages by three extension agents of the District Agricultural Office, in conjunction with the District Director of Agriculture, one region was chosen for the research. The selection of this location was based on an evaluation of the area's production capacity, the number of farms, and its level of stakeholder participation.

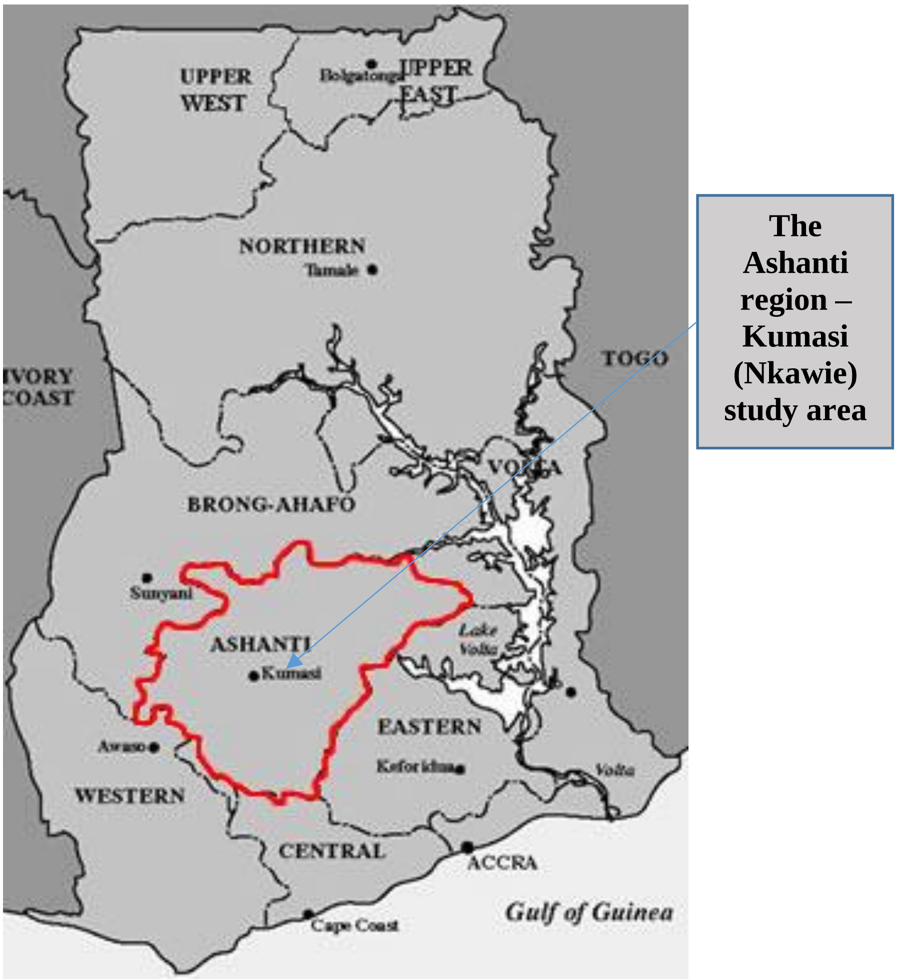


Figure 4.3 The Ashanti region – Kumasi (Nkawie) study area map from the (Ministry of Agriculture Ghana archives, 2021).

Figure 4.3 illustrates the selected study area, which is locally named 'Nkawie'. This region is approximately 25 kilometres from the capital city of Kumasi, and the villagers' primary occupation is cocoa growing. All cocoa farmers cultivate food crops in addition to cocoa, while some male and female cocoa farmers participate in additional income-generating activities such as palm wine production and masonry. Most importantly, there is dominant presence of a cocoa supply chain, which renders the pool of stakeholders in this area very diverse with multiple stakes and capacities to facilitate the adoption of UAV (UAVs).

Table 4-3 Study area profile (the Ashanti region - Kumasi (Nkawie))

Kumasi (Nkawie)	
Total area (sq. km.)	2,411 sq. km.
Total population	9,376
Annual rainfall variation	1270 mm to 1651 mm.
Humidity	85% to 90%
Temperature	22 degrees C to 28 degrees C

Source: Ministry of Agriculture Ghana archives (2021).

Table 4.3 is critical to the study and choice of location as it details the topographical characteristics of the study and provides evidence for the choice of conditions and how these natural conditions are pivotal to the growth of cocoa in the Nkawie Cocoa District.

4.11 Profile of participants

Patton (2002) holds that deliberate sampling is intended to produce an in-depth knowledge of the experience(s) of selected people or groups, as opposed to empirical generalisation. In view of this, the study selected its subjects using a method known as 'intentional sampling'. Snowball or chain sampling, which entails examining information from key informants regarding the specifics of additional information-rich examples, are among the deliberate sampling procedures employed in the research field (Suri, 2011). This research additionally incorporates criteria sampling, which entails prioritising: "all instances that satisfy a pre-set criterion of relevance" (Patton, 2002). Thus, situations which fit a specified threshold of significance concerning cocoa farmers and stakeholders directly- and indirectly involved in cocoa agricultural operations were investigated.

This study defines cocoa farmers and their stakeholders as those organisations or persons who are involved with cocoa productivity efforts and may therefore influence or be influenced by the decisions and actions related to such initiatives (Waligo et al., 2013).

Therefore, based on deliberate sampling, cocoa growers and their stakeholders, who are regarded as vital information sources, were identified as participants. This included, for example, the representatives of organisations and industries concerned in cocoa production in the Ashanti area. These comprised government entities, policymakers, companies in the cocoa supply chain, and local groups such as farmers. The identification and development of the major stakeholders involved in cocoa farming operations in the Ashanti area of Ghana was based on a literature analysis of cocoa farming management studies and secondary data sources such as websites, brochures, and books as evidence in chapter 2. This first investigation enabled the researcher to compile an initial list of relevant parties (Baah and Anchirinah, 2011).

Table 4-4 Demography of participants' profiles

Age		Gender		Occupation		Years of experience in the cocoa sector	
60-70 years	**7**	Male	**25**	**Local level** Farmers	**26**	Over 30 years	**14**
50-60 years	**14**					20-30 years	**15**
40-50 years	**12**	Female	**11**	**Middle level** Regional Chambers of Commerce Association and intermediaries	**4**	10-20 years	**6**
30-40 years	**3**			**Ministry of Agriculture officials** Ghana Cocoa Board, economic, education and research agencies	**6**	5-10 years	**1**
Total	**36**	**Total**	**36**	**Total**	**36**	**Total**	**36**

Source: Author's data (2021).

Table 4.5 shows the demographic characteristics of the study's participants, with careful stratification of their levels of stakeholder involvement and their number of years in the sector; this is critical in influencing the richness of the information obtained from them. Appendix 2 describe into depth the demographic breakdown of the population

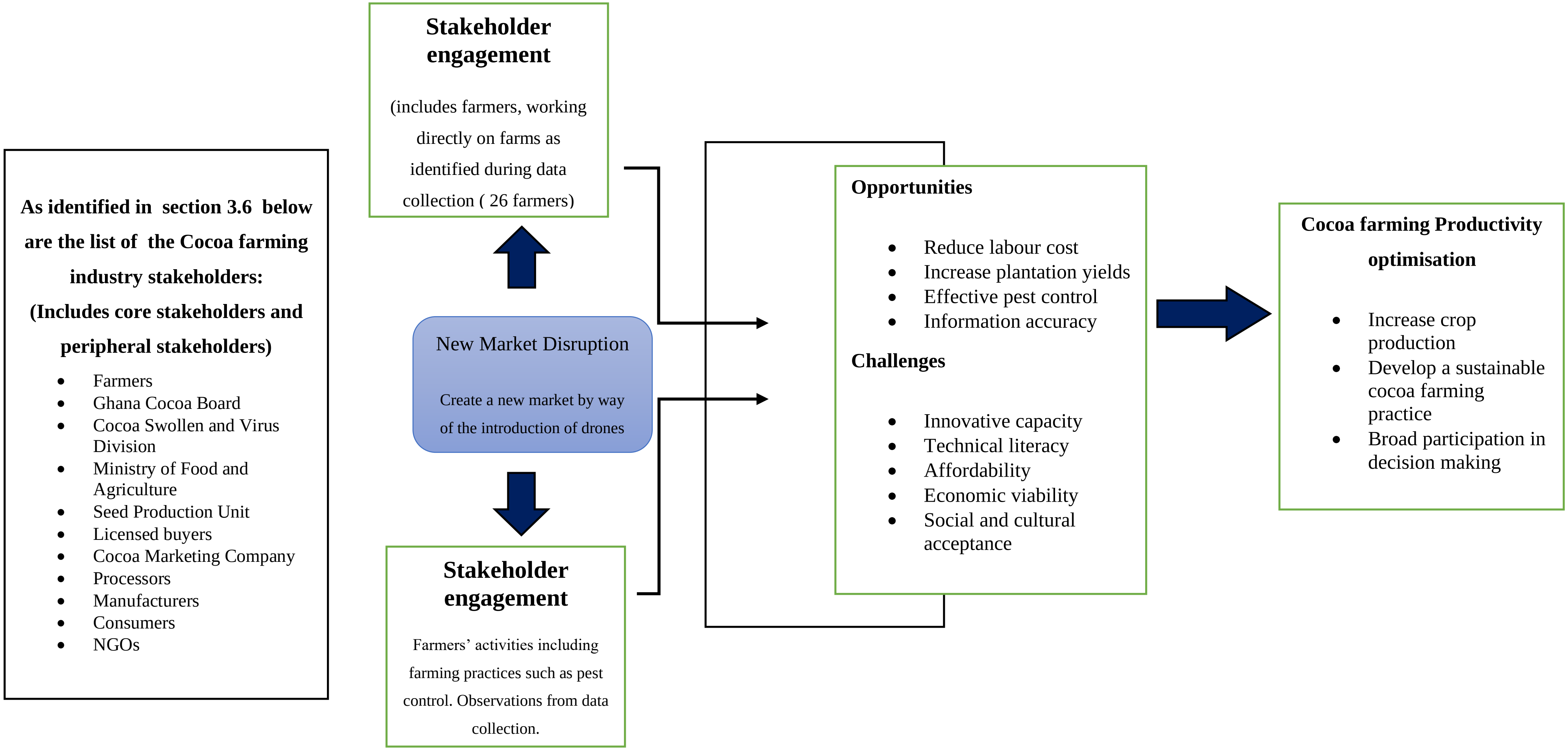


Figure 4.4 Stakeholder mapping, identification and engagement (Author, 2021).

Figure 4.4 is essential to the development of this study's stakeholder identification and engagement approach, it demonstrates the pool of stakeholders involved in the cocoa farming ecosystem, this was discussed in chapter 3 of section 3.6 and identied during data collection.

Figure 4.4 also exhibit details the intersection of stakeholder engagement while outlining the opportunities and challenges associated with the acceptance and implementation of the technology proposed in this study, i.e., UAV.

Table 4-5 List of key cocoa farmer's stakeholders identified

Key cocoa farming stakeholders
1. Government
2. Local authorities, policymakers
3. Cocoa farmers' associations
4. Ministry of Agriculture i.e., education and research agencies, Ghana Cocoa Board.
5. Local level (farmers)

Source: Author (2021).

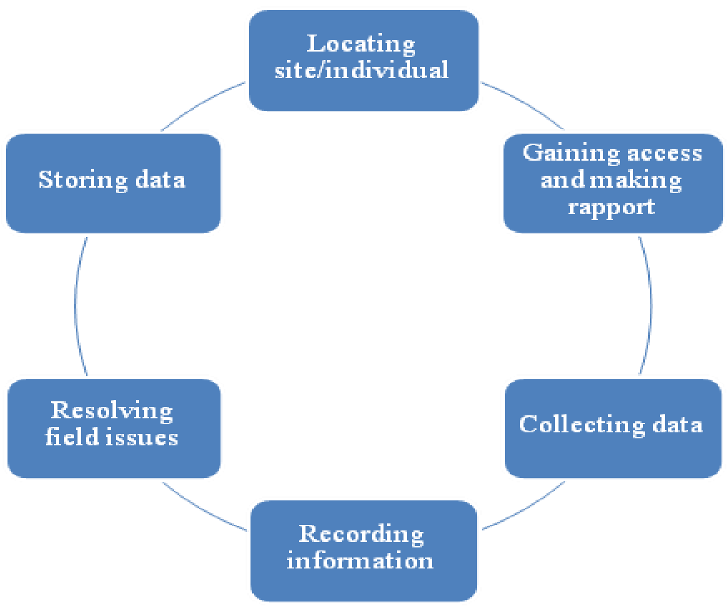
Table 4.6 demonstrates from the stakeholder identification framework the selection of key stakeholders, whose activity and/or passivity exerts a strong influence and impact on the decision-making process for the adoption or otherwise of any initiatives, including technology. The table is elaborated further in Appendix 2.

4.12 Data collection

Collection of data from the cocoa farming stakeholders, which included farmers, officers of the Ministry of Agriculture, regional boards, cocoa farming associations, the Ghana Cocoa board, and policy makers was undertaken in the Ashanti region of Ghana, specifically in the village known as 'Nkawie'. The rationale for the selection of this area is the predominance of cocoa farming activities which are carried out in this part of the country. Another reason is the contribution of this area to the total output of cocoa of its region and country.

The Ashanti region of Ghana is well-known for its cocoa plantation and contributes significantly to the regional percentage of the country's GDP. Various undertakings of the cocoa farming activities, from the planting stage through to harvesting are carried out here, thus the huge supply chain involved here accounts for the diversity of stakeholders based in this area. Consequently, the data gathering phases of this study, as shown in Figure 4.8, mirror the phases of data collection described by Creswell (2013).

Figure 4.5 Data collection activities



Source: Creswell (2013).

Identification of the case study region formed part of the data collection process; it included the selection of participants who were judged as the best prospects for exploring practices and concerns relevant to the research subject, and who were prepared to contribute rich information. Consequently, as demonstrated by the demographic information of the participants, years of working experience in the cocoa ecosystem and wide exposure to a variety of traditional and modern agricultural techniques were viewed as markers for the gathering of rich information, among other characteristics. Participants were chosen through the Ghana Cocoa Board's directories and interviews with the Agriculture Ministry, which identified major cocoa growing industry players.

In addition, to provide an accurate representation of the sample community, the researcher used a shared ethnic and linguistic affinity with local farmers to ensure the involvement of women and more reticent residents. This was completed before the start of the data collection phase.

4.13 Participant observation

In order to gain a greater knowledge of the responsibilities of the major cocoa farming stakeholders involved in the adoption of UAV (UAV) on their cocoa fields, participant observation was used in this study. This technique is defined by O'Connor (2005) as: "the act of immersing oneself in the study of persons with whom one shares many similarities". In this participant observation study, the researcher played a passive role, because they did not deliberately interact with the target population in order to acquire or otherwise influence the group's behaviour.

O'Connor (2005) states that: "If it's a group you already know a great deal about, you must take a step back and adopt the perspective of a 'Martian', as if you were from another planet and viewing things in a new way”. Polkinghorne (2005) states that: “Observation is the process of obtaining information via direct touch with an object, often another person”. Behaviours of participants were watched and recorded (Polkinghorne, 2005). This method enables a researcher to gain direct experience and provide authentic interpretations (Musante and DeWalt, 2010). The researcher approached and observed key cocoa farming players in their natural environments, such as their workplaces and other work-related activities, also taking photographs of the farms to supplement the narrative and analysis with visual evidence.

4.14 Semi-structured interviews

This study used semi-structured interviews to gain a comprehensive picture of participant and stakeholder participation in cocoa growing processes and practices. The major objective was to comprehend farmers’ and stakeholders’ perspectives on the adoption of UAV’ application in farm operations, and how this could enhance of agricultural output.

Hesse-Biber and Leavy (2004) contend that the semi-structured interview is a valuable approach that researchers can use to study participants’ perspectives, attitudes, and explanations of their position in response to research questions. Throughout the interview process, emphasis was placed on the establishment of trust and the fostering of co-operation between the researcher and participants in order to obtain an authentic image of social reality.

To achieve the study objective and involve all relevant actors who may provide rich data for the research topic, the interviews were planned to obtain information from a variety of players from different agricultural sectors. Participants from stakeholder groups other than farmers were chosen on the basis of their professional backgrounds and affiliations. There was a total of 36 participants in the semi-structured interviews. Thus, four national governmental organisations' officers, six regional cocoa producing stakeholders, and twenty-six farmers were interviewed. Each interview was of 90 minutes' duration; this enabled participant to explain their experiences, voice their opinions, and contribute far more information .

4.15 Interview design

The following sub-sections provide a detailed description of the study's overall questionnaire structure. It takes into account how the key stakeholders' interview questions were developed.

4.15.1 Overall structure

'Grand tour questioning' was used for this research (Spradley, 1979), with the particular aim of asking participants questions on themes with which they are familiar; these include personal behaviours, attitudes towards relationships, personal background information, and their job responsibilities. The interview questions were designed to elucidate the participants' historical, political, social, cultural, and personal settings in relation to the fundamental theoretical ideas Saxena and Singh (2002). Consequently, the interview questions were organised as follows:

The first part comprised questions about the relevant stakeholders' profiles; participants were asked about their personal backgrounds, their experience, and their historical involvement in cocoa farming. The second part comprised questions about participants' involvement with other agencies; they were asked about their perceptions, expectations, and benefits in regard to these relationships. The third part comprised questions about participants' knowledge and perceptions about the use of UAV (UAV's) on farms, and any issues which might arise as a result of their use. The fourth part asked participants to make suggestions about the future development of the use of this technology in cocoa farming.

4.15.2 Interview themes

In order to ensure that the interview themes were within the correct parameters, in accordance with Mitchell (1969), consideration were given to the content, intensity, frequency, duration, and direction of the relationships to ensure that all theoretical concepts were addressed.

4.15.3 Conduct of interviews

Interviews were conducted during the period of the global COVID-19 pandemic. They took place during a three-month period from April to June, 2021. This was a very busy time for cocoa harvesting, although activities were at the bare minimum level due to the impact of COVID-19 restrictions. The majority of study participants were contacted via mobile phones and with the support of friends and family members who are also occupationally involved in cocoa farming. Their involvement provided this study with credibility and encouraged participants to collaborate without fear of information being sought for information for unlawful purposes.

An in-depth explanation of the research aims was provided to all participants, and they were encouraged to collaborate positively after acceptance of the invitation to interview. This was followed by a formal letter to the agreed participants as a formal means of obtaining their contractual consent to take part in the study. Some of the participants requested information in their local language (Twi), which was supplied to them. Some participants requested advance sight of the interview questions to ensure that they had a full understanding and clarification of the interviews process and the purpose of the study. The interview schedule was developed in English and was guided by Disruptive Innovation and stakeholder theory.

4.16 Validity

The qualitative paradigm, according to Creswell and Miller (2000), argues that reality is socially produced and is what people perceive it to be. Consequently, it views realities as numerous, interpretive, open-ended, and contextualised. Validity methods are represented in credibility and originality (Creswell and Miller, 2000). Triangulation and member-checking approaches are used to improve the integrity of this study (Creswell and Poth, 2016).

The triangulation technique can improve the quality and credibility of research by cross-checking data and interpretation from multiple sources using a range of methods, such as documents, interviews, and observations, to confirm certain aspects of a study or to complete the understanding of different eras and areas of observation and interviewing (Krefting, 1990).

4.17 Limitations of semi-structured interviews

Participants' potential unwillingness to participate, provide rich and detailed information, or allow their interview to be used in the research process are among the constraints of the semi-structured interview process. Within the time constraints and limitations of the COVID-19 pandemic, participants were not necessarily able to provide all the necessary and detailed information (Kallio et al., 2016). Thus, it was essential to establish a rapport with study participants, and to thoroughly prepare questions and interview approaches, while also having considered a response strategy for the aforementioned contingencies. These factors were considered in advance, and were accordingly prepared for.

4.18 Data analysis

The interviews were transcribed, as evidence in (Appendix 6) with the data analysed and categorised to create themes such as: social relationships with stakeholders, benefits provided by agencies, stakeholders' activities, farmers' and stakeholders' motivations, traditional practices, traditional belief systems, positive and negative attitudes towards technology, positive and negative attitudes towards cocoa productivity, trust, mistrust, corruption, and its negative impacts on cocoa farming.

This research used the NVIVO10 software to facilitate its data analysis process. Careful consideration was given to this, as the NVIVO software has its own limitations in terms of data analysis and data searching. For example, as noted by Denzin and Lincoln (2002), searching for particular terms and/or key words and auto-coding them can cause a researcher to fail to check on which passages were actually coded in the auto-coding process, and whether to use their own skills to analyse whether the codes and the passages fit or otherwise. It was decided that the NVIVO10 software served the purpose of managing and analysing data in terms of coding and categorising information collected and collated into various theme folders. Thus, the NVIVO10 software enabled the researcher to arrange, sort, and store data into categories in a systematic and efficient manner.

The programme enabled the researcher to import documents such as text, and simply code these documents on-screen by marking text chunks with distinct codes which reflect the conceptual categories for categorisation (Denizin and Lincoln, 2002; Hilal et al., 2013). In addition, the NVIVO10 software enables rapid and precise processing to search for information throughout an entire whole dataset (Beekhuyzen et al., 2010). As a result, the usage of NVIVO software enhanced the quality, rigour, and credibility of the research (Denizin and Lincoln, 2002; Richards, 1999; Ozkan, 2004).

The procedures for the use of NVIVO10 software are as follows:

1. Firstly, folders for the storage of data of different types needed to be created, to facilitate data management. For example, a folder containing the semi-structured interviews was created, as well different text file folders.

2. Nodes for the research themes were created.

3. The interview data in the text files were manually analysed because they were in the native Ghanaian language of Twi.

4. Data were manually coded from each individual interview in text files. The NVIVO10 software aided this coding step by labelling text sections, making coding easier for the researcher; the researcher simply underlined and coded the appropriate quotation.

5. These coded quotations were automatically stored within the nodes of the study themes previously created by the researcher. NVIVO software assisted by categorizing the data and automatically providing the researcher with the data. For example, it enabled the researcher to rapidly determine which interviewees had mentioned social relationships with stakeholders, benefits from agencies and/or business originations, stakeholders' activities, farmers' motivations, traditional practices and belief systems, positive and negative attitudes towards technology and cocoa productivity, trust, mistrust, corruption, and the negative impacts of cocoa farming.

4.19 Summary

In conclusion, the key focus of this chapter was a description of the methodological approach and specific procedures used, influenced by constructivist philosophical assumptions and empirical investigation. For data collection, qualitative techniques and methods were used, with semi-structured interviews constituting the main tool. Qualitative approaches are both appropriate and necessary for research which seeks rich information and explanations from the participants' and stakeholders' views on the rising usage of technology. The discussion in the following chapter (Chapter 5) focuses on the interrelationships and acceptance of technology applications such as UAV among cocoa agricultural stakeholders by use of using these analytical techniques.

Chapter 5 Findings from cocoa growers

5.1 Introduction

This chapter presents an analysis and insight into key cocoa farming stakeholders and the roles they play in managing the cocoa farming industry with the use of technology in the Nkawie district of the Ashanti region, where this research was carried out. It presents the key functions, interrelationships, and activities which influence the cocoa production and supply chain in this area. In particular, the focus of the study is on the acceptance of a new technology in enhancing production in the light of the religious beliefs and practices towards cocoa farming production, including stakeholders' values, attitudes, interest, motivation, and expectations.

As explained in Chapter 4, data were obtained through the use of semi-structured interviews. The importance of this work lies in the acceptance, adoption, and implementation of a new technological application, specifically UAV to enhance productivity within the cocoa farming industry at Nkawie in the Ashanti region of Ghana. As indicated, the data were analysed by focusing on the participants' viewpoints captured in their direct quotes, and the paraphrasing of common ideas, which emerged from the interviews, to fully underscore the experiences of farmers (Aronson, 1994; Kiger et al., 2020). Themes are derived from patterns such as activities, feelings, proverbs, and informal conversations (Taylor and Bogdan, 1989, cited in Aronson, 1994). The discussion also focuses on the challenges faced by farmers such as limited resources, lack of capacity, and associated constraints.

The improvement of systems to optimise cocoa production has not been achieved to date, as primitive tools are predominantly in common usage within the Nkawie cocoa districts. The historical antecedents of the farming practices behind cocoa production within the Nkawie cocoa districts provides credence for this research, as the study seeks to investigate the implication of the use of a system, i.e., the adaptation of UAV to improve production, with a focus on how this technology can enhance pest control and farm management.

Data collection from this research suggests that farmers are likely to benefit from a change in methodological approach in the production of cocoa. Technological applications to reduce labour costs and save time are notably accepted by farmers; some respondents mentioned this:

> "Once I can understand how to use a drone, then it would be good to use it on my farm. I would not have to pay more people to spray my farm manually. If a drone can do it for us in a day, that would be great and it would save us money and time. For now, I have to pay labourers for three days to do that for me" (Male farmer aged 60).

Another respondent showed the researcher a cocoa bean affected by swollen shoot virus and stated that:

> "This is how it looks. This can affect the entire cocoa farm and you will make nothing from your farm. The virus is very dangerous and very difficult to control. It makes cocoa farming sometimes difficult to manage. If a new system can improve this for us, that would be great for every farmer within the district. Cocoa beans matter a lot in cocoa farming. It is the beans that we sell to make money. Most farms within this region suffer from swollen shoot virus, and it is very difficult to control this. In 1992, I did not make any money on my cocoa farm, as the cocoa beans were full of swollen shoot virus because this affected my cocoa trees. The regional office rejected all my cocoa beans. The main problem is that we need government support in tackling this virus. The

government can give support by providing us with fertilizers and even machines to spray our cocoa farms instead of us using our manpower all the time" (Male farmer aged 68).

The figure below shows the defect in cocoa beans affected by swollen shoot virus and vascular streak dieback virus as a result of poor pest management on a cocoa farm in Nkawie:

Figure 5.1Sample of defect in cocoa beans form (Author 2021).

Figure 5.1 illustrates an example of defective cocoa beans affected by swollen shoot virus and vascular streak dieback virus. This is due to inadequate pest control practices on the cocoa farms. In order to prevent or reduce the spread of this virus, an effective pest spraying system should be developed, however, it is difficult to achieve a result on a large-scale cocoa farm when doing this manually.

As noted by various academics (Owusu and Thresh 1983; Thresh et al. 1988; Ollennu et al. 1989; Andres et al., 2017; Dzahini-Obiatey 2008; Ameyaw et al., 2014, 2016; Padi et al., 2013;

Dzahini-Obiatey et al. 2010; Danso-Abbeam and Baiyegunhi 2018; Amon-Armah et al. 2021), cocoa diseases, including swollen shoot virus, continue to threaten the yields of cocoa production, particularly in West African countries such as Côte d'Ivoire, which currently sits as the world's largest producer and exporter of cocoa beans (Wessel and Quist-Wessel, 2015).

The illness caused by swollen shoot virus continues to damage cocoa plants, the principal source of income for both smallholders and large-scale cocoa growers. In rural regions of Côte d'Ivoire, where over 60% of the world's cocoa is produced, there has been widespread devastation (Amon-Armah et al., 2021); this presents a grave threat to the nation and the affected farmers. A proactive and effective pest management approach, on the other hand, tends to provide high yields, as seen by the flawless cocoa beans in figure 5.2.

Figure 5.2 sample of cocoa beans which are not affected by swollen shoot virus and vascular streak dieback virus (Author, 2021).

During data collection within this district, the researcher was informed by some farmers that cocoa produced there was not accepted due to poor practices and beliefs such as women not farming on some weekdays, and the use of primitive tools. The government had no interest in supporting farmers with farming equipment, making insufficient investment in the cocoa production sector due to the significant contribution and prospects of this crop in terms of the country's overall GDP and foreign exchange. For example, the Ghana Commercial Agricultural Project (GCAP), facilitated by the government of Ghana, was implemented by The Ministry of Food and Agriculture (MoFA), whose report of 15th July, 2019 states that:

> "Traditional agriculture, which is mostly found around the Ashanti region, must be improved. The primitive styles of crop production such as cocoa farming, which involve the intensive use of indigenous knowledge, land use, traditional tools, organic fertilizer, and cultural beliefs of the cocoa farmers in the Nkawie district, has not helped to increase their yields" (GCAP, 2001).

Part of the project report was highlighted in an interview which was broadcast by a local radio station in May 2001 within the region; the Regional District officer said that:

> 'Until farmers within this district (Nkawie) improve on their farming practices and accept woman as part of them, not only to be in the kitchen and home cooking on Wednesdays according to tradition, production and yield will slow down. Encouraging women all year round will help their husbands to see a rise in capital gain or input intensity as well as consistency in the cocoa farming occupation. Those days could equally be an effective day towards production on their farms but beliefs which prevent women from farming on Wednesdays are a threat and restrict production. Although this is a long-standing tradition, we have to also remember that farming in today's world is different from that of yesterday (Radio 1, 2001 – community radio station).

This quote expresses the contention of the Regional District officer towards Nkawie's tradition of women not working on farms on Wednesdays. Although this is a long-standing tradition, the Regional District officer encourages farms to adapt to current changes, as this will help farmers to improve their cocoa production and also enhance their livelihoods.

The Regional District officer concluded his interview by stating that: "All these are poor farming practices, which do not support great output" (Radio 1, 2001 – community radio station).

This research acknowledges the fact that cocoa farmers within the Nkawie District have traditional beliefs which constitute obstacles to major change, such as the acceptance or adoption of technologies like UAV for the improvement of cocoa productivity. Although a change such as this could be a significant intervention in contributing to successful farming output, the reluctance shown by most farmers concerns scepticism over the functionality and efficiency of this application implementation, including its productivity compared to their current traditional and manual practices.

5.1.1 Size of cocoa farmland

From the data collected, it was clear that the majority of the respondents had previously inherited their land from their grandparents, parents, and other family members, although currently 92% of the respondents own the various farmlands in their names. Ownership of the farmlands is very important to the study, as this indicator has an influence on the choice of acceptance or otherwise of new technology because farmers cannot make decisions over assets which do not belong to them. They further associated ownership of farmlands to reasons such as they purchased it, received by inheritance, or "dc ma yen ky3" meaning, shared it on the basis of shared cropping, received it as gift from their partners due to marriage, and other traditionally recognised civil unions, and/or from chiefs of the area for various reasons.

The first cocoa farmyard which was identified in the area dated back in the 1960s; it belonged to a woman within the Nkawie district, comprising farmland of two acres, which was a family owned- and run farm. A lack of support from stakeholders and the central government hampered the spread of cocoa cultivation on this farm and others in the region because local skills, funding, and stakeholder networks were unable to provide an environment to enable growth. The use of primitive tools, high labour engagement and intensity, and lack of up-to-date knowledge on effective farm management practices were challenges for the sector. Some of the farmers mentioned that the government showed reluctance in releasing some of the forest lands to them to enable them to cultivate more cocoa.

Thus, contention of state-gazetted landed properties, including the effects of the traditional land tenure system, coupled with inadequate credit facilities and a lack of subsidised fertilizer and seedlings to replant ageing farms to increase cocoa yields to enhance the output of production were all cited as barriers to expansion. For example, a famer explained:

> "I own this land, and it has been ours for many years. My great grandfather left this cocoa land. The government keeps on making promises to support us with fertilizers to fight pesticides every year, but it seems not to be reaching us when they are distributing it from the head office here. I continue to use hoes and cutlasses for farming because this is all that I know. Nkawie is predominately well-known for cocoa farming, but I still do not receive government help, very few farmers within this region have been to school to learn how to effectively manage their farms. Personally, I think the government should supply us with seeds for planting and the money to pay labourers when it is harvest time. I would be very happy to see this happening to help myself and others to increase their cocoa farming production" (Male farmer, age 68).

As previously mentioned, the people within this farming district had inadequate knowledge of modern cocoa farming practices and there were very limited benefits and skills to their cocoa farming, as the government paid no attention to farmers from Nkwaie (Amoa-Awua et al., 2007).

Many older farmers maintained that individual families who started operating by very small-scale farming within the region did so to earn extra income for their families and themselves (Amoa-Awua et al., 2007). This is evident from the interview that the researcher conducted with the oldest farmer:

> "… in the 1970s, when I went into cocoa farming, it was very difficult as we had no knowledge of it, but the purpose was just to make extra cash to feed the family. We

only used an old cutlass, hoe, and axe for farming. The government never bothered and cared for us until more people also started farming. In the 1980s, the government wanted powers to govern and needed our votes, so they visited this district and noted the hard work we were doing here. This is when the government decided to spray our cocoa farms for the first time. I was so happy and would never forget it" (Male farmer, aged 68).

Below are two sample pictures collected by the researcher from the respondents, who are farmers. The picture shown below in **Figure 5.3** shows the farm practice of nursing seeds before planting them on farmland on a small-scale cocoa farm which was run by a small family in the mid-60s, compared to a recent photograph as **Figure 5.4** illustrating current farming trends, which was taken during the field work. It is noteworthy that both pictures demonstrate farming on a small scale run by small families, which creates a fair and balanced basis for this comparison.

Figure 5.3 Comparison of farmyard from the mid-1960s and current production Cocoa Farmyard from (District Office Archives, 1960).

Figure 5.4 Current cocoa farmyard from (Author, 2021).

As illustrated by Figure 5.3, the cocoa farming processes were all carried out on a very small cocoa farm in the mid-60s, applying various traditional methods for farm management and practice. This rendered farm management very challenging, with threats such as pest and disease control limited due to overdependence on traditional knowledge and expertise which did not embrace innovative approaches and alternatives. However, as demonstrated by Figure 5.4, cocoa farm practices are beginning to improve, although farmers still face challengers such as poor farm spraying and defects in pest and disease control mechanisms, as farm management practices are now organised from the nursing stage to the harvesting stage (Amoa-Awua et al., 2007).

From Figure 5.3 and Figure 5.4, the researcher compared the nursing stages of cocoa seeds as practiced in the 1960's to how this is currently carried out in the 21st century. Figure 5.4 shows the initial nursing stage of the cocoa beans before the plants are transferred onto the farmland for planting, known as the growing stage. Proper care at this stage would mean that there is the chance for the cocoa trees to yield pods by their fourth or fifth year, which can continue for 30 years. The figure below shows a fully-grown cocoa farm with a crop which is ready for harvest.

It is evident that, whilst the cocoa farming practices in the Nkawie district have grown considerably, such simplicity and dependence on traditional practices continues to characterise what is happening in the entire cocoa industry.

As an example, manual spraying of cocoa plants, which dates back to the early days of cocoa farming, still occurs in the cocoa industry.

Figure 5.5 Manual spraying on cocoa farm in 1960s from (Author, 2021).

Figure 5.6 Manual spraying on cocoa farm in 2021 from (Author, 2021).

Figures 5.6 and 5.7 clearly show that, although farming practices have improved, they remain behind contemporary and innovative farming as seen in other developed countries in which cocoa is produced. These findings indicate a relationship to previous studies which conclude that cocoa farming practices amongst farmers in the Ashanti region remain behind current trends and innovation in the sector, which has ignited debate among stakeholders about the future of this industry, making it a social phenomenon (Otchere et al., 2013; Kyei et al., 2011; Aidoo and Fromm, 2015).

Morgan and Smircich (1980) contend that qualitative research considers a social phenomenon from the viewpoint of the participants and individuals under study, placing considerable emphasis on the participants' subjective meanings and perceptions (Schmid, 1981, cited in Krefting, 1990). The study's findings indicate that, over time, farmers in the Nkawie cocoa district of the Ashanti region have established practices which are closely aligned with their beliefs. This enables the researcher to gain detailed information from their actual experiences, which were observed from both stakeholders and the farmers during the field work, as well as representing a particular social phenomenon.

To further develop valid justification for the choice of the location for the study, the researcher considered other constant variables which would enhance the viability of the research. These included some positive benefits of this cocoa district, such as the quality of the soil conditions and the support systems available to the farmers, including the work of their extended families. This was echoed by other interviewees who also owned cocoa farms within the district; one started his cocoa farm on a very small piece of land and had since grown it to a large acreage. This interviewee stated:

> "… My cocoa farm was very small, and now it has become very big, to feed my family …" (Male farmer, aged 55).

Another farmer said:

> "I started my farming on a very small piece of land which was inherited from my grandfather. With the help of my children and wife, we have been able to expand further.

I have been lucky because the land is very fertile and so it produces more cocoa pods for me. As a result of this I can sell more cocoa beans and make more money from my production" (Male farmer aged 58).

The majority of the interviewees were very happy with their occupation being cocoa farming, and derived happiness from their interaction with the various actors within the ecosystem. This aligns with the findings of other studies which report farmers' satisfaction with their occupation as a source of livelihood and business (Jouzi et al., 2017; Dixon et al., 2001; Behera and France, 2016).

Their primary source of income is cocoa cultivation, which enables them to educate their children and provide for the other essentials of family and life. Another person opined that:

"Although we do now get a little help from the local government and stakeholders, cocoa farming in this district of Nkawie has also helped us to educate our children. Cocoa farming has helped all my close relatives, including receiving training from the COCOBOD. If it had not been for the government coming to help by investing heavily in these practices, we would all be living in poverty in this district" (Male farmer aged 60).

Thus, the benefit of this sector to its primary actors, that is, farmers, has been extremely high. Gradually, the entire cocoa industry from this district in the 1970s and the mid-1980s has seen a rise and positive transition towards a more involving phase (Hashmiu et al., 2022). The Nkawie district has undergone a developmental phase in its cocoa production in recent years, with both public and private stakeholders becoming more involved in the farming process. The role of the government as a key stakeholder has been well-established between farmers, and more stakeholder awareness has now been extended to the farmers within the region (Yamoah et al., 2020).

Both public and private stakeholders play key roles in the cocoa production and supply chain, from the nursing stage through to harvesting. Recent initiatives such as the ‘Cocoa and forests programme’ introduced by the government have seen the significant involvement of cocoa farmers and who have received training on farm management practices (Amoa-Awua et al., 2007).

Private stakeholders have now been issued with more licenses to establish training centres within the district to educate farmers on how to optimise cocoa productivity most effectively. Other initiatives, such as the inception of international awards schemes by the Biodiversity International and Event International (CHED, 2017), the introduction of digital scale for rural farmers (QCCL, 2021), educating farmers on artificial pollination through the Cocoa Pollination Programme (CPP) (CHED, 2020), and other activities have increased stakeholder interaction and engagement within the cocoa sector.

In addition, local authorities, in collaboration with policy makers as part of the developmental stage, have agreed to supply cocoa farmers with fertilizer to spray on their farms; this is designed to help reduce the spread of swollen shoot virus and vascular streak dieback virus. Amoa-Awua et al., (2007) report that the government’s initiative of the Cocoa’s Farmers Scholarship Scheme, which is administered by the COCOBOD, has also helped to improve farmers’ knowledge and education; they can now participate in formal education without having to pay fees (Tham-Agyekum et al., 2021).

Measures have now been put into place by both private and public stakeholders to support the development of cocoa production in the Nkawie district, which has brought about the developmental phase of cocoa farming within the district. In 2008, the district recorded a significant rise in cocoa production and its contribution to national GDP (Aidoo and Fromm, 2015).

5.1.2 The developmental phase of cocoa farming

Amoa-Awua et al. (2007) hold that the district reached its development stage phase during the mid-1990s, as this was the point at which the role of the government as a key stakeholder became noticed, with events demonstrating the promotion of development and marketing, along with the provision of farming equipment, insecticides, and training in farm management taking prominence in the sector. For example, Ghana Ministry of Agriculture's initiative led by the late agriculture minister, Ibrahim Issaka Adam (1992 -1995) focused on extending cocoa production in five major cocoa districts, of which the Nkawie district was part (Nyanteng, 1995). The primary focus of the government at that time was to promote cocoa farming in this district, as it was recognised as contributing significantly and increasingly to the national GDP coffers. As a result of this initiative, the government supported local farmers and invested heavily in training farmers with the best farming practices (Amankwah-Amoah et al., 2018; Amoa-Awua et al., 2007).

Table 5.1 shows the output of the government initiative among the five regions, of which Nkawie is a part.

Table 5-1 Output of the government's initiative among the five regions

Year	2001/02	2002/03	2004/05	2005/06	2006/07	2007/08	Total increase in farmland
Ashanti Nkawie	25	28	30	38	40	45	208
Central region, Hemang	20	22	23	24	26	28	148
Brong Ahafo, Dormaa	20	22	26	28	34	37	167
Aowin Suaman (Samreboi)	23	25	26	28	29	31	162
Eastern region, Kade	16	21	25	27	28	29	146

Source: Crosson (2009).

It is clear from Table 5.2 that the Ashanti region, in which Nkawie is located, has seen an increase in its cocoa farmland production from 25 acres in the year 2001/2002 to 45 acres in the year 2007/2008. The impact of the government's initiatives from these regions contributed a total of 3.4% to the total Gross Domestic Product (GDP) annually and an average of 29% to total export revenue between 2001 and 2008 (Gockowski et al., 2011).

The impact of this strategic initiative by the central government saw the Nkawie cocoa district positioned firmly on the cocoa production map. This has since drawn attention to cocoa production in this area, and is currently in its consolidation phase, with cocoa farming now the main agriculture crop, which is supporting other ancillary sectors. Currently, due to its expansion and contribution to the country's GDP, the use of technological applications has been welcomed in this sector to enhance production, provide robust pest and disease control mechanisms, save time, and minimise costs (Anderson and Gaston, 2013).

The majority of recent reforms and initiative from the Ghana Cocoa Board (COCOBOD) have seen the government calling for the use of modern technology such as UAV to be used in the farming industry, for example in cocoa farming for pest control and management (Bosompem et al., 2011; Bongiovanni and Lowenberg-DeBoer, 2004). This is also reported by an interviewee:

> "… Now, we pray that the government invests more in UAV to help farmers spray their farms. As these have been used in different countries such as Abrokyi (the local name for America, as it is very popular country in this district)" (Farmer, aged 45).

In essence, both private and public stakeholder groups have welcomed the implementation of the Unmanned Aerial Vehicle for use on the district's cocoa farms. From engagement at the data collection stage, it was clear that some farmers were aware of other countries such as America, Japan and Europe which are using this technology on their farms. This created their understanding that the technology in question can be helpful in increasing productivity and promoting effective farm management practices.

5.2 Demographic profile of the Nkawie cocoa farmers

To analyse the agricultural techniques in this region, it was necessary to consider the responsibilities and experiences of the farmers, as well as their overall demographic backgrounds. Berg (2004) explains that understanding subjects' demographic background supports researchers by appreciating the nature of qualitative data and eliciting information about how the relationships and experiences of interviewees correspond to the various attitudes and behaviours recorded elsewhere in the interviews. Therefore, this section provides the basic demographic background of the Nkawie cocoa area farmers who participated in the fieldwork as study participants.

5.2.1 Farmers' personal circumstances and backgrounds

Participants were recruited from various age groups, marital statuses, and levels of education due to the relevance of these features to this study. These are extremely powerful indicative tools which enable the researchers to create a more in-depth and thorough analysis of this study in order to reach a fully informed conclusion and policy proposal for the many stakeholders involved in this research. This study identified Nkawie cocoa area producers from diverse demographic and personal backgrounds as participants. The participants range in age as detailed in Table 5.3

Table 5-2 Approximate ages of the farmers

Farmers' approximate ages	**Number of farmers**
60-70 (Elderly)	5
50-60 (Elderly)	10
40-50 (Middle-aged)	9
30-40 (Young)	2
Total	**26**

Source: Author (2021).

This age-based analysis reveals that most experienced farmers are likely to be in their late 50s, with the majority being men. This is important, as it corresponds to the traditional beliefs and constructs which regard men as being accountable as the leaders and heads of their families. This accounts for the fact of the dominance of men in the leadership of the cocoa farming business and ecosystem.

However, this research also identified the fact that most farmers were unaware of their age and had to use traditional symbols or events to recall this. The significance of the ages of the farmers is important in assessing their long-age expertise and experience in the sector, as well as their dependence on traditional practices, in order to measure their response to changes such as the implementation of the UAV in their farming practices. For example, some of the farmers recalled their age by recalling specific storms or fire outbreaks which occurred around the time of their birth; this knowledge was transmitted to them through oral history.

A very elderly farmer described his young friend as:

> "… just after Papa Kofi passed away as a result of the Dinki fire outbreak was when your mother gave birth to you. The fire outbreak was in the early 70s and you were born three days after that" (One of the respondent farmers, 2021).

The absence of official recorded or documented information regarding the participants' date of birth as a normal phenomenon was encountered throughout the data collection period. Due to the high rate of illiteracy of the cocoa farmers within the Nkawie district, the data collection process progressed slowly in engaging farmers on their farming practice in the region. The response plan implemented by the researchers to accelerate and mitigate this was to secure the engagement of interpreters who could speak the local language, which gave them the linguistic advantage to obtain as much information as was required for this research.

The training of farmers has been very challenging, as the majority can neither read nor write. Less training on farming practices is offered to farmers, which does not help in optimising cocoa production, especially when resources and other printed matter provided to them after training are all in English, with no translation support in the local languages. Generally, the yield of cocoa is lower within the majority of farms run by owners who are uneducated than those of the region's educated elites. Reasons for the low level of productivity are lack of knowledge and poor farming maintenance practices, which have a positive correlation to these farmers' low literacy levels. As a result of the high illiteracy rate, such farmers are unwilling to accept improved systems to enhance their production, as they are unable to read and investigate for themselves, believing what they are told by the producers of the intervention (Läderach et al., 2013; Amon-Armah et al., 2021).

In an attempt to increase cocoa production in this region, the government has implemented a policy which is aimed at providing a free Senior High School (SHS) education for all children from the ages of 12 to 18 years (Chanimbe, 2019). The policy seeks to enhance education throughout the country; thus, the region is a beneficiary of it. As it is noted, children from farming communities tend to join their parents in farming; they now have the opportunity to further their education as a means of closing the literacy gap in the farming sector.

From the data collected, a respondent from the Education and Research Agencies mentioned that:

> "The government has also introduced an education policy known as the 'free senior high school scheme' (SHS) in September 2017. The policy's core aim within the Nkawie cocoa district is to help farmers' children educate themselves while their parents focus on their farms. The benefit of this policy is to support the livelihood of cocoa farmers' families, where these children will help to close the literacy gap and help their parents to integrate change" (Education and Research officer, 2021).

5.2.2 Farmers' educational status

The Nkawie region is one which is solely noted as a farming community; this is one of the reasons for its selection for this study. The density of farming activities, practices, production, human resources, and occupation bases, along with the longevity of farming in this region provides a valid sample for the purposes of this research study. Kabeer (2005) argues that access to education can bring about changes in people's cognitive ability which translate into reflection on their life conditions, as it empowers people to gain access to knowledge, information, and new ideas. This suggests that education has become a critical tool in adapting to change and acquiring knowledge. One of the challenges negatively impacting the Nkawie community is the illiteracy rate, which renders information accessibility very difficult for these farmers. The implementation of new technologies appears to be news for the farmers, as the majority of them are uneducated, and embracing knowledge of this kind is accompanied by challenges.

Fartyal and Prajapati (2012) contend that education not only liberates people from illiteracy, but also improves their access to opportunities, including income-generating ones which can help in the improvement of their standard of living. This research identifies the fact that, during the past decade, farmers' highest qualification has been A levels. Table5.4 below illustrates farmers' education status.

Table 5-3 Farmers' educational status

Level of education	**Number of farmers**
Graduate	0
Higher secondary	0
Secondary	3
Primary	8
No education	15
Total	**26**

Source: Author (2021)

Many participants reported that they were unable to attend school or advance their education due to poverty, technical limitations, and other social obligations to their families and wider society. For example, a farmer stated:

> "… I wish that I had gone to school; my parents had no money to take me and my siblings to school. Even if they did have money? The school was very far away from my village, and I had to walk miles to it. I know this has impacted my farming practices a lot, as I find it difficult to understand writing in English, so how can I even operate a drone if we have to use them on our farms? I could not even read the manual in order to operate it" (Farmer, 2021).

As evidenced from the above statement, farmers within the Nkawie cocoa district, where this research was conducted, do not have a strong educational background; this limits their access to information, making them closed-minded and 'stuck' in their traditional ways. Thus, this attitude encouraged farming activities being run within family settings and supported by a limited number of associated stakeholders.

5.3 Profile of key cocoa stakeholders

Key cocoa stakeholders within the Nkawie cocoa district from the public, private and non-profit organisations contribute to the optimisation of cocoa production there. The key public sector actors are governmental bodies such the Ministry of Agriculture and the Ghana Cocoa Board, who have sole responsibility for policy making and direction (Gyamfi, 2017). The Ghana Cocoa Board (COCOBOD) was founded by ordinance in 1947 with an initial operating capital of USD$27 million (representing Ghana's portion of the West African Produce Control Board's net profit). The Board traces its origins further back, to the '1937 cocoa heist' after the takeover attempt by foreign firms. The Board's objective is to support and assist the development of efficient and cost-effective production, processing, and marketing of high-quality cocoa in all its forms (COCOBOD, 2021).

In this sector, COCOBOD controls the affairs of the entire cocoa industry supply chain, and has the power and legitimate authority to manage the development of cocoa production. The control of budget for cocoa production is in the hands of the government's agricultural ministry, who are tasked with the management, planning and implementation of modernised developments for the strategic positioning of the industry in the global supply chain. However, the absence of innovative and modernised resources, such as the use of new technologies, specifically UAV (UAV) on the farms in the Nkawie cocoa district have reduced production, as well as effective pest and disease control mechanisms.

Through the field work studies, the farmers expressed their concerns as follows:

> "We lack the technology to improve our farming practices. The government has a limited budget for the Nkawie cocoa district, but still expects more from us. Production could be improved significantly if more money was invested in our production. The money is in the hands of local and regional officials, and gaining access to it is a big problem. There is not even enough money to buy insecticides to spray our cocoa farms. The drones would strongly help us to achieve this, but the question is, do we have the money to implement this?" (Male farmer in his 70s).

The key private sector stakeholders include young farmers' associations and their related agencies. These groups have sound knowledge and skills relating to current farming practices and management, as they gather information on general cocoa production markets across the country to address issues in their local areas. They also conduct research into best practice in cocoa farming in other countries, which puts them in a strategic position to offer good counsel to farmers. Their collaboration and support from the other larger stakeholders such as government agencies enable them to have more influence on the cocoa production supply chain, especially in terms of developmental strategies.

Public sector stakeholders play an important role in the provision of quality cocoa planting materials, financial resources, facilitating and co-ordinating the activities of other stakeholders with local farmers. For example, the Ministry of Food and Agriculture (MoFA) is the principal agency and focal point of the Ghanaian government, charged with establishing and implementing policies and strategies for the agricultural sector within the context of a coordinated national socio-economic growth and development strategy. Through policy and strategy frameworks, the Ministry's plans and programmes are established, co-ordinated, and implemented using a sector-wide approach. In this context, MoFA sponsored the development of the Food and Agriculture Area Development Policy (FASDEP II) and the Medium-Term

Agriculture Sector Investment Plan in the first quarter of 2021 in order to increase productivity in this sector (MoFA, 2021).

Another essential stakeholder is the public-private sector. As an example, the World Cocoa Foundation African Cocoa Initiative II programme is a public-private partnership which responds to the need for increased capacity in the cocoa sector among national institutions, and addresses specific gaps in cocoa productivity improvements, such as the provision of better planting materials, pesticides and fertilisers, and financial credit to cocoa farmers (African Cocoa Initiative, 2021). Among other measures, their focus is on supporting farmers with the evaluation of financial services across the leading cocoa markets of West Africa, including Ghana as a significant partner. They offer a number of areas for additional investment designed to improve the lives of farmers and rural residents. In addition, this initiative contributes to the distribution of high-quality cocoa planting materials, such as new techniques to improve planting, the piloting of innovative irrigation strategies, providing support for farmers in understanding and adopting new technologies, and developing screening protocols for drought- and heat-tolerant planting.

Table 5.4 provides an overview of the key cocoa stakeholders' profiles and the roles they play within the cocoa industry.

Table 5-4 An overview of key cocoa stakeholders' profiles

Cocoa stakeholders		**Role in the cocoa industry**	**Initiatives implemented to address problems**
Public	Government	Responsible for: 1) co-ordinating, facilitating, and supporting the agricultural cocoa industry in the Nkawie district 2) Planning, strategies, and monitoring 3) problem-solving regarding cocoa production issues 4) providing knowledge for local farmers 5) researching, collecting, and analysing data about the cocoa industry	The Africa Cocoa Initiative. The Africa Cocoa initiative helps with the provision of financial resources and planting equipment for the enhancement of cocoa production. For example, the introduction of temperature- and moisture sensors allows for more efficient and safer cocoa planting.
	Local authorities Policy-makers	This is a local administrative body which reports to central authorities and is responsible for the overall management and production of cocoa farming, farmers' welfare and benefits. They ensure that laws and decision taken for the cocoa production sector are complied with and are well-implemented.	Free Senior High School (SHS) Scheme This provides education for farmers children from the age of 12 to 18 years, to enhance farmers' future livelihoods.
	Ministry of Agriculture Education and Research Agencies Ghana Cocoa Board (COCOBOD)	This plays a crucial role in the development of marketing plans and strategies, seeking new markets, and optimizing cocoa production. It also provides up-to-date harvesting and plantation information to farmers.	The Cocoa and Forests Initiative. This initiative was designed to persuade governments, companies, civil organisations, and cocoa-growing communities to achieve the objective of a thriving and sustainable cocoa sector, where farmers prosper, communities are empowered, and the planet is healthy.
Private	Cocoa Association	This organisation supports SMEs and promotes cocoa production. Its co-ordinates and collaborates with different public and private sectors to organise training, marketing, and problem-solving.	Cocoa Abrabopa Association (CAA). The Cocoa Abrabopa Association (CAA) is an independent organisation run for and by cocoa farmers from Ghana. It is not political and does not exist to generate profits, but seeks to create better lives for its members by professionalising cocoa farming.
	Young farmers' Association (SSA)	This organisation supports young farmers' well-being. It also collaborates with other stakeholders such as government bodies to launch innovative activities with the support of local farmers.	

Source: Author (2021)

As illustrated by Table 5.5 above, it is clear that the public sector has a very important role to play, as its organisations formulate plans and strategies for the benefit of both cocoa production and farmers themselves. The approval of budget and other key policy issues is carried out at this level. Private sector stakeholders play a key role in terms of the implementation of new technological applications, sharing new knowledge, training, and skills capacity development which enhances productivity and ethical farming practices.

Both the private and public stakeholders' roles are very important for cocoa production, however, as explained by the Ghana Cocoa Board (COCOBOD) and the Ministry of Food and Agriculture (MoFA), the cocoa industry continues to face challenges in the improvement of yields and farming practices (Benin and Tiburcio, 2019). There is urgency for cocoa farming stakeholders to increase their engagement with farmers in order to help to improve their standard of living by providing more knowledge and training to farmers (Martey et al., 2014; Roldan et al., 2013).

5.4 Key barriers facing the Nkawie cocoa farmers from the implementation of UAV

Despite the support of public stakeholders in the cocoa production ecosystem, i.e., from planting to harvesting stage, farmers still face many key challenges in the adoption and implementation of the Unmanned Aerial Vehicle technology on their farms. These are namely:

5.4.1 Insufficient financial support from the government

The findings of this study include the fact that the majority of farmers were struggling with funds to support their farming practices due to strict government budgets. This is supported by a statement from the Finance Minister, Hon Ken Ofori-Atta, captured in the Budget Statement and Economic Policy document of the 2018 financial year, presented to the Parliament of Ghana. It stated that:

> "The Ghana Cocoa Board (COCOBOD) refuses to secure an amount of USD$1.3 billion for the purchase of cocoa fertilizer for the 2017/2018 crop season. This follows the rejection of grant by Parliament as a result of strict government spending. The facility, which is usually provided by a syndicate of banks, comprising the Ghana Commercial Bank, Investment Bank, and Ghana International Bank has been denied at this time. The facility, which is an equivalent of GH¢5.850 billion cedis, was intended to support farmers, in their initial cocoa nursing, controlling pests on their farms, marketing operations, and farmers' services, among other issues. It was designed to help to increase cocoa production to more than one million tonnes per annum within the next four years" (Wednesday, 15th November 2017).

Although Nkawie cocoa district is noted as a major contributor of cocoa to Ghana's GDP, there still remains a lack of funds to support cocoa farmers, especially with pest control within farms, as this is very expensive for farmers to handle on their own. Prices inherently influence customer preferences for one technology over another; hence, cost and finance strategies are undeniably essential to the process of the adoption of technology (Kurtenbach and Thompson, 2000; Sunding and Zilberman, 2001).

Farmers indicated that implementation of UAV to help in spraying farms may be very expensive, but will also help to reduce their costs in the long term, as well as saving them valuable time. This aligns with the government's innovative initiatives on the use of technologies in farming, which were introduced in 2010 by the Agricultural Ministry (Amanor, 2013). In developing nations, lack of affordability is a concern at both national and family level, and Ghana is no exception. UAV are a costly technology, which partially explains why the majority of farmers in the Nkawie district are hesitant about their use.

For example, a cocoa farmer who showed an interest in the application of UAV in spraying his cocoa farm stated that:

> "Although I do reap a lot of cocoa during the harvest session, most of it goes to waste because of poor pest management, the reason being that the government does not support us enough in financial terms. We are unable to buy the insecticides for spraying on our farms; we need to apply by completing a lengthy form before money can be released for this. We still need to pay labourers to do this for us, and we are unable to afford all of this. The government in power needs to help us with money and even pay for the labourers spraying the entire farm. I do wish that the application of UAV was on the government's priority list, as this would reduce my costs and could save the cost of paying labourers, but again, I do not think the government can afford this technology" (Male farmer, in his 60s).

This interviewee has the largest cocoa farm in the district, and employs over 300 local people to support his farming activities. He expressed his frustration and anger at the lack of financial support from the government towards the improvement of farming practices to optimise production. This interviewee expresses his anger at the funding allocation procedures which are intended to support farmers in optimising production, but are being misappropriated by the local authorities and being used to build houses for private use, having individual parties, and going on expensive holidays. The implementation of UAV for pest spraying is known to be very useful, as one of its advantages is cost reduction (Hassan-Esfahani et al., 2015).

This provides an illustrative example of farmers' willingness and acceptance of UAV' application on their farms, but on the other hand, the lack of financial resources from public stakeholders can represent a significant barrier.

5.4.2 Corruption among local authorities

The findings again reveal that there is corruption at local authority level. The majority of stakeholders at this level have direct network connections with the central government where most decisions are made, and resources accessed. Although there appears to be a link between farmers on the ground and the central government, the local authority stands between these two actors; as a result, there is constraint on opportunities for farmers to take part in decision-making to help them optimise production. Most decisions made are not in favour of farmers, but instead benefit the local authorities. The sting of corruption at local level is a replication of what happens at the higher levels, as there are credible reports to suggest that the whole cocoa industry suffers from corruption and regulatory mismanagement.

For example, the World Bank quarterly report in 2017, cited by the Reuters News Portal stated:

Box 5.1 Corruption, mismanagement, and hurt in Ghana's cocoa industry World Bank

"Corruption and regulatory mismanagement of Ghana's cocoa industry are denting production and harming farmers, underlining the need for reform, the World Bank said in a draft report seen by Reuters.

Ghana produced a record of 1 million tonnes of cocoa in the 2010-11 season, but output has since declined to around 800,000 tonnes due to poor management, corruption and underpayment of farmers, the World Bank said. Farmers are paid a fixed price each year, known as the farm gate price, which is announced by the regulator, COCOBOD, before the season begins in October. Lack of transparency and poor pricing, according to the World Bank, prevented farmers from planning future crop investments.

"The board (COCOBOD) has been unable to achieve one of its most important goals -- to stabilise farm gate prices at levels that permit farmers to earn an adequate return on their land, labour and capital," the report said.

Instead, COCOBOD, which is also Ghana's sole cocoa exporter, has prioritised increasing its export margin, which boosts government income in the near run but reduces farmers' pay and investments.

The export margin made in Ghana is about double that of neighbouring the Republic of Côte d'Ivoire, the World Bank said.

"Successive governments have prioritised revenue collection, treating the final price received by farmers as a secondary consideration rather than an objective," the World Bank said.

Reforms to COCOBOD's "institutional arrangements and policy framework could greatly increase cocoa output with a minimal budgetary impact," the draft report said.

COCOBOD also controls the provision of fertilisers and chemicals used to combat illness to farmers. According to the World Bank, its mishandling in this area has also negatively impacted productivity.

"Distribution is often erratic and is subject to corruption and capricious political interference," the World Bank said. Occasionally, farmers do not get the goods, which are frequently trafficked into neighbouring nations.

COCOBOD chief executive Joseph Boahen Aidoo told Reuters that management was aware of the report and that it would meet to gain a "full understanding" of the issues raised.

The World Bank report is due to be published but the release date has not yet been fixed. Ghana, which also exports gold and oil, is following a three-year, $918 million aid programme with the International Monetary Fund to restore fiscal balance and reduce a distressing public debt.

The government of President Nana Akufo-Addo, which took office in January, aims to restore cocoa output to 1 million tonnes by 2020" (Reuters 2017).

Source: Reuters News Portal (2017)

From this report (Box 5.1) it is clear that there is systemic corruption within the cocoa industry. For example, distribution of equipment to various farmers is carried out via the local authorities. Local authorities in turn sell this to farmers to make money out of them; the lack of direct connection of the farmers to the government has resulted in this situation.

An interviewee reported that:

> “Although the government provides free farming equipment such as hoes during the planting session, I still need to pay for them at the local office in this district, and this money does not go back to government, but ends up in the local authority workers’ pockets” (Female farmer, in her 50s).

In addition to this, some farmers expressed their frustration with the lack of accountability process throughout the entire cocoa supply chain. Farmers want to have access to information about resources and other equipment provided by the government, but unfortunately farmers describe the secrecy and sharing among the local authority workers, with equipment being later sold to farmers.

> “There is no accountability to farmers, we do not know what equipment the government is issuing to us at any time; all we hear is ‘free farming equipment’, yet we still have to pay for the items at the local authority” (Male farmer, in his 60s).

This finding is supported by Amankwah-Amoah et al., (2018) who also report that government corruption at local authority level is threatening development and adaptability to change by the farmers who are the integral actors in the cocoa supply chain.

The findings also indicate the potential inability of local authorities to fairly accept the implementation of UAV, which in essence would provide enormous benefits to the cocoa farmers. This is illustrated in an expression from the statement below:

> "Even though the application of drones would improve our cocoa farming, the local authority would be reluctant to accept it because the drone is a big machine to steal and hide in their home, so they could not make any money out of that" (Male farmer, in his 60s).

However, the implementation of new technological applications such as UAV, which can enhance cocoa production to reduce costs and maximise production, is mentioned in the government's agricultural initiatives, and it is widely agreed by stakeholders such as local authorities that this would be beneficial (Bosompem, 2021; COCOBOD, 2009). A statement released on 24th February 2014 by the director of Nkawie's cocoa district emphasises the need for the use of UAV for pest spraying of cocoa farms within the region, arguing that cocoa farms should be ready to welcome this innovation as it will help to reduce costs and time spent on the farms in the planting and spraying of crops. Bosompem (2021) also suggests that UAV offer the advantage of saving time in terms of planting and pest management, as they can reduce labour costs while helping to detect areas of land which are most fertile for plantation.

The study identifies major corruption activities as a theme throughout its research findings. This is mostly evident across the various government hierarchies or levels which discourage farmers, as they perceive these initiatives as money-making ventures for these stakeholders, while also having concerns over their own lack of ability to access the necessary training and education required for the usage of this technology to enhance and optimize cocoa production.

5.4.3 Superstitions and traditional beliefs

In general, the findings of this study show that farmers regard cocoa farming production as their largest source of income and livelihood. It is their belief that the pathway to becoming rich in society is cocoa production, and as such it cannot be compromised by the introduction of any new technological implementation. The acceptance of UAV to enhance cocoa production is viewed as a contributory factor to the loss of labourers' jobs, challenging beliefs and traditional farming practices. Despite prevalent evidence of opportunities for their acceptance in farming, a significant number of studies (Mogili and Deepak, 2018) provide evidence that their use has stifled many farms in sub-Saharan countries, and that farmers are often very reluctant to accept the implementation of these technological applications on their farms, especially when they threaten their traditional practices and beliefs.

Due to the ancient religious systems of certain farmers in this region, the acceptance of modern technological applications in agricultural techniques has resulted in a multitude of challenges. Most of the farms are owned by inheritance; as such they are highly protective of outside infiltration by visitors. The traditional belief is that the use of primitive tools such as the cutlass, hoe, axe, 'go to hell' and other tools for production represent best practice, having been used since the 1970s. These farmers have developed a social and personal associations and connections with these farming methodologies. The introduction of a new system is perceived to be a hindrance which will entirely remove these associations and their personal touch from their farms. For example, farmers have a superstitious belief involving the pouring of libation on their farms before conducting activities such as spraying and harvesting. Libation is the pouring of a bottle of alcohol onto the cocoa farmland, calling for ancestors to come to their aid during the farming season.

According to Essel (2014) and Silberberger and Kimengsi (2021), libation is a verbal socio-cultural practice which has been perpetuated by Africans for centuries. These beliefs are part of the mindset of most farmers, and as a result many worry about the implementation of new technologies due to fear of them taking over and minimising the amount of their personal input and influence on their own farms. The photo below was taken during the field work; the researcher witnessed the pouring of libation on a cocoa farm.

The limited level of education of many farmers has caused fear and panic in response to the prospect of any further changes or the introduction of any systems for enhancement.

In a respondent’s opinion during the interview, he stated:

> “The only thing I have is my cocoa farm, and I am happy to use the hoes in farming, I do not want any technology to do any work for me; I am very strong and can do it all. All I need is a bit of libation to the gods for strength and favour in other to harvest more cocoa” (Male farmer, in his 60s).

The above statement illustrates the socio-cultural construct and mindset of these farmers, and the dominant role played by superstitious beliefs and traditions in the lives and the practices of the study’s respondents.

This strongly aligns with farming practices in the Nkawie cocoa district, and has over time led farmers to believe that their ‘smaller gods’ have an essential role to play in their entire cocoa production processes. This study acknowledges that, although farmers are willing to improve their farming practices to increase their cocoa production levels, their traditional belief system is a huge obstacle to this change; it will take a considerable amount of time to educate farmers to relegate these attachments to tradition so that they can embrace change and reality. From the researcher’s point of view, farmers’ illiteracy and limited experience is a challenge, as they have a significant role to play in the implementation process.

5.4.4 Rate of illiteracy

The study’s findings revealed that approximately 70% of the farmers were uneducated; this poses difficulties in underscoring the positioning and importance of innovative technology to their farming practices, including pest- and disease- control mechanisms. Asiedu-Darko (2013), argues that education in farm management is a form of service which supports farmers through the delivery of learning programmes designed to enhance their knowledge of farming methods and techniques, increasing their production efficiency and income levels, improving their standard of living, and generally enhancing the social and educational standards of rural life.

Nkawie cocoa farmers would immensely benefit from extension education services which could provide them with opportunities to learn and implement practical knowledge, addressing the daily farming activity requirements on their farms. There is a need for farmers to recognise and appreciate why change is desirable, and to embrace it in whatever field they are operational (Asiedu-Darko, 2013; Ahmadpour and Soltani, 2012). As farmers continue to battle with pest management and disease control mechanisms, opening themselves up to new knowledge and embracing change is a secure way of developing pragmatic and proactive solutions to some of the challenges they face on their cocoa farms. The lack of understanding and reluctance to accept change was noted as a critical issue during the fieldwork for this study.

A farmer reported that:

> "I have never been in a school before, I can neither read nor write, so I am happy with what am doing on my farm" (Male farmer, in his 70s).

The effective implementation of innovative technologies such UAVs requires measures which ensure that farmers are steadily guided through this process of change, while also gaining the necessary skills to improve their effectiveness in the use of their farms.

Despite the reservations and reluctance voiced by some of the study's respondents, the research also identifies some opportunities for the development of pathways for the introduction of UAV. Most farmers regard this technological application as a step in the right direction for the enhancement of their cocoa productivity. This study argues that, despite the challenges faced by the Nkawie district farmers, which include dependence on traditional beliefs, rates of illiteracy, corruption among local authority officials, and other factors, there is a significant amount of research which confirms the benefits and opportunities which would be offered by the use of UAV for farming practices. Research by Raheem et al. (2020) concludes that this technology already provides significant benefits to the cereal grain industry in countries such as Ghana where food security and sustainability are becoming integral to the development of the agricultural sector.

Annor-Frempong and Akaba (2020) provide evidence of how UAV or drone-applied pesticide on maize farms has been beneficial to smallholders and medium-scale farmers in Ghana. In the domain of producing prime varieties of pineapples in Ghana, the findings of Shaibu et al., (2020) confirm that drone technology has provided an effective and efficient system for the management of crops, ensuring improved plant growth and higher yields. In the classification of maize in complex smallholder farming systems, Hall et al. (2018) conclude that the addition of a near-infrared (NIR) channel and red–green–blue (RGB) spectra, in combination with texture or IHS, increased the classification accuracy of both single and mosaic images to higher than 94%. Thus, the method proved adequate for the definition and categorisation of maize using RGB and NIR imaging and the computing of the vegetation proportion, an essential statistic for the estimation of yields in varied smallholder farming systems.

To explore another beneficial impact of the use of UAV, the Cocoa Research Institute of Ghana (CRIG) recently used this technology for the: 'Topographical Mapping of Inaccessible Land Areas in Ghana'. This study demonstrates that the integration of this technology with Global Positioning System (GPS) and Geographic Information System (GIS) approaches decreased the time and expense involved in the acquisition of data for inaccessible land regions (Quaye-Ballard et al., 2020).

5.5 Opportunities for the implementation of UAV

The use of this technology in other Agri-based sectors such as the grain and fruit industry, as evidenced from the previously discussed studies and research, demonstrate the impact this technology is exerting on the agricultural scene in Ghana. Despite the conservative attitudes of stakeholders and farmers to the implementation of UAV, there were some opportunities for their deployment which were outlined during the interviews.

5.5.1 UAV for disease control and farm management

During the field work it was made clear by participants that cocoa swollen shoot disease (CSSD) was the biggest challenge facing farmers, as they have to face the damaging effects of this virus on their cocoa trees every year. The reactive decision of eradication by the manual cutting down and replacement of affected trees has had an impact on the entire cocoa production supply chain, as more labourers being involved in the process means higher production costs. All the farmers interviewed did accept that the use of UAV would increase their farms' productivity, enabling them to detect very early-stage plants with defects, and reduce the use of labour by spraying pesticides or fertilizer applications on the farm.

Tsouros et al. (2019) contend that the use of UAV in relation to pesticides might achieve either observational or participatory objectives. UAV may fly over cocoa farms, taking photographs for the user to view and analyse the terrain; they can alternatively use infrared and multispectral cameras to examine the interior of cocoa trees to evaluate how the newly applied pesticides are affecting them. In its function as a participant, the drone can spray the insecticide automatically using the onboard software (Silberglitt et al., 2002). Figure 5.7 shows how UAV are used for spraying crops as pest and disease control mechanisms:

Figure 5.7 UAV used for spraying crops from (Baraniuk, 2018).

5.5.2 UAV for cocoa seed planting

Again, the majority of farmers accepted that the manual planting of cocoa trees was time-consuming, daunting, and hard work. Similarly, the significant level of labour engagement associated with the cost of production is another huge challenge that farmers have always had to overcome. They perceive the implementation of UAV as a means of spending less time carrying out farm duties whilst significantly reducing labour costs. UAV can help to eliminate the requirement for physical labour, as well as providing access to other parts of the farm in good time compared to the use of human staff. Figure 5.8 shows how drones are used for the planting of trees during a study in South Africa:

Figure 5.8 UAV used for planting trees from (Caboz, 2019).

This revolutionary South African invention enables UAV to sow seeds in areas earmarked for crop production. This is accomplished by shooting two seeds per second at speeds ranging from 150 to 300 metres per second. The study demonstrates that this method is quicker than a passenger jet’s cruising speed, rendering it more efficient than manual labour (Caboz, 2019).

Figure 5.9 UAV and seed storage from (Caboz, 2019).

Figure 5.9 illustrates the feature of UAV technology which has a seed storage facility which enables it to carry and store seeds for planting on either small- or large-scale or acreage farms. This can therefore be used at different levels of production by both smallholder farmers and for commercial purposes.

5.5.3 Enhanced crop yields

The group of educated stakeholders in the study sample also explained their perception that UAV would help them to obtain data rapidly and frequently. UAV are likely to provide help both to stakeholders and farmers, enabling them to have a firm grasp of data management of the farm issues they face, especially for plant disease control and the assessment of soil conditions.

Kyei et al. (2011) hold that farmers, particularly in the cocoa industry, can improve and enhance their productivity by using UAV for data-driven variable rate assessment. UAV can help to detect areas of cocoa farms which are not producing healthy cocoa trees; they can enhance the detection of the location of problems within the farm environment, and target areas for improvement. In short, this will improve the overall quality of the cocoa farm and enhance productivity. The findings of the study also suggest that UAV can significantly contribute to the enhancement of cocoa productivity, as evidence suggests that the use of technologies in other farming processes, such as for maize and rice, have led to increased production (Kyei et al., 2011). However, the adaptation of technological applications is also subject to the views of cocoa stakeholders, thus, stakeholders' attitudes towards UAV becomes an imperative consideration.

5.6 Examining the implementation of UAV and stakeholders' perceptions

As seen in Figures 3.2, 3.4, and 3.6 of Chapter 3, this study's empirical framework, studies on Disruptive Innovation and stakeholder theory remain scarce. As a result, this study aims to address a significant research gap in the field of the use of UAV in agriculture, notably cocoa cultivation, as few studies have examined the link between Disruptive Innovation and stakeholder theory. To date, no research has been undertaken in the context of Disruptive Innovation in the cocoa farming industry which considers the perceptions of stakeholders about the use of a technology such as UAV on cocoa plantations in Ghana.

Previous research into precision agriculture in the context of Disruptive Innovation shows that UAV are useful in the enhancement of production, as their findings show that this technology has helped farmers to optimise their profitably (Bosompem, 2021). This research study supports the argument that the application of technologies such as UAV on Nkawie's cocoa farms can enhance productivity if adequate training, funding availability, and education are provided to the local farmers. These previously mentioned factors were identified as obstacles to the implementation of this technology in this context.

The unique findings of this study are that, although the majority of farmers are ready to embrace change in order to enhance productivity and improve farming practices, there is a high level of corruption at local authority level, which serves as an obstacle to the initiation of any change. Superstitions and traditional belief systems entrenched in the cycle of farmers' activities are additional key determining factors in the implementation of this technology. Lack of knowledge and experience on the part of farmers have resulted in a strong belief that rituals such as the tradition of libation pouring as a *'sine qua non'* for the improvement of productivity. However, these are beliefs which can be changed by educating farmers, as well as increasing involvement and engagement between them and both private and public stakeholders.

From the findings of the studies discussed, the influential roles of stakeholders came across strongly, as their involvement in the farming processes is evident from the growing stage through to the harvesting stage. In the case of the Nkawie cocoa districts, some public stakeholders are also considered in the light of regulators who make policies for the cocoa industry.

5.6.1 Policymakers' views on technological applications

Nooghabi et al. (2018) argue that the application of innovative technologies in Ghana has recently been a policy priority for the enhancement of agricultural activity. Loevinsohn et al. (2013) describe technology as the means and techniques of generating goods and services, including organisational methods and physical techniques, which have become an intrinsic part of every production and development sector. Clearly, technology offers the infrastructure, knowledge, and data which enable some jobs to be completed more efficiently and more services to be offered (Lavison, 2013).

Policies regarding new innovations are decided on by the government of Ghana under the directive of the Ministry of Food and Agriculture (MoFA). This ministry serves as the decision-maker in the matter of the introduction of new and emerging technologies to enhance cocoa production in the industry. The Ministry, however, has also mandated a fully-fledged organisation, the Ghana Cocoa Board, COCOBOD, which oversees the entire cocoa supply chain business, while ensuring that all initiatives introduced by the ministry are implemented effectively (COCOBOD, 1959).

According to policymakers within the cocoa industry, farm size has a significant impact in the adoption of new technologies, including UAV. This has been affirmed by other experts who contend that farm size may influence, and be influenced by, the other factors affecting adoption (Lavison, 2013). Numerous studies have identified a correlation between farm size and agricultural technology usage (Kasenge, 1998; Ametepey, 2020; Ahmed, 2004; Uaiene et al., 2009; Mignouna et al., 2011). Unlike farmers with smaller farms, those with larger holdings are more likely to accept a new technology because they can afford to devote a portion of their land to the testing of it (Uaiene et al., 2009).

The adoption of UAV is influenced by the fact that the majority of farmers in the district do not manage vast farmlands, according to the findings of this study. Nevertheless, experts such as Yaron et al. (1992) and Harper et al. (1990) believe that small farm size may create an incentive for farmers to embrace an input-intensive innovation, such as a labour-intensive or land-saving technology. As an alternative to increasing agricultural productivity, small-acreage farmers may employ land-saving technologies such as ‘zero grazing’ and ‘greenhouse technology’. The use of UAV has been proven as a land saving technology, as it detects the most fertile part of the soil for planting (Bonabana-Wabbi, 2002).

5.6.2 Public stakeholders' perception of UAV on farms

The majority of cocoa stakeholders in the survey expressed the view that this technological application lacks the characteristics associated with traditional agricultural techniques, posing a challenge for its adoption by cocoa producers in the Nkawie area. Van de Ban and Hawkin (1988) define perception as the process by which information or stimuli are acquired from the environment which changes our psychological awareness, and may have a substantial effect on our response to products and services. In accordance with the decision-making model of pest control posited by Norton and Mumford (1983), there is an element of proof that perception is an integral process used by a farmer to assess conditions which will affect expected outcomes.

Findings from this study show that most stakeholders' actions are dependent on their evaluations and all outcomes, in terms of their own personal perspectives, are critical; they influence their attitudes and levels of support for the implementation of UAV. In summary, Chilonda and Huylenbroeck (2001) state that: *"farmers' attitudes determine the adoption of new technologies. Attitudes are evaluative responses towards technology, and are formed as farmers gain information about it"*. Therefore, it was important to learn how both private and public stakeholders perceived the implementation of UAV for a better understanding of their decision as to whether to adopt it or not.

5.7 Acceptance of UAV as innovations to optimize productivity

Based on the research findings, UAV in the Nkawie cocoa district are regarded as a 'stigmatised' technology. Due to their lack of exposure, farmers have an unclear, and sometimes inaccurate, understanding of these technologies; this results in a stigmatisation of the technology as a whole. This is due to a multitude of variables, including perceptions of exceptionally high risk, mistrust in management and government, corruption within local authorities, perceptions of unsuccessful technical trials, and stakeholder assurances.

The stigma associated with UAV is primarily the result of debates about ‘drones’ and US military strikes in Afghanistan and Pakistan, which revolve around issues of efficiency i.e., unmanned versus manned missions, ethics i.e., desensitised killing, and accuracy, as it relates to collateral damage and indiscriminate civilian deaths (Efron, 2015; Lee, 2016).

Moreover, UAV raise privacy issues among individuals and organisations which fear that these technologies will be used to spy on them (Lee, 2016). This is consistent with the way in which farmers regard the usage of technology on their farms. As illustrated by the example of the Nkawie cocoa district, the stigmatisation of technology can constitute a considerable barrier to its acceptance.

The research reveals principal themes related to the adoption of UAV, as well as the key roles of both public stakeholders’ involvement and private stakeholders’ engagement in the implementation of this technology on Nkawie’s cocoa farms. Throughout the study it was evidenced that cocoa farmers within this region attach strong traditional sentiments to their indigenous practices, which renders it difficult for them to accept change. The implementation of UAV within the Nkawie cocoa district will require the support of both public and private stakeholders.

5.8 Summary

Key findings presented in this chapter which show that, although cocoa farmers are interested in the implementation of the UAV, there are some significant barriers which increase their reluctance towards the acceptance of this technology. The findings of this study reveal that both private and public stakeholders are willing to invest more in training to educate cocoa farmers in preparation for the implementation of this technology.

The key revelation here is that cocoa farmers regard Disruptive Innovation in their farming practices as ‘taking their farms away from them’ due to the personal and traditional attachments and associations they have with their holdings. The study’s findings further reveal that the existence of an effective collaboration pact and transparency between farmers and stakeholders to increase the understanding and impact of the implementation of UAV as an innovation to improve production would be imperative in the future. The following chapter discusses the pathways towards the implementation of UAV in this context.

Chapter 6 A perspective roles on non farming stakeholders

6.1 Introduction

The perceptions of farmers as integral stakeholders to the implementation of UAV in the farming ecosystem has been explored and analysed extensively in Chapter 5, with findings highlighting over-dependence on traditional farming practices, high illiteracy rates among farmers, over-reliance and dominance of the effects of superstitious beliefs, and perception of corrupt practices of public stakeholders as barriers. The findings also highlight drivers for their acceptance and implementation, including time-saving advantages, reduction in labour costs, the ability to reach inaccessible areas for large farmlands, providing accurate and timely information on soil conditions, pests, and diseased trees and seeds, as well as aiding the spraying of chemicals on the farm.

Some farmers who participated in the study also mentioned that lack of government support regarding the supply of fertilizers and cushioning labour costs to help spray cocoa farms to control pests such as swollen shoot virus was having an adverse impact on their cocoa production. Nonetheless, with farmers' limited skills and knowledge on farm practices, farmers have been able to hold the forte to meet in a way the demands of the industry.

6.2 Public stakeholders

As seen in industrialised nations, precision farming advice based on drone technology has led to global improvements in land usage and agricultural yields (Mogili and Deepak, 2018; Shafi et al., 2019). This technology has been explored extensively on different crop farms including rice, maize, coffee and wheat production. The benefits of this technology have improved land mapping, spatial farming, imagery, assessing soil conditions, and the testing of leaf viability, among several other benefits (Khosla, 2010). This has harnessed much stakeholder interest and debate about the present benefits and future prospects of this technology in developed countries, especially with crop improvement and performance (Nandurkar et al., 2014).

The awareness and adoption of UAV (UAV) in developing countries remains a huge debate amongst the stakeholder community, as the reluctance for the uptake of this technology in farming has not been investigated thoroughly, most importantly in the area of cocoa farming. More importantly, the perspectives and roles of stakeholders in the adoption and implementation of this technology is critical to its uptake for successful implementation in the cocoa industry. The following sections detail the diversity of the perceptions and roles of various stakeholders, as highlighted from the themes extracted from the interviews analysed during the study.

6.2.1 Ministry of Food and Agriculture (MoFA)

The Ministry of Food and Agriculture (MoFA) is government's designated department for overall policymaking and management of the agricultural industry where the cocoa sector is positioned. One of the stakeholders from the ministry interviewed mentioned that the government has sought to integrate and roll out policies which align the cocoa sector to practices that are globally accepted and locally-relevant. He explained that:

> "Today, the whole agriculture landscape has changed globally, and if a country or ministry does not align itself to this change, it will either be still relying on old farming methods or cut off from development. It is becoming serious that international donor agencies and foreign countries, whose expertise and funds developing countries rely on, may threaten us if we continue with our old ways" (Officer from MoFA).

This accounts for initiatives such as the Ghana Cocoa Forest Programme (GCFRP), which has been endorsed for implementation by the Carbon Fund of the World Bank, in collaboration with the Ministry to enact policies which engage all stakeholders in the cocoa ecosystem to be active participants for the smooth delivery of new policies targeted at sustainable cocoa farming. The GCFRP is a landscape-wide initiative directed at the enlargement of cocoa farms within cocoa regions in Ghana, of which the study area is part.

The success of this initiative is highly dependent on the introduction and integration of technologies such as drones in farming, as this will provide accurate and timely data for tracking interventions deployed in the cocoa industry.

An interesting observation made by the officer who explained the aim of this initiative was geared towards the reduction of carbon emissions, which is imperative in sustainable cocoa farming. He commented that:

> "Enlargement of cocoa farms also comes with the threat of deforestation of vegetation, which is of serious concern in the cocoa industry. The aim of this initiative is the reduction of carbon emissions. The big question is, how will we be able to track down farmers and other illicit practices of deforestation if we do not use drone technology? It even includes illegal chain saw operators, who cut down trees and smuggle them. The best thing about the drones is that, instead of moving between farms to catch these people, who run away, the drone is able, within minutes, to fly longer distances, take pictures and give us specific locations on which to concentrate. This same approach will allow us to monitor farming practices which amount to inappropriate deforestation practices and contribute to global warming" (Officer, MoFA).

Thus, from the MoFA officer's point of view, the ministry's role in the introduction and implementation of UAV across the cocoa sector to enhance productivity and farming practices is of the utmost importance to the industry. This means that acquiring the technology through this funded initiative is a strategic intervention which will not only achieve the improvement of farming practices and reduce carbon emissions, but will also be less expensive for farmers to use on their cocoa farms for crop maximisation. The Nkawie cocoa district is known to be one of the Hotspot Intervention Areas (HIAs) identified by this initiative. According to the MoFA officer:

> "The HIAs are made up of several districts that were selected on the basis of deforestation trends, drivers of deforestation, production challenges, and the occupations of the population in cocoa farming areas. Due to this, the government is focussing on cocoa expansion and improvement within these regions, and considers the implementation of UAV as a sure way of using innovation to contribute towards cocoa productivity" (MoFA officer).

It is evident that the debates on the deployment of drone technologies in Ghana, and farming in particular, have started, as the Ministry is taking steps to digitize and revolutionize its agricultural sector.

6.2.2 Public Private Partnership (PPP)

According to the ministry, Public Private Partnership (PPP) is another key step the ministry has initiated to develop a broader stakeholder approach in scaling up this technology's application in cocoa farming. The Ministry has been engaging with some private innovative enterprises including Amdrone Tech drones, which are currently being used in precision farm spraying and crop diagnostics respectively in Ghana (MoFA, 2021).

These PPP's are aimed at directly offering farmers the support they need to enhance their cocoa productivity, while also increasing the accessibility of these applications.

An observation made by the respondents showed that the purchase of Unmanned Aerial Vehicle for farmers is a seemingly impossible venture for them, as they do not have the lump sums of cash to purchase these drones. As such, the Ministry, through these partnerships, is calling for payment plans which will offer flexibility for farmers to make payments, or otherwise resort to the use of pre-financing credit schemes from fully-fledged banks, as well as rural banks.

The MoFA officer, however, noted that there have been difficulties for farmers to access these credit facilities from the banks because some of the banks deem them as not credit-worthy with the high risky tag associated with the farming industry, especially with cocoa. One of the MoFA officers shared some experiences recounted by the farmers with the researcher, saying:

> "After introducing the farmers to some of these local drone companies, I remember some saying that they went to different banks to apply for a loan, but all the banks turned them down. According to them, the banks were reluctant to grant them these loans because they categorically told them that agriculture in general is a high-risk sector, and the lack of an adequate risk assessment framework, including risks associated with pest- and disease control, is not helping them, as banks and credit institutions, to conduct a thorough assessment to help assess farmers individually based on their farm to make an informed decision" (Second Officer, MoFA).

This is the case for the majority of smallholder cocoa farmers who reside in remote locations such as Nkawie and have limited access to financial services such as savings accounts and robust bank transaction accounts. The 'cash and carry' system, including paying for labour cost on a cash basis, which is normally not documented, remains a major support for financial inclusion in the cocoa farming sector. The emergence of rural banks was one of the early interventions the government established with the Ministry to help resolve some of these financial inclusion deficits. This is consistent with the research findings that approximately 46% of farmers in Ghana keep their money at home, whereas just 26% save in a bank and 28% use a 'mobile money wallet' (Abu and Haruna, 2017).

Another respondent from MoFA, referring to his personal interactions with some of the loan officers from some leading financial institutions, had this to say:

> "The loan assessment officers of some banks told me that most of these farmers save with village institutions, credit unions and 'susu' (small personal savings) collectors, which makes it difficult to assess their creditworthiness, as they do not save with us. Although they acknowledged that some of the farmers have promising farms due to their capacity, there is no guarantee that they can make the loan repayments".

Another respondent, who has worked extensively with farmers in several cocoa districts, helping some with access loans and other credit facilities from rural and big banks and financial institutions for cocoa farming, said that:

> "The banks are now not prepared to help the farmers because they have been left down by the farmers themselves before. The farmers failed them, which is reason why farmers applying for a bank loan are usually unsuccessful. This precedent that has been set by previous farmers make it difficult for banks to trust and deal with new farmers, especially those who operate small- and medium-scale farms. In addition to this, price instability on the local market and the government's delays in paying cocoa farmers are additional contributory factors which cause farmers to default on loan repayments with the bank. It is a whole complex issue

to consider, but drone technology is still important for farming" (Third Officer, MoFA).

Again, the MoFA stated that the PPP plan includes the use of huge commercial drone businesses in the cocoa sector. GEM Industrial Solutions, a Ghanaian supplier of commercial Unmanned Aerial Systems (UAS) services, which was launched in 2017, focused on the agricultural sector in general. Using drone technology, the company offers a variety of services, including mapping, crop health assessments and diagnostics and tree counts.

According to one MoFA officer, the Ministry is currently promoting a campaign of attracting Ghanaian innovators and entrepreneurs in the diaspora to consider tapping into the country's technological space, with a specific focus on the development of UAV with super intelligence for the development of the cocoa sector. Thus, he contended that:

> "We have already identified some Ghanaians in the diaspora who are doing incredibly well in the technological space by developing very intelligent and multi-purpose drones for the rice, wheat, and coffee industries, and we want to attract them to come and develop some for our cocoa industry".

6.2.3 Ghana Cocoa Board (COCOBOD)

The Ghana Cocoa Board (COCOBOD) is the lead institution and strategic business unit established by the government for the implementation of the majority of the commitments around production of cocoa, the management of pricing and the supply chain, and the enhancement of farmers' livelihood within every cocoa farming district, of which the Nkawie cocoa district is part (COCOBOD, 2021). In particular, this institution provides fertilizers to farmers for spraying their cocoa farms while also spearheading local policy for cocoa production and management. Strategically, this institution works collaboratively with several other institutions such as the Ministry of Food and Agriculture and the Ministry of Environment, Science, Technology, and Innovation, as well as academic and research institutions, to support COCOBOD in the improvement of cocoa farming practices.

To this effect, COCOBOD, from the researcher's interaction with the respondents, has been actively engaged in promoting the investment and integration of technologies such as UAV in cocoa production for purposes not limited to spraying crops and fertilizer application, but also mapping and plant and soil diagnostics, which prove beneficial compared to the manual delivery of these farming functions.

This advocacy for technological investment and application in the cocoa sector by COCOBOD is not a new concept to this strategic unit in the cocoa industry. A news report published in 2021 on the introduction of new technologies states that:

> "The Ghana Cocoa Board (COCOBOD) has adopted the use of cocopeat and receptacles as new technologies for raising cocoa seedlings at nursery sites. The initiative is part of the Board's moves to streamline its core activities to align with best practices that protect and conserve the environment" (Ghanaian Times, 2021).

Cocopeat is a 100% soilless organic medium produced from coconut husks with some trace elements which make it a good substitute for topsoil, whereas the receptacles are plastic containers which are used to replace the polybags often used in raising cocoa seedlings.

Commenting on when the new technologies would be rolled out, the Executive Director of the Seed Production Division (SPD) of COCOBOD, the Reverend Dr. Emmanuel Ahia Clottey, disclosed that 25 of the country's 32 Seed Production Division Stations had implemented the innovation for the 2020/21 crop year" (COCOBOD, 2021a).

In response to questions about the significance of this twin technology for farmers and the cocoa industry as a whole, the COCOBOD officer explained to the researcher that:

> "The two media are not only ecologically-friendly, but also provide good conditions for the proper growth of the seedlings. The cocopeat promotes high water retention, ensures good germination, and rapid seedling emergence. The receptacles, on the other hand, have holes underneath which ensure good drainage and guarantee the formation of intact and healthy roots. Again, removing seedlings for transplanting from receptacles is achieved with minimum

> disturbance to the young plant, and these qualities are essential for a high survival rate of seedlings" (COCOBOD officer).

This significantly evidences the exposure and drive of COCOBOD to embrace the implementation of technologies for the overall growth and productivity for cocoa farming while reducing the burden of loss on cocoa farmers.

On the matter of the role that UAV will play in the cocoa industry, a number of the respondents from COCOBOD maintained that:

> "The next phase of cocoa farming will be about who is able to leverage technology for cocoa growth. Our neighbours Cote D'Iviore, who are the highest producers and exporters of cocoa in the world, are using drones; this is providing significant benefits such as effective disease and pest control as well as testing the viability of seeds and trees grown. What is stopping us here in Ghana from applying this technology if we are serious about wanting to overtake Cote D'Iviore?" (COCOBOD officer).

The industry awareness of COCOBOD, as stakeholders of the deployment and extensive use of UAV, is not just in developed countries like Japan, UK and the USA, but the acknowledgement of their use in a competitor industry, who also happens to be a neighbour, is a strong indication of the willingness of this ministry to support the implementation of this technology in Ghana's cocoa sector, and Nkawie specifically. This also evidences the recognition of how technology is playing an integral role in the reduction of incidences of pests and diseases, as well as the benefits it creates for soil and seed sampling, which is a critical element of the cocoa farming and supply chain.

One of the respondents explained that:

> "To enhance cocoa production in Nkawie, there is now a need to invest more in technology to help our farmers who struggle all year round. We are in talks with stakeholders to support us in establishing a clear initiative which will make this happen. As part of the COCOBOD budget, we have now factored in the purchase of new farming technology such as drones for use by farmers on their farms. There is no doubt that investing in technology will serve as a massive benefit for our cocoa farmers and the entire cocoa production, as we are seeing in Cote D'Ivoire" (COCOBOD officer).

This clearly evidences the efforts being made by policy-makers as a form of readiness to formulate effective polices and initiatives for both private and public stakeholders for the implementation of new technologies in cocoa farming. These statements, as demonstrated, consider the inclusion of the adoption of UAV in cocoa farming in the district of Nkawie, which is one of the target areas for the production of cocoa in high volumes.

Apart from the Ministry of Food and Agriculture (MoFA)'s efforts to invest in drone technology, targeted at tracking deforestation issues and carbon emissions reduction, COCOBOD also operates a jointly-coordinated environmental programme with the Forestry Commission which also seeks to considerably increase the afforestation of degraded farmlands in the country's cocoa landscape. The initiative seeks to expand cocoa cultivation into forest regions, whilst simultaneously tackling illicit logging and chain sawing and illegal mining, which undermine the sustainability of cocoa farms and encroach into cocoa fields.

Here, one respondent from COCOBOD noted that the protection and security of cocoa farmlands from activities such as illegal mining and encroachment is important because these issues are serious threats to the sector; this explains why the implementation of UAV would be an essential intervention in warding off unlawful activities and providing security for these farmlands. One of the officers commented that:

> "Due to the vast area of the land, by the time farmers become aware of who is encroaching on their land, then it is too late. Sometimes finding the culprit is difficult because by the time you even get there they are gone. It is always your word against theirs, but when we get these drones, we will be able to obtain pictures and images which we can rely on for the prosecution of illegal encroachers of farmlands. Therefore, these drones will work as security agents; the good thing is that they can travel around within a small space of time compared to human beings traversing hectares of farmland" (COCOBOD officer).

By addressing these threats, Ghana is not only seeking to secure the future of its cocoa farmland and ward off insecurity while boosting investors' confidence, but this afforestation strategy involving drones to assess the viability and growth of planted trees will also render the cocoa sector more climate-resilient, while simultaneously sustaining and enhancing income and livelihood opportunities for farmers and forest users across the programme area.

6.2.4 Cocoa Health and Extension Division (CHED)

The Cocoa Health and Extension Division is another government agency which plays a crucial role in providing learning opportunities for farmers, engaging with external cocoa stakeholders, while also acting as a bridge for communication between other stakeholders and farmers. This agency is able to transcend the language and technical barriers, which facilitates the transfer of new knowledge from research institutions to farmers and vice versa. Giving farmers the opportunities to learn about technological application such as UAV and to understand the importance of adopting such technology is this agency's responsibility. The agency motivates farmers while also whetting their appetite for embracing change, including the implementation of drone technology for the enhancement of productivity in cocoa farming.

Both public and private stakeholders such as the Ghana Cocoa Board, farmers' associations, local authorities, farmers, and educational institutions rely on this agency, tasked with practical and hands-on activities, delivering meetings, organizing workshops, technical roundtables, and stakeholders' programmes towards the technological adaptation of the cocoa ecosystem. This study uses the experience of members of this agency who have earlier conducted round table consultations with other stakeholders, including farmers, on the adaptation of Unmanned Aerial Vehicle technology for farming.

One respondent explained that:

> "During the drone test sessions organized for farmers , they were excited to see how drone technology was working effectively with the images of the farm it

> captures, including how the spraying of the fertilizer onto the crops is carried out" (Health and Extension officer).

These practical sessions, according to the officer, offered stakeholders opportunities to experience a practical visualization of the use of drone technology in farming. Although some of the stakeholders, according to the health and extension officers, were sceptical about the efficiency of the technology in terms of its ability to spray every single crop, a walk-through inspection and practice also proved vital in improving the user experience of the stakeholders, who were eager to observe the implementation of drones in precision farming.

In developing activities to assist farmers understand the whole concept of this technology, the health and extension officers, through their education workshops, introduce videos which have had a positive effect on farmers' perspectives, attitudes, and interest in the application of this technology for cocoa farming. This, in their opinions, enhances knowledge exchange and experiences, encouraging the approach of optimising cocoa production.

> "Watching YouTube videos on drone technology for farming was integral in psychologically preparing farmers for the practical test sessions, which were influential in providing them with a 'teaser' of what the technology can do for them on their farms. The farmers' knowledge of what the technology really is, and how it can improve their crop performance and farming practices was rendered visual through the video sessions which including practical test sessions" (Health and Extension officers).

Figure 6.1 Farmer observation of deployed drone from (Author 2021).

As shown in the figure 6.1, a farm owner is carefully observing a drone conducting a diagnostics test on cocoa trees, while concurrently taking images. The feedback from these practical test sessions, according to the health and extension officers, evidences the readiness of the farmers and other stakeholders for the implementation of this technology.

Figure 6.2 Drone deployment for pest scaring from (Hastings-Spaine, 2021).

According to the health and extension officers' observation, which was shared with the researcher, in addition to the general purpose and benefits offered by drone technology to farmers, which includes helping farmers to map fields and spray fertiliser more efficiently, it emerges that the drones also have a 'buzz effect' which irritates pests. As shown in Figure 6.2, a health and extension officer demonstrated how a single drone can be deployed to scare away birds on a farm, even during nursing or replanting stages on farmlands.

6.2.5 District Cocoa Office

The integral role of the District Cocoa Office in the cocoa ecosystem cannot be underestimated. This office is the station unit within the farming community which constitutes the link between farmers and the marketing and buying community in the cocoa supply chain. The office also plays a critical role in the development of stakeholder relationships as a means of creating an internal support system to help farmers to gain access to local technologies to support their farming activities. Therefore, instead of waiting for the big players, this office extends and seeks out stakeholders who are willing to provide investment, expertise, market information and technology to farmers at local level. For example, an officer explained that:

> "Instead of depending on health and extension officers' visits to organize workshops and training sessions for our farmers and their workers, we sometimes take it on ourselves to offer that service and support for the farmers so that they do not fall behind in the matter of what new farming practices are being applied elsewhere" (Officer, DCO).

The researcher's interactions with the officers at this station showed that they were knowledgeable and had been exposed to the drone technology used in farming, as their engagements with other stations and stakeholders outside the district had been integral to their acquisition of this knowledge. They share knowledge of how this technology offers timely and strategic benefits, that are not currently provided to farmers regarding manual or manned processes and activities. In sharing an experience of drone technology for pineapple farming, which was witnessed live in operation, one of the officers explained:

> "We have an information system established to link farmer production to market information so that both investors and farmers can be given up to-date information on the conditions of their cocoa plant, but because we still have to resort to the use of manual processes, we are not able to provide timely and accurate information. Conducting laboratory tests to assess soil and plant conditions can be cumbersome and time-consuming at the same time. When I visited a pineapple farm, I was surprised to see their system, which uses drones which are small, Unmanned Aircraft which provide feedback information on crop health, performance and yield estimates and then relay this through a mobile phone platform linking farmers to extension agents, markets and others" (Cocoa Office officer).

This clearly evidences the level of exposure these officers have to the application of drone technology in other farming activities for crops which also operate on a small, medium and large scale. This same technology can revolutionise the cocoa industry in the Nkawie district and the country as a whole. The researcher was also shown how the office is currently engaging with some local companies and innovators who have developed UAV for other sectors of the agricultural industry. What is interesting about some of these local companies is not only their development of, and advocacy for, the use of drone technology in farming, but the fact that some of these organisations have developed a rental scheme which provides smallholder farmers with the opportunity to afford the rental of this new technology for their farms.

One such company is ‘Acquahmeyer’; this start-up leases out drones which enable small-scale farmers to inspect crop health and apply pesticides only where necessary, thereby decreasing environmental and health concerns. According to a representative of this company, drones help farmers to identify pests and diseases in order to determine which crops require spraying, and which do not.

In a report broadcast by Cable News Network (CNN) Business news, the Chief Executive Officer (CEO) explained that:

> “Acquahmeyer is now working with 8,000 farmers, who pay USD$5 to USD$10 per acre, approximately six times a year, to assess their crops and soil and apply pesticides. Each drone costs USD$5,000 to USD$15,000 to build, and can spray 10,000 acres annually. Acquahmeyer’s strategy of training locals to pilot and repair the aircraft is helping to fuel interest in the company and its growth, says Nelson. He says: “In every farming community we have ambassadors for our company who are pilots, and we are creating jobs. We want to make sure that technology and agriculture becomes an exciting job” (CNN Business News, 2019).

According to the District Office, the presence of companies of this nature, and their active involvement in introducing ambassadors who are stationed in Nkawie, as well as the training of farmers and young people within the local area to learn how to operate and repair these drones, is sparking significant interest in the use of this technology for farming. The success of this in other sectors such as vegetable and fruit farming, which was a pilot of a European Union (EU) project, is a clear indication that this technology can be applied to cocoa farming, which is why the District Office has been actively advocating for the implementation of UAV in the Nkawie cocoa farming district.

Figure 6.3 Deployment of drones for aerial shots from (Author, 2021).

Figure 6.3 illustrates a pilot flying a drone over a cocoa farm, where the technology provides accurate imagery taken at a high speed, meaning that it can cover large surface areas while providing timely and up to-date feedback on plant and soil conditions.

6.2.6 Cocoa Research Institute of Ghana (CRIG - Ghana)

The Cocoa Research Institute of Ghana (CRIG) is the single and mandated research and educational agency of the government and stakeholders in the cocoa farming ecosystem. This agency is tasked with collaboration with international agriculture-based organizations and research and academic institutions in the cocoa sector to study trends in cocoa farming practices aimed at improving the prospects in the industry. This agency also has a Seed Unit which conducts research into seed viability and performs test on soil samples and plants to assist farmers deal with diseases and poor soil conditions.

Among other functions, the CRIG also works on experimentation with seed varieties to support farmers. One of the officers of this research institution interviewed maintained that, although collaborations for cocoa research are increasing due to the economic contribution of the crop in the global market, the influence of technologies such as the UAV cannot be ruled out, as it offers enormous support and facilitates the work they carry out, especially in terms of collecting farm data for their laboratories. He explained that:

> “The implementation of drones in cocoa farming is long overdue; trust me when I tell you that the implementation of this technology in cocoa farming will restore investors’ confidence in the sector. This is because we will be able to project yields and returns for investors by telling them the number of cocoa plants on the farms which are disease- and pest-free, as well as telling them about the measures we are taking on the diseases which affect plants and/or seeds to make sure that they do not lose out in the long run. These drones will also assist smallholder farmers with relevant and real-time information on which parts of their farm and plantations are doing well, as well as soil conditions. It will help to prevent post-harvest loses and reduce the perceptions investors and stakeholders have about cocoa being a high-risk venture, especially the banks and financial institutions who fear granting loans to cocoa farmers. We will be able to support farmers’ loan applications with digitized data and research results, which will help banks to make informed decisions based on live information and updates on farm conditions. The Unmanned Aerial Vehicle technology will improve the reliability of information which can be fact-checked based on the farmers’ own land and crops, yields and even the quality of the seeds produced” (CRIG research officer, Seed Unit).

The relevance of this agency’s perspectives in underscoring the benefits of drone technology to farming and farmers in general in laudable, as it removes many of the bottlenecks faced by farmers when accessing credit facilities for their farm operations. In essence, a farmer applying for a loan will not only rely on hard copy pictures taken from the farm which may be deceptive of a healthy farm, as explained by some loan assessment officers. With drone technology, the introduction of digitization to the cocoa farming business will help farmers to apply and rely on the data on soil and plant conditions as well as yielding estimates provided by the CRIG agencies to banks which support loan applications. Here, banks can verify information and gain the opportunity to sit in the comfort of their offices and watch what is happening on farmers' farms in real time. The relevance of this intervention, according to the research officers, will be a breakthrough for the cocoa industry as a whole.

On other matters, the CRIG has also mentioned that the agency has partnered with drone manufacturing companies locally to support its initiative of growing forests around cocoa farms in conjunction with the land commission. The partnership with Micro Aerial Projects LLC, a mapping drone manufacturing company, and Omidyar Network, a non-governmental organisation, will focus on improving land rights and registration in developing countries. Dual frequency GPS receivers, training drones and parts, a complete toolbox for the repair of drones, a mobile workstation with a high specification laptop, processing software, and four terabytes of external hard drives will be provided.

What this means for cocoa farmers who have not inherited family land or cocoa farms from their ancestors, which is the usual path to ownership of cocoa farms, or those who do not have full purchasing and ownership rights over the lands they farm, is that they will enjoy protection and security of their investments through the mapping and surveillance of their farms. Here, disputes over farm allotments and land boundaries will be easily resolved, as the Land Commissioner does not need to be on the land in person when a dispute is reported; instead, drones can be launched to pick up a live feed as well as completing the mapping.

6.2.7 Local Authority

The Local Authority plays a key role in attracting strategic stakeholders while building tactical partnerships with companies which have resources and expertise suitable to support the players in the cocoa farming sector, specifically famers. Agripower Ghana Limited, the company behind Ghana’s fertiliser manufacturing, has deployed ten UAV in the Ashanti region to support farmers in spraying their fields with fertilisers and pesticides, as well as facilitating the mapping, monitoring, and fumigation of farms.

A local authority officer interviewed during the field study process provided images illustrating of some of their engagements with the company, including the sensitization efforts established by the company to engage farmers in accelerating their acceptance of drones in farming, and specifically precision farming in the Nkawie District. Although opportunities of this kind are national interventions, it takes the efforts of the local authorities to establish good working relationships with companies of this nature to attract them to a District like Nkawie to offer their services to farmers. According to one respondent:

> “We have been to these workshops organised by the company and have seen what the drones can do, but it is better if we bring them to the district for the farmers to

see them for themselves, so that it does not become ‘reported speech’. There is already a perception of corruption amongst public officials in the minds of these farmers, so when they see the illustrations live and hear from the horse’s mouth, they will see and believe that the benefits and prospects of using drones to farm bring many advantages. From where I sit, drones help labour on the farms and decrease their costs, also guaranteeing high yields” (Local Authority officer).

In reality, additional enquiries by local government employees indicate that drone technology is undoubtedly one of the most rapidly emerging and fast-advancing technologies. Indeed, this technology has proven useful to various parts of the American economy, not simply the military. Although helicopters were the main machinery used for aerial operations and air transportation, the officer referred to the uses of drone technology in distributing medical supplies in the country, as well as the invaluable contribution it made during the heat of the COVID-19 pandemic, when drones were used by a company to fly samples for testing for the COVID-19 virus in patients.

In fact, according to the CEO of Zipline, as reported in the Verge News Portal:

> "The reason why Ghana was the first country to receive the COVAX vaccine is that it had the strongest application; this is because they can guarantee the delivery of this vaccine to any health facility or hospital in the country via Unmanned Aerial Application which comes at a low cost and very high reliability rate" (Zipline's CEO Keller Rinaudo).

Another employee of Zipline explained that:

> "The speedy nature of drone delivery helps with the challenges posed by 'cold chain logistics'. There is no need to worry about traffic delays in the sky, he says, and the drones, which travel at 100 km/h, take only 30 to 40 minutes on average to complete each delivery" (The Verge, 2021).

This, according to the local authority officer, evidences the huge strides that drone technology is making in other sectors, which explains the reason for their strong advocacy for this technology in cocoa farming using Nkawie as the centre of technology-aided farming, what is now termed: 'precision farming'.

6.3 Private stakeholders

As shown in section 3.6, chapter 3, the role of private stakeholders is crucial to the adaption and application of UAV. The various roles for these private stakeholders are thoroughly explained in the next subsection.

6.3.1 Farmers' associations (Ghana Cocoa and Coffee and Sheanut Farmers' Association)

Farmers' associations in the agricultural industry are some of the groups which protect the rights and interests of their members, as well as negotiating for resources for the interests of other stakeholders. The positions and views held by this association are critical because its support or otherwise may impede acceptance of the implementation of the Unmanned Aerial Vehicle application in cocoa farming. The purpose of the Ghana Cocoa, Coffee and Sheanut Farmers' Association is not the protection of its members, but also their education on the debates on current technologies and farming practices which, when adopted, would enhance their practices and production. During one of the field visits and discussions with the Head of the Association, he said:

> "We have heard of the drone technology and have visited the farmers and other friends who are involved in vegetable growing. In fact, I led the cocoa farmers on a tour during a pilot of one of the drones on a maize farm, and what we saw with our own eyes was amazing. My members themselves came to tell me that they wish we had this technology, but I was told it would be very expensive for us due to the features associated with a drone for cocoa, especially with the kind of analysis it can perform on seeds and cocoa plants. We have engaged with our members, and they are ready to accept it, if we can have access to it". (Head of Cocoa Farmers' Association).

This clearly evidences the role the association plays, with its members ready to accept and implement the technology of UAV, which the researcher posits should be the focus for the expansion of cocoa production in a less costly, effective and sustainable manner, as a means of improving farmers' yields and income, while the use of technologies such as the Unmanned Aerial Vehicle also decrease labour costs and the level of manual work required. Focusing on UAV' implementation will help to achieve strides in sustainable cocoa production while farmers' livelihoods will be significantly improved. There is no doubt that farmers' associations form and play an integral role in the decision-making nexus for technological acceptance of the aim of achieving higher cocoa productivity.

6.3.2 Nexus of research organizations, institutional and individual investors

In addition to the Cocoa Research Institute of Ghana (CRIG), which is the government's research agency, there are other private stakeholder-run research organisations and partnerships whose research input plays a significant role in the implementation of UAV in the cocoa industry. These organisations supply the cocoa growing business with knowledge and, in particular, a framework for the support of farmers. A project led by the Department of Agricultural Economics and Extension of the University of Cape Coast, with the support of the Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA), the MasterCard Foundation, and the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), aimed at providing drone services to assist farmers in specific stages of their production, is an illustration of one of these interventions. Although this project was started in 2018 and ended in 2020, with considerable success, there is a growing likelihood that the cocoa sector will be the focus of the next phase of this project due to the significant role these drones will play in increasing cocoa productivity (Hinneh, 2020).

The principal member of this partnership project, which recorded remarkable success in the pineapple and vegetable sector, as captured in Hinneh (2020)'s news article, noted that:

> "Using drone technology has enabled farmers to be more effective and efficient in managing their crops and has ensured improved plant growth and higher yields. The drone, a Parrot Bluegrass, was used to map the demonstration plot, and also captured initial relevant agronomic data of plants on the field. The drone's sensors collect multi-spectral imagery of the pineapple crops; this captured imagery was processed to generate index maps. These index maps showed the chlorophyll content of individual pineapple plant, which were used to estimate their nutrient

requirements. It also provides recommendations for fertilisers to be applied by the farmers" (Principal member, Festus Annor-Frempong, 2021).

Due to the remarkable contribution of drone technology in plant diagnostics with the pineapple fruit, the researcher observes that such partnerships are currently ongoing to develop more sophisticated features on drones to be used for cocoa farming; this evidences the level of stakeholder commitment to the implementation of UAV for cocoa farming in the whole value chain having a significant impact on cocoa farming in the Nkawie District.

In the same vein of partnership, some of the respondents informed the researcher about other past projects focusing on Climate Smart Cocoa Value Chains in Ghana, which was piloted in 2016 under the CGIAR's global 'Climate Change, Agriculture, and Food Security' (CCAFS) research programme and delivered by a project consortium comprising pre-eminent actors in agricultural climate science and the sustainable value chain development, namely: the CGIAR (represented by InterAction) and the International Institute for Sustainable Development (Hinneh, 2016).

Through the application of climate science and impact investment, this initiative sought to mainstream climate-smart agriculture into cocoa-based agricultural systems. This initiative made substantial use of technology to translate climate knowledge into tangible plans for farmers, supporting players such as industry, certifiers, and investors (Hinneh, 2016). These partnerships which have applied technologies in varying degrees attest to a robust debate on the application of technology in the cocoa farming domain. Some of the respondents noted that pilot events like this one psychologically prepared the stakeholder community, including farmers, especially about the need to adapt to technology as the new phenomenon in the global agriculture production industry. This is because countries which do not integrate technology will be left behind in the digital revolution which is under way in agriculture all over the world. As such, the support for drone farming technology has become a pivotal concern for innovators and entrepreneurs in the agricultural sector, specifically for cocoa farming.

The research and investor business Unitrans Africa have been active in agricultural innovation on the African continent for the past 50 years, providing cutting-edge agricultural inventions. Following the company's recent acquisition of a fleet of the largest spraying drones in the world, this organisation is poised to reach new heights. The company's spokesperson explained:

> "Unitrans' purchase of seven Chinese-made DJI T30 Agras drones, which were developed at a cost of over R400 million, is set to become a game-changer for the agricultural industry across Africa in general and the Southern African Development Community (SADC) region in particular. Drones use batteries instead of fuel and can spray at night, whereas a plane cannot, thereby allowing for 24/7 spraying operations. Drones also allow for greater penetration through the crop canopy, as well as offering variable rates of application within the same

> field, which is a major advance in aerial spraying worldwide and a first for Africa" (Africa Science News, 2021).

One of the respondents, who is an individual innovator in agriculture technology, mentioned that this company, and similar ones, are considering launching operations in the Nkawie District to deploy this drone technology in the region, as the prospects for increased agricultural productivity are very high in cocoa-farming regions. He explained:

> "There is something good about this area. The cocoa beans are of high quality because the region has very favourable climatic conditions which supports cocoa farming. Once the problems on the ground such as pests and diseases are addressed, cocoa production will increase, and this place will be the next setting for massive cocoa production" (Individual investor).

6.3.3 Extension community

The work of the extension community in the cocoa production supply chain means that they are another important group of stakeholders, although they do not exert a significant impact on stakeholder relationships and the decision-making process. However, their connections to the farmers who trust them as having their interests at heart cannot be overlooked. They constitute educated, individual buyers of cocoa seeds, and have a strong lobbying skill which are harnessed by other stakeholders when it becomes difficult to get farmers to agree to a decision. There is an informal route sometimes used as 'grapevines' to test farmers' perception and knowledge of a subject matter before formal talks, or when communication is held among stakeholders. One of these individuals said:

> "For successful adoption of the Unmanned Aerial Vehicle, there should be regular communication among stakeholders and farmers, so that we are 'on the same

> page'. Here, nobody thinks that the government, or the district office is planning to use the drones as a cover-up for any corrupt deals and other purposes, but most of the time this is the mentality of farmers. These farmers are sick and tired of failed promises, which sometimes makes it difficult for them to support initiatives of this nature. Transparency and the inclusion of everybody from the start is the sure way to success. The bigger stakeholders need to build strong partnerships with farmers and encourage trust. For the farmers within this district, there is a need to provide regular training, as most of them are uneducated, although once they fully understand the positive impact of the Unmanned Aerial Vehicle, they will never let go of the idea" (Individual from the extension community).

According to the members of this group, who hold many informal interactions with farmers due to the amount of time they spend with them on the field and in their homes, group discussions among farmers, particularly at their Farmers' Association Meetings, have helped them to understand the relationship between land size and crop density, land size and the amount of agrochemicals required, and the costs associated with the production of a particular crop. These informal discussions among farmers play an important role in the smooth rolling-out of Unmanned Aerial Technology in cocoa farming in the Nkawie District. Again, these community extension group individuals also play the role as the 'ears' of the farmers in meetings where these farmers are not present. Their influence, by way of how they advise farmers, potentially impacts the latter's' understanding of these new technologies and their economic impact, not just for their cocoa farming business, but also on their livelihoods.

6.3.4 Voluntary stakeholders (i.e., Non-Governmental Organizations)

Additional significant stakeholder players in the cocoa ecosystem are the international non-governmental organizations and other voluntary groups which offer specialised and targeted services for farmers across different planting sectors, especially in the domain of vegetable and fruit production. One of the very popular voluntary groups which provided the researcher with respondents prepared to discuss their attitudes on initiatives in cocoa farming is the International Executive Service Corps (IESC). This is a non-profit organisation which has been granted funding for a two-year initiative to improve the export quality of fruit and vegetables from Ghana.

According to Hinneh (2016), this initiative is part of USAID's 'Farmer-to-Farmer Special Program Support Project' and was granted funding through the Volunteers for Economic Growth Alliance, of which IESC is a leading member. The 30-year 'Farmer-to-Farmer Program' uses the knowledge of US volunteers to support developing nations and rising economies in strengthening their agricultural sectors. The Improving Food Safety Systems Program, valued at USD$2.8 million and financed by the United States Agency for International Development (USAID), will utilise the IESC's fifty-year history of international volunteer experience. In total, volunteer experts provide more than 1,000 days of service to the initiative, continuing IESC's 52-year tradition of deploying seasoned professionals to advise businesses and organisations, fostering economic progress in developing nations (Hinneh, 2016).

It is noteworthy that the Nkawie Cocoa farming district has held correspondence with the IESC, who have expressed an interest in delivering engaging programmes to increase farmers' awareness and knowledge regarding the acceptance and use of UAV for cocoa farming. As the United States is a pioneer and leader in precision agriculture, the role and activities of IESC in the Nkawie Cocoa farming District would be critical in accelerating the implementation of UAV in cocoa farming.

6.3.5 Traditional authority stakeholders

The role of traditional leaders as custodians of the customs and traditions of the people and community is influential in the implementation of UAV in cocoa farming in Nkawie. Traditions and customs are deeply intertwined and rooted in farming practices and activities, not just in the district but as a routine practice in African societies, of which Ghana is no an exception. Deeply rooted superstitious beliefs are central to the farming framework and development of a community like Nkawie. For example, a traditional leader respondent explained that:

> “Until we pour libation before the farming season, we are not sure of our yields. We need the gods to look down and favour us with a good farming season. I am not joking. We have faced several consequences like little rain and long dry seasons when we do not appease the gods before each farming season” (Traditional leader).

What the researcher makes of the phrase: “faced several consequences like little rain and long dry seasons” is that the impact of climate change and global warming is having an effect on weather conditions, especially for farmers in developing countries who are heavily dependent on natural climatic conditions for their farming activities. To these custodians of tradition, this weather is a stroke from the angry gods. Other traditional customs mentioned which are applied to farming included:

> “We do not go to the farms on Tuesdays because it is the day for the gods. It is sacred and must not be denigrated. There are some parts of the farmlands which are not accessible, and we have reserved them as places for the gods” (Traditional leader).

It is the accessibility challenges, as mentioned by this traditional leader, as: *“There are some parts of the farmlands which are not accessible, and we have reserved them as places for the gods”*, which render the introduction and implementation of UAV essential to the deconstruction of these traditional notions and superstitious beliefs. The traditional leader also made mention of the social and cultural attractions and attachment these farmers have to their farms, which he thinks will decline because of “too much technology”. Traditional leaders in the Nkawie district have opinions that are congruent with the barrier mentioned in section 5.4 towards the implementation and adaptation of UAV, and these opinions are extensively documented throughout the data collection. However ,the researcher is certain that the involvement of the traditional authority figures within the Nkawie community will, steadily over time, increase their acceptance of the role of technology in modern agriculture, specifically precision agriculture.

6.4 Themes linked to farming practices in Ghana during the data collection

Throughout the empirical data collection process, some thematic concerns arose repeatedly from many respondents. Traditional and superstitious beliefs was one such topic; both private and public cocoa stakeholders mentioned that traditional and superstitious beliefs within the cocoa farming community are regarded as part of farming practice within the Nkawie Cocoa district. Traditionally, cocoa farmers have followed the long-standing spiritual belief that the pouring of libation to the smaller gods would help them to increase their cocoa production, rather than technology as proposed. However, awareness created of the implementation of UAV during the field study has impacted farmers' attitudes towards their cocoa farming practices.

As explained to farmers during the field study, the use of UAV on cocoa farms can help reduce both labour and operational costs, but they potentially come with the advantage of increased cocoa production, enabling farmers to enjoy economies of scale. The implementation of this technology, as noted in the research findings, seems to be perceived as promising for farmers if it is adopted, as it will add value to their cocoa production. This strategy can be fully achieved by focusing on effective technological awareness for the Nkawie cocoa farming community and ecosystem. This also aligns with the proposals by the Ministry of Food and Agriculture in a farmer's day celebration event, where the minister mentioned that:

> "Our gods are dead and gone, please let us leave them alone. The gods will not be doing the planting for you farmers. It is your hard work which will help you to

> produce more. I urge all farmers to be open-minded and willing to accept change in their practices. The introduction of new fertilizers and technologies should be welcomed. More information about the use of technology will soon be available, and I urge every farmer to co-operate and support this new dawn of agriculture. Ghana must lead again" (MoFA, 2000).

In addition, several other respondents such as farmers and private stakeholders did mention that the use of primitive tools such as hoes and rakes for planting cocoa trees is low-cost in comparison to UAV. They still have a liking for manual approaches to farming and its practices. Although the existing primitive tools appear to be low-cost, it was also noted that their use is time-consuming, increasing production costs and proving ineffective in today's evolving phase of modern agriculture, as well as farming management in general.

This was also echoed by the Minister of Food and Agriculture on a farmer's day celebration event, with the minister stating the following:

> "I am fully aware that primitive tools for cocoa farming are regarded as the oldest form of equipment and it is about time for them to be set aside. Change is calling all of us. The use of primitive tools for farming means that no technology is welcomed, instead household labour is used to produce a small output of cocoa production. There are no technologies being used by our cocoa farmers. You just plant the cocoa trees alone or with your family, and it takes longer to complete this task. The use of modern technology such as drones for planting, spraying crops and even for harvesting the cocoa is one of government's priorities for our cocoa farmers, and we need you all on board for this change. This will help you farmers to turn your farms and families' lives around for good" (MoFA, 2000).

Clearly, from the minister's statement, the use of technology such as UAV is regarded as a breakthrough innovation in Ghana's cocoa sector. Although its degree of adoption remains negligible, the cocoa sector awareness policy introduced by the Ministry of Food and Agriculture (MoFA) on the use of technologies for farming have gradually gained the attention of most cocoa farmers who are open to the implementation of UAV by cocoa farmers to enhance productivity.

The summary of the key findings from this chapter are as follows:

- The multi-faceted stakeholder engagement approach is critical for the implementation of UAV on cocoa farms.
- Superstitious beliefs play an integral role in the acceptance of disruptive technology, as the anthropological construct of most rural societies means that there is continued belief in traditions and customs.
- The limited creditworthiness of farmers and low financial inclusiveness are major barriers to the usage and ownership of technologies such as UAV.
- Amid underlying scepticism about the expensive nature of these technologies, there is an overall preparedness on the part of the stakeholders to ensure their implementation, as many of the respondents have witnessed the benefits of the usage of UAV on vegetable and fruit farming.

Due to the detailed analysis and outcomes of this section, which primarily focuses on stakeholders' perceptions of the implementation of UAV, the following chapter provides an overall summary of the study, followed by a conclusion which sets out recommendations and suggestions for further research.

6.5 Summary

This chapter provides a comprehensive description of the various stakeholder responsibilities associated with the introduction of UAV in the agricultural environment. This chapter proposes a new conceptual model which identifies how this implementation may be accomplished. This model will assist in guiding future study on this issue in general. The subsequent and concluding chapters present a reflective summary of the research process, key lessons learned, and contributions to the body of literature on the subject of the implementation of UAV in precision cocoa farming in developing countries using Ghana, specifically Nkawie, as a case study. Additionally, the limitations of the study are explored, with an emphasis on future research directions.

Chapter 7 Recommendations and road map to the implementation of UAV

7.1 Introduction

On the basis of the study findings described in chapters 5 and 6, the development of UAV has become a significant alternative in the optimization of cocoa production within the Nkawie cocoa Direct where the research was conducted. The current level of technical advancement has made it possible for UAVs to be used in agriculture, as mentioned in industrialised nations like the USA, Germany, and Japan. This is mostly because UAV are now considerably less expensive, and production needs are no longer as pressing. Based on the benefits and drawbacks noted during the entire research, this chapter makes recommendations for the study. A road map for the acceptance and use of UAV has also been proposed in the chapter.

7.2 Recommendation to the study

1. The study recommends that the government should be ready both to support farmers financially and also to provide education and training. There are ongoing policy discussions about the introduction of technological applications on cocoa farming, and this study provides a comprehensive set of evidence and credence to the urgency of the need to implement technologies such as UAV.

2. There should be a robust financial inclusion strategy and approach which will extensively engage farmers in sound financial practices while encouraging banks to also engage with farmers.

3. It is also recommended that, in the case of the implementation of this technology be successful in the cocoa farming industry, a wider credit scheme and financial strategy is of the utmost importance in order to enhance financial access to these loans. Although a bank like the Agricultural Development Bank (ADB) provides loans for farmers from every agriculture unit, which is very wide-ranging due to the fact that Ghana is largely an agrarian society, establishing a separate financial inclusion strategy and fund for cocoa farmers would be essential for the development of the sector.

4. It is also noted in chapter 6 that, COCOBOD, which is governed by the Ministry of Food and Agriculture, plays an essential role in boosting the cocoa output of the Nkawie cocoa area. To that effect, It is also recommended that strategic agencies such as COCOBOD, should prepare action plans for both public and private stakeholders within the cocoa ecosystem which clearly define the specific actions to take to implement or adopt technologies such as UAV in cocoa farming. Such action plans should also provide practical guidance on their implementation by farmers who are able to afford the technology.

5. The study has uncovered data which contributes significantly to the attainment of this study's primary objective; both private and public stakeholders have significant roles to play in the introduction and implementation of this technology. It is therefore recommended that, the proposal and implementation of national and local level policies and initiatives such as 'Tech for Cocoa' and 'Ye Sesem', which is a local term meaning *"We are changing"* as specific technology-based interventions designed to harness stakeholder involvement which will support the development and acceptance of

disruptive and other technological innovations to improve cocoa productivity and farming practices. For example, the 'Yen Ndobuo' – a local term meaning *"Supporting each other in farming"* initiative has been integral in deepening the social bonds between farmers and their farming communities for the sharing of knowledge and experience. In the case of the cocoa beyeyie ('beyeyie' is a local term which means: *"there is hope"*), this was a local initiative which was undocumented but very popular among farming communities, in which oral tradition and word of mouth tales describe the impact the initiatives already made in the production of different varieties of cocoa seeds, which have now become predominant in today's cocoa sector.

Table 7.1 illustrate the the summary of the recommendation and the implications of the research.

Table 7-1 Policy recommendations and implications of the research

Financial support: • Limited access to financial entitlement for farmers to support the maintenance of farms due to high levels of corruption at local authority level, and limited credit access opportunities. • Lack of training initiatives to promote innovations	The current 'monopoly system' has led to farmers failing to gain access to funds which are available to them. The government should create an open system of application for all farmers to apply for the necessary funds to support their cocoa farming. There should be open and improved access to credit facilities, and improvement of farmers' and innovators' creditworthiness, as well as engagement with financial institutions to support the cocoa sector. The government should recruit expert and responsible individuals able to offer training on current farming practices to local farmers.
Traditional and superstition beliefs • Lack of knowledge due to primitive methods of farming • Lack of initiative to raise awareness of modern farming practices such as the implementation of UAV	Traditional community leaders should be encouraged to become open-minded and to lead local farmers in embracing change if it will exert a positive impact on their livelihoods. Traditional leaders can be provided with information to resolve their scepticism and reduce the reluctance they show towards technology; this can also be resolved through participation in additional training.
Perceptions of corruption at local level • Limited control of corruption among local authority officers. • Lack of farmers' involvement at decision-making and implementation level.	Policy-makers should introduce tougher measures and sanctions to minimise corruption and bribery at local authority level. In the decision-making and implementation process, COCOBOD should include farmers' input, which in one respect might increase productivity and provide answers to problems.

Source: Author (2021).

7.3 Road map towards the adoption and implementation of UAV

Based on this study's empirical findings, the implementation of UAV on Nkawie's cocoa farms would help farmers to increase their cocoa production. However, barriers such as high illiteracy rates among farmers and farming practices which are deeply rooted in traditional and superstitious beliefs restrict their adoption among farmers and traditional authorities. Thus, this study argues for both private and public cocoa stakeholders to form a strong collaboration in creating awareness for farmers' attitudinal change in their farming practices towards new technological applications for farm management. Other proposals include a comprehensive financing strategy, financial inclusion, access to credit facilities, and robust programmes of local technological development. In order to achieve this, the study proposed the roadmap below.

1. Nkawie cocoa district can achieve or enhance its cocoa production through effective collaboration and the formation of strong partnerships with its key cocoa stakeholders.

2. Key stakeholders' roles are diverse, and are predicated by different channels such as education and research institutions, and support organisations, as well as efforts made by non-profit organisations .

3. Public stakeholders' involvement, which includes financial support for farmers, will be an integral element of this change, although governmental restrictions on budgeting and spending remain an ongoing debate.

4. Affordability of the technology is very important as farmers are not in a position to purchase it themselves for individual use. This affects the implementation process, as

policymakers are unable to develop and introduce rules for its adoption. This makes the collaboration of stakeholders as evidenced in Chapter 5 in Figure 5.14 very critical to the implementation of UAV for cocoa farming

The road map plan for the UAV's adaption and execution is shown in Figure 4.4, the figure identifies and gathers all significant stakeholders—public and private—of the Nkawie cocoa district during the data collection.

To contribute to the achievement of the recommendations below, the author publishes the study's findings as well as sharing the research outcomes with the members of his network within the agriculture ministry. Thus, the author guarantees that this organization receives a copy of these findings.

7.4 Summary

In conclusion, it can be stated that the employment of UAV has a substantial impact on cocoa output. It has been proven to double farms' productivity in other countries (Finger et al., 2019). With the support of both private and public stakeholders in offering basic training, experience, and investment in technology for local farmers, acceptance of the implementation of UAV can be achieved among the rural cocoa farming regions where such resources are scarce. The decision-making process should take into account the views of stakeholders, particularly local farmers, because previous study findings indicate that farmers have had limited opportunity to engage in farm management decision-making.

Chapter 8 Conclusion

8.1 Conclusion

This study explores the opinions and responsibilities of stakeholders towards the adoption of UAV (UAV) in cocoa farming in the Ashanti Region of Ghana's Nkawie Cocoa District for crop optimization and production. This study empirically determines the characteristics and functions of major cocoa stakeholders which impact acceptance of the implementation of UAV within the study region. Both commercial and public players have awareness of the technology's application in industrialised nations and in other agricultural production sectors, such as fruit and vegetable growing, according to the study's findings. Some participants went as far as to mention the usage of UAV in the medical industry for transporting samples and other vital materials. There were significant barriers such as limited funding, credit architecture, perception of corruption, traditions, customs and superstitious beliefs, and scepticism towards the efficiency of technology, all of which influence farmers' attitudes towards the acceptance and adoption of this technology for the optimisation of their cocoa production.

On the other hand, there was overriding evidence to suggest that both the private- and public stakeholder community were keen to support the implementation of this technology in the Nkawie Cocoa farming district due to the enormous benefits UAV offer to farming practices, improving the livelihoods of farmers while also revolutionising the entire cocoa farming ecosystem.

In addition, the research observed farmers' attitudes, views, beliefs, and perceptions of change for the improvement of farming practices, thus technological applications such as UAV on farms are a critical intervention to improve cocoa production and farm management practices, specifically in the area of pest- and disease control, seed and plant diagnostics, and mapping of farmland, among other actions. Studies on the implementation of Unmanned Aerial Vehicle on cocoa farming from emerging markets remain scarce due to the lack of clarity concerning the inputs of key cocoa stakeholders and their involvement to improve cocoa farm management for the enhancement of productivity. Therefore, this research fills a significant gap in the literature and provides novel conceptual and empirical insights into an under-explored field which will be of practical and academic use.

8.2 Significance of conceptual framework in addressing the research aim

The main focus of this research study was to examine the adoption of UAV on cocoa farms in Ghana, especially the implications of this for farmers and key cocoa stakeholders. The study was conceptually underpinned by the interplay between Disruptive Innovation and stakeholder theory, which is discussed extensively in Chapter 3. This is illustrated below.

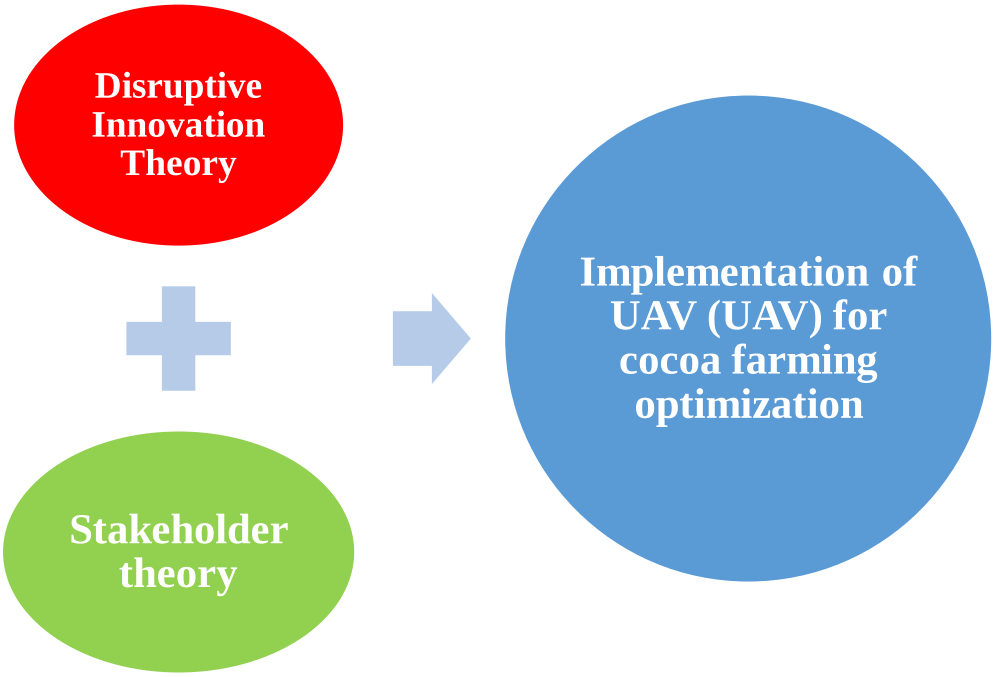


Figure 8.1 Disruptive Innovation and stakeholder theory from (Author, 2021).

From the perspectives illustrated in Figure 8.1, the researcher sought to investigate the impact that Disruptive Innovation such as UAV would have on cocoa farming practices and crop optimization, while considering the perceptions and roles played by stakeholders in the cocoa ecosystem in order to influence their implementation in the Nkawie Cocoa Farming District.

Investigating this innovation from the perspectives of these theories in isolation to the feelings of stakeholders with regard to their role in influencing the acceptance of the technology does not provide a comprehensive snapshot of how this innovation will integrate with cocoa farming in the district.

The findings of this study provide evidence that the application of both theories have an effect of interdependence in order to answer the research questions, in the light of the aims and objectives that the research set out to investigate. Whereas Disruptive Innovation theory explains how unsettling this innovation would be on current farming practices and norms, stakeholder theory is useful in providing evidence of the perceptions, views, and roles played by the various stakeholders as drivers or barriers to the implementation of the Unmanned Aerial Vehicle technology on cocoa farming in Nkawie.

Disruptive Innovation theory has been used as a critical tool in this research to appraise the adoption of UAV as a disruptor or Disruptive Innovation having a significant impact on cocoa farming practices and farm management in the area of the study. The impact of UAV on cocoa farming practices and management means that this clearly satisfies the definition of displacing an established norm, approach, or technology, as posited by several academics in their definition of Disruptive Innovation (Christensen et al., 2013; Schmidt and Druehl, 2008; King and Baatartogtokh, 2015; Christensen, 2006; Christensen and Raynor, 2003).

Stakeholder theory helps in the identification of key players, whose activities have significant implications and influence on the acceptance and implementation of UAV in the cocoa farming ecosystem. The theory facilitated the categorization of the players, as evidenced below.

Table 8-1 Categorization of key stakeholders in the Nkawie cocoa farming district

Public stakeholders	**Private stakeholders**	**Voluntary stakeholders**	**Traditional authorities**
Ministry of Food and Agriculture (MoFA) Ghana Cocoa Board (COCOBOD) Cocoa Health and Extension Division (CHED) District Cocoa Office (DCO) Cocoa Research Institute of Ghana (CRIG - Ghana) Local authority	Farmers' Associations (Ghana Cocoa, Coffee and Sheanut Farmers' Association) (GCCSFA) Research Organizations (RO) Institutional innovators (Drone companies) Individual investors Extension community (EC)	The International Executive Service Corps (IESC)	Traditional leaders and chiefs

Source: Author (2021).

The theory also enabled the researcher to access the profiles of these stakeholders, providing an understanding of their influences in the cocoa sector, including their roles, attitudes, views, beliefs, and attitudes towards cocoa farming operations. The emphasis was on the profile and key roles played by these cocoa stakeholders. The study was able to categorise the various stakeholders and the roles they play in the entire conceptualization and implementation process of UAV in cocoa farming in the Nkawie District.

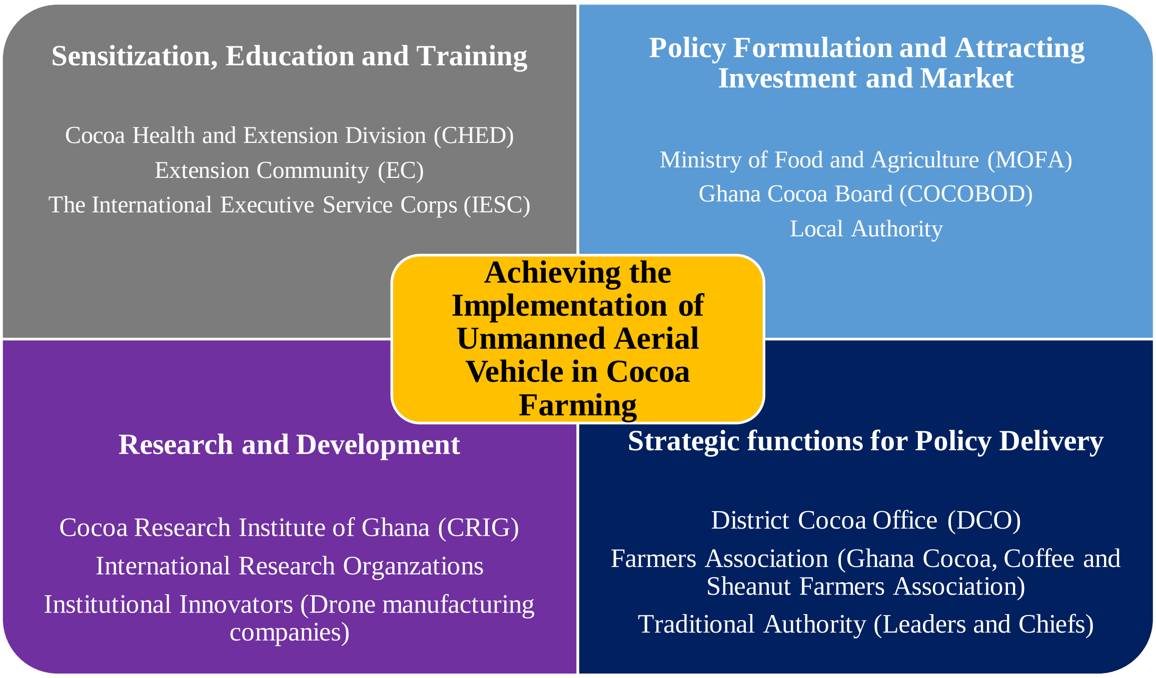


Figure 8.2 Stakeholder categorization and their roles in the implementation of UAVs from (Author, 2021).

Figure 7.2 clearly demonstrates the intersection of the roles and functions of the various stakeholders and their individual and collective influence on the implementation of a Disruptive Innovation such as UAV in the cocoa farming sector at Nkawie. The emphasis of this study has been on the simultaneous and mutual use of these theories in order to develop a holistic framework of cocoa stakeholders' key roles, views, beliefs, and attitudes towards the implementation of UAV in cocoa farming operations.

It is evident that the two theoretical concepts, i.e., Disruptive Innovation and stakeholder theory have demonstrated how the interplay of the stakeholders identified in the study interpret UAV as a Disruptive Innovation which can revolutionise cocoa farming in the Nkawie Cocoa District.

Overall, this study is guided by four key objectives, as stated in Chapter 1; key lessons emerging as a result of addressing these four objectives are summarised in the table below:

Table 8-2 Lessons from the study

Research Objective 1 with reference to Chapter 1	As previously stated and detailed in **Chapters 1, 2,** and **3**, a literature assessment was conducted on UAV (UAVs) and their implications for farms. This evaluation assisted the researcher in identifying the primary functioning and mission of UAV (UAVs) for agricultural enhancement, particularly for pest control and/or crop spraying.
Research Objective 2 with reference to Chapter 1	As stated above and detailed in **Chapters 4, 5** and **6**, a critical review was undertaken of the literature and NVIVO analysis of interviews was conducted on stakeholders' attitudes and knowledge of the use of UAV (UAVs) for the improvement of productivity on cocoa farms. Nkawie District was the study area, and is well-known for its cocoa production. Predominantly, farmers within the study area are accustomed to traditional and primitive farming practices, although there are potential prospects to increase yield and use more effective methods of farm management. The main occupation of farmers within the study area is cocoa farming, with majority being uneducated and representing a high illiteracy rate. The study identified that the use of UAV (UAVs) on farmers' land would increase cocoa production, enable effective pest and disease control management, the mapping of fields, and the performance of seed and plant diagnostics but these are accompanied by their own barriers to effective implementation.

Research Objective 3 with reference to Chapter 1	As mentioned above and evidenced in **Chapter 6**, analysis conducted of the interviews with respondent stakeholders using NVIVO developed 'brought forward' themes which summarize the barriers which potentially impede the implementation of this innovation in the cocoa farms of Nkawie. Some of the topical themes noted by most respondents included the deep-rootedness of farmers and the community as a whole in tradition and superstitious beliefs, which are common in their farming practices, as noted by the study's findings. Other frequently-mentioned themes by stakeholders were negative factors including the high expense of the technology, inadequate credit facilities, lending institutions' reluctance, farmers' credit unworthiness, low-income inclusivity, and perceptions of corruption by local authorities.
Research Objective 4 with reference to Chapter 1	As explained in **Chapters 6** and **7**, this study aimed to review current farming practices while offering recommendations and presenting a framework for the players in the cocoa sector to support the maximization of cocoa productivity by use of conceptual and empirical insights on Disruptive Innovation and stakeholder roles in cocoa farming, specifically in the Nkawie cocoa district. This helped the researcher to fully understand how cocoa farming activities are carried out, and what solutions may prove viable and feasible.

Source: Author (2021).

The implications arising from this study are far-reaching. For example, at governmental level, there is a need for further engagement with the private sector and international funding organizations regarding on the development of an all-inclusive and robust funding policy to improve farmers' access to credit facilities while developing local capacity to lead this change in the country's agricultural sector. As the country aims to become the world's leading producer and exporter of cocoa beans, such policy interventions are essential in accelerating the achievement of the government's aims and objectives; this study provides a road map to support the realization of this goal.

This study also provides evidence of the need to engage with the wider stakeholder community on how technological integration is becoming an almost inevitable process in the cocoa farming productivity landscape, as well as enhancing effective management practices. The implications of this study to this objective primarily recommend a more open approach to the adoption of practices, while ensuring that importers of technology have the capacity to meeting the local needs and challenges.

8.3 Research summary

The primary findings provided in **Chapters 5** and **6** demonstrate that both private and public stakeholders play important roles in the application of UAV on cocoa production in the Nkawie cocoa area. There are again various pieces of evidence from the literature review conducted which suggest that the key cocoa stakeholders identified, such as voluntary groups, district offices, farmers' associations, health and extension officers, and local authorities, have been neglected by academic researchers in their assessment of attitudes and roles in the implementation of new technologies in agricultures. The scarce literature available has instead primarily considered the roles of the big players such as the Ministry of Food and Agriculture and Ghana Cocoa Board (COCOBOD) (Yamoah et al., 2020). This study was conducted in order to bridge this key research gap.

The study fills the research gap by providing empirical evidence on the following knowledge in the area of Unmanned Aerial Vehicle implementation in cocoa farming.

Tradition and superstitious beliefs hinder the implementation of UAV, and new technologies in cocoa farming, as farmers and traditional leaders are deeply-rooted in their customs and traditions.

The influence of private and voluntary stakeholders, especially local drone manufacturing companies in the cocoa production ecosystem, is critical in the development of the implementation of the technological framework for emerging economies.

Cocoa farmers face significant challenges in accessing funding for the purchase of technologies due to the general perception of the farming sector as being 'high risk'.

There is a lack of financial inclusiveness among certain stakeholders in the farming sector, specifically local innovators and farmers.

Cocoa farmers, using the Nkawie district as a case study, have limited access to modernised farm management practices, especially the use of technologies such as UAV to increase productivity.

8.4 Key opportunities and challenges for the implementation of UAV

This study determines that cocoa cultivation is the primary source of employment and income for the farmers of the Nkawie district. Thus, this study aligns with the Ministry of Food and Agriculture's report issued in 2000 which explained that: "cocoa farming in rural regions in our country is regarded as a major contributor to the country's GDP, it is also a major source of employment for people within such communities, and many farmers depend solely on this production" (Hainmueller et al., 2011).

Table 7.3 summarises the key opportunities and challenges facing the optimisation of cocoa farming within the Nkawie cocoa district.

Table 8-3 Opportunities and challenges

Opportunities	Challenges
• 'Grey area' for technological incorporation into cocoa farming • Promotion of new cocoa farming management practices • Introduction of unique methods of pest and disease control • Investor confidence due to digitized facilities • Reduction of labour costs and time	• Social norms • Superstitious beliefs • Limited exposure to modernised farming practices • Inadequate education and training • Lack of financial support from local and/or national authorities • Issues of farmers' creditworthiness • Low-income inclusivity for local innovators • Corruption perceptions among the stakeholder community

Source: Author (2022)

8.5 Contributions of the Research

The research context for this study is Unmanned Aerial Vehicle implementation for cocoa farming within the Nkawie cocoa district. This research investigates the existing practising conditions of cocoa farm management which hinder the optimisation of cocoa production. It considers the implementation of UAV as a disruptive technological application, and stakeholders' attitudes and roles in the improvement in cocoa farming

practices.

The contributions made by this study include**:**

This study contributes to the body of literature and knowledge on stakeholders' attitudes and the diverse roles played by them to achieve the implementation of UAV in the cocoa sector within the Ashanti Region of Ghana.

The study contributes to the body of knowledge for policy-making by providing a road map for the implementation of UAV in different aspects of cocoa farming.

The study also contributes to the body of evidence from emerging economies such as Ghana on the roles played by stakeholders in the integration of technology in the cocoa farming sector.

8.5.1 Theoretical contributions of the research

The study offers a distinct theoretical contribution to academic research. To the author's knowledge, this study is the first in the field of cocoa farming research in a country with an emerging economy to apply both stakeholder theory and Disruptive Innovation theory by investigating the implementation of UAV as a disruptive technology for cocoa farming. These two theories help the researcher to understand and provide evidence of the interplay which influences the acceptance by cocoa farmers and stakeholders within the study area of the implementation of UAV for cocoa farming.

Having considered the significance of stakeholders' positions and attitudes towards disruptive innovation, this research proposes a new model, adding this study to a sector which will require both private and public stakeholders' attention and intervention for the implementation of new technologies. Corley and Gioia (2011) contend that an incremental viewpoint might be a slight, marginal, or even negligible development over previously-held theory.

This contribution is an incremental theoretical contribution. Clearly, this new development can supplant the current paradigm, meaning that theory has become obsolete (Corley and Gioia, 2011). Thus, a Disruption Innovation – stakeholder theory examines the interplay between Disruption Innovation Theory and stakeholder theory to underscore how the stakeholder community of a particular sector influence, perceive, and define a technology as disruptive and useful for implementation for service improvement. This is illustrated by the diagram below.

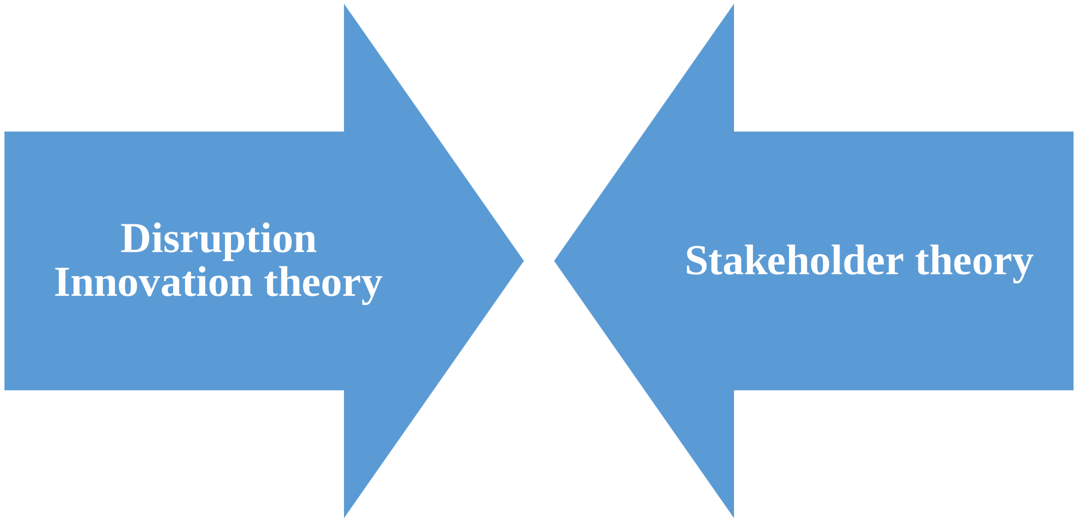


Figure 8.3 A Diagram of Disruption Innovation – Stakeholder theory from (Author , 2021).

Figure 8.3 clearly illustrates the convergence of both theories to underscore the interplay of stakeholders' influence on the implementation or adoption of Disruptive Innovation. This evidences the fact that Disruption Innovation theory in isolation cannot in itself be used to ascertain how disruptive an innovation is, and how likely it is to be accepted without evaluating it under the guise or lens of the diversity of stakeholders' perspectives, views, and positions on whether it is considered disruptive or not. The mixture of challenges associated with the implementation of UAV, such as increased cocoa production, effective pest and disease control, the mapping of fields, the performance of seed and plant diagnostics, being costly, threatening traditional practices, and the socio-cultural construct of superstitious beliefs and customs add to existing research findings and provide new knowledge of a far reaching nature to be carefully considered prior to the launch of this Disruptive Innovation after evaluation of stakeholders' views.

The second contribution of this research is the finding that stakeholders in the supply and value chain of occupy a key role in the cocoa production process, as each one is related directly and/or indirectly to cocoa farmers in the enhancement of cocoa farming practices. It is a theoretical contribution which is revelatory because Corley and Gioia (2011) define a revelatory contribution as anything not previously observed, known, or conceived. This discovery has never been seen, known, or even envisaged in the current context because no prior study has been conducted on the current issue.

Thirdly, this study reveals that the attitudes and perceptions of local farmers within the cocoa farming community, using this study of the Nkawie cocoa district as a case study, more often than not significantly influence other farmers on the acceptance of technologies such as UAV to be implemented on their farms. This is also a revelatory contribution. As discussed earlier in Chapters 2, 5 and 6, technological applications such as UAV focus not only on pest- and disease control, but take a holistic approach to farm management including, but not limited to, diagnostics. Considering that farmers benefit in the use of UAV, this imperative for the implementation of any other technology means that it is likely to be accepted for use on cocoa farms, although there are no studies at present to suggest that the acceptance of disruptive technological application for cocoa farming has yielded results.

8.5.2 Methodological contribution

Due to its nature and features, this study adopts a qualitative research technique and is guided by the interpretative research philosophy. This investigation was undertaken in the Nkawie cocoa area of the Ashanti region of Ghana to examine the usage of UAV on their cocoa plantations, to increase productivity. This study employs both stakeholder theory and Disruptive Innovation to enable the researcher to interpreting the subjective significance of social occurrences. In addition, an anthropological technique is used to describe the underlying social phenomena in the region where the research was conducted. The researcher uses semi-structured interviews and participant observation as study methodologies. As a methodological contribution, the research adopts a broad and diverse sample strategy which leads to the classification of stakeholders; according to Corley and Gioia (2011), this is a revelatory contribution of this study.

8.5.3 Practical contributions of this research study

This study presents some imperative findings which potentially contribute on a practical level to the formulation of strategy and policy. Currently, COCOCBOD is the regulator of all cocoa activities in Ghana; it plays a vital role in the development of marketing plans and strategies, the pursuit of new markets, and the optimization of cocoa production, also supplying farmers with information on current harvests and planting. COCOBOD intends to improve cocoa output so that it can contribute to the country's overall development in terms of reducing poverty in rural agricultural communities and boosting national GDP. Thus, the advocacy and implementation of the technology this study proposes will accelerate the achievement of its vision in order to achieve the aforementioned aims.

For the Ministry of Food and Agriculture (MoFA), which aims to understand and interact with all formal and informal stakeholders in the cocoa ecosystem by consolidating the positive aspects of the supply chain process while eliminating and closing all relevant gaps, this finding provides a comprehensive categorization and list of stakeholders whose activity directly and indirectly affects the outcomes of the implementation of decisions and policies at the bottom of the decision and delivery chain.

This will help the Ministry in its budgetary deliberations to know where to focus its resources and expertise, both wisely and appropriately. As the Nkawie cocoa district is well-known for its cocoa producing contribution to Ghana's GDP, having a robust stakeholder framework and architecture, and knowing the perceptions of these players for the implementation of a Disruptive Innovation such as UAV is important for both the region and the country's exact farming goals.

Further to this, the acknowledgement of the efforts of local drone manufacturing companies and research organizations in the country, which are targeted at developing solutions which meet global standards and yet remain locally relevant is brought to bear by this study. This creates a roadmap to help the government to channel local resources while also attracting foreign aid, grants, and loans to raise investment for local company growth and expansion. In particular, the conclusions drawn by this study are of particular importance for the guidance of the Government's current and future plans for the expansion of cocoa production technology, not only in the Nkawie cocoa area, but throughout the entire cocoa industry.

Again, from a policy perspective, this study unveils the deficits in the financial accessibility and credit inclusivity framework which currently constitute strong barriers to farmers and local innovators who want to venture into technology-aided farming, i.e., precision farming. The findings of this study provide insight into this situation as a major impediment to the implementation of technology and assist the central government in its planning in order to mitigate these inadequacies.

The respondents, as farmers, emphasised that this technology in their farm management practices will contribute towards the increase of their cocoa yield as well as enhancing their pest- and disease control mechanisms, if the opportunity is provided.

8.6 Limitations of research

In spite of its illuminating and incremental contributions, this study, like any other research study, has limitations that should be considered when interpreting its conclusions. This study adopts a qualitative ethnographic methodology; every methodology has certain limitations.

Firstly, the primary restriction of qualitative research is that the quality of the outcomes is dependent on the researcher's abilities; and there may have been an increased likelihood of personal bias in the approach to the study and the interviewing of respondents because of researcher's affiliation to his home country and prior knowledge of this cocoa farming community. To overcome this limitation, the researcher engaged research assistants who were not conversant with the locality to ensure open mindedness in the collection and analysis of the data collated.

Secondly, for data collection, this study utilises semi-structured questionnaires and interviews. This potentially results in the collection of unanticipated data, which can in reality impede analysis and interpretation of research findings.

Thirdly, the researcher's personal biases and pre-determined outcomes may have influenced the interpretation of the opinions and views expressed by the stakeholders interviewed.

Fourthly, this study explores the deployment of UAV in cocoa farming to increase productivity, proposing a model based on the current findings; nevertheless, further research is required to broaden the scope of these findings.

Fifthly, the impact of the COVID-19 pandemic delayed the data collection process, limiting access to some key respondents whose opinions and views may have potentially altered the study's outcomes. Issues relating to quarantine and even the death of some initial respondents caused the loss of some historical data which the researcher required for the study.

Lastly, majority of respondents struggled to express themselves during the recorded interviews because they were unable to speak English. The transcription process may have omitted certain important information due to the difficulty of finding the appropriate lexicon in English to capture the true meaning of the local dialect and context in which interviewees responded to the questions. Again, some of the farmers were conservative in the expression of their views for fear of giving too much information to the researcher, also showing reluctance to criticize a farming system and traditions which have served all and sundry for many years. Consequently, the majority of responders requested that their names were not disclosed.

8.7 Areas for future research

In view of the limitation and shortcoming in the study future study could involve the use of a mixed-methods approach.

Respondents were recruited only from the Nkawie area of the Ashanti region, which may have resulted in the exclusion of other key respondents due to oversight and/or time restrictions. As a result, future studies should seek to open up and accommodate the wide variety of all cocoa stakeholders in the Ashanti area as respondents, in particular those who work in Nkawie but do not live there.

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Appendix 1

Below illustrates the implementation stages of UAV (UAVs) technologies, which has been grouped in terms of developing, less developed and developed countries, and in accordance with the FAO's (2018) drone implementation guidelines.

Unmanned aerial vehicles (UAVs) implementations in Developed Countries In Europe and America	Unmanned aerial vehicles (UAVs) implementations in Developing Countries	Implementation purposes for both Developed Countries and Developing Countries.
1. South America	Tanzania	Unmanned aerial vehicles (UAVs) implementation in these countries is used in the monitoring of crop health and precision application of chemicals. This allows for early and more precise treatments where irrigation, fertilization and pesticide need are most urgent, thus lowering overall input of resource and reduction fertiliser and pesticide use. Unmanned aerial vehicles (UAVs) implementation in these countries is utilized for Precision farming combines sensor data and imaging with real-time data analytics to improve farm productivity through mapping spatial variability in the field.
2. China	Rwanda	
3. Netherlands	Philippines	
4. Brazil	South Africa	
5. Canada		
6. Japan		
7. Italy		
8. Germany		
9. United States		
10. United Kingdom		
11. Australia		
12. South Korea		

13. Finland		Unmanned aerial vehicles (UAVs) implementation in these countries is also useful in supporting precision farming, it is used in checking soil health scans, monitor crop health, assist in planning irrigation schedules, apply fertilizers, estimate yield data and provide valuable data for weather analysis. Unmanned aerial vehicles (UAVs) implementation in these countries is used for data collection on large scale farms. Mostly these drones are combined with other data sources and analytic solutions to provide actionable information.
Commonly unmanned aerial vehicles (UAVs) used for agriculture growth in Developed Countries	**Most specific existing application of unmanned aerial vehicles (UAVs) used on farms Types of Technologies includes AgEagle RX-47, and Agribotix Agrion unmanned aerial vehicles (UAVs).**	
1. United Kingdom **2. South Korea** **3. Australia** **4. Finland** **5. Canada**	As noted by Challa (2013), increasing Agriculture Intelligence to the next Level is critical to meet expected rising demand. It is notable that, the existence of Unmanned aerial vehicles (UAVs) such as the AgEagle RX-47 are used to improve agricultural growth and is on the rise in developed countries such the United Kingdom and Germany, but unpopular in developing countries (Jain et al., 2009). AgEagle RX-47 are rugged and reliable, and it weighs 4 pounds. It is constructed of highly durable	

6. Japan **7. Italy** **8. Germany** **9. United States**	polypropylene material covered with a composite layer of extruded polypropylene and carbon fiber rods embedded in the wing and fuselage. The AgEagle RX-47 are designed to cover a minimum of 250 acres per battery charge. It has a powerful flying wing boasts, a true NIR (Near Infrared) global shutter sensor that is capable of creating extremely accurate prescription maps for the application of chemicals and nutrients from a precision application tractor. According to Loevinsohn et al. (2013), AgEagle RX-47 are the best for management regimes; soil fertility management; weed and pest management; irrigation and water management.
10. China **11. Japan** **12. Germany**	Loevinsohn et al. (2013) again talked about the existence of the Agribotix Agrion unmanned aerial vehicles (UAVs), which are in use by most farmers for food production in countries including China Japan and Germany. The Agribotix Agrion drones are very portable and equipped with near-infrared (NIR) camera designed to capture superb field-level imagery, which is uploaded to the included Agribotix Farm Lens platform for processing. Results are produced automatically in the cloud, eliminating the need for hard-to-use software packages. The Agribotix Agrion drones as stated by Loevinsohn et al. (2013) is very powerful for real-time decision support tool for farming operation.

Appendix 2

List of Participants for Semi-Structured Interviews

Interview summary

Level	Participant #	Participant profiles	Business profiles	Date of Interview
Farm Dynamics and the Respondent' s role	1	Male Famer Age 53	Local Farmer 28 years in cocoa farming	7th April 2021
	2	Male Famer Age 39	Local Farmer 15 years in cocoa farming	7th April 2021
	3	Male Famer Age 47	Local Farmer 15 years in cocoa farming	7th April 2021
	4	Female Famer Age 36	Local Farmer 14 years in cocoa farming (Family Business)	7th April 2021
	5	Female Famer Age 48	Local Farmer 20 years in cocoa farming	7th April 2021
	6	Male Famer Age 55	Local Farmer 30 years in cocoa farming	9th April 2021
	7	Male Famer Age 54	Local Farmer 34 years in cocoa farming	9th April 2021
	8	Male Famer Age 51	Local Farmer 31 years in cocoa farming (Inherited from Father)	9th April 2021
	9	Male Famer Age 51	Local Farmer 20 years in cocoa farming	9th April 2021
	10	Male Famer Age 47	Local Farmer 27 years in cocoa farming	12th April 2021

	11	Male Famer Age 46	Local Farmer 18 years in cocoa farming	12th April 2021
	12	Male Famer Age 65	Local Farmer 40 years in cocoa farming (Family Business)	12th April 2021
	13	Male Famer Age 68	Local Farmer 47 years in cocoa farming (Family Business)	12th April 2021
	14	Male Famer Age 45	Local Farmer 25 years in cocoa farming	16th April 2021
	15	Female Famer Age 60	Local Farmer 45 years in cocoa farming	16th April 2021
	16	Female Famer Age 47	Local Farmer 32 years in cocoa farming	16th April 2021
	17	Female Famer Age 52	Local Farmer 35 years in cocoa farming	20th April 2021
	18	Female Famer Age 68	Local Farmer 48 years in cocoa farming (Inherited from husband)	20th April 2021
	19	Female Famer Age 48	Local Farmer 22 years in cocoa farming (Family own land)	20th April 2021
	20	Male Famer Age 58	Local Farmer 33 years in cocoa farming	20th April 2021
	21	Male Famer Age 55	Local Farmer 34 years in cocoa farming	29th April 2021
	22	Male Famer Age 51	Local Farmer 30 years in cocoa farming	29th April 2021
	23	Male Famer Age 44	Local Farmer 23 years in cocoa farming	29th April 2021

	24	Male Famer Age 42	Local Farmer 30 years in cocoa farming	29th April 2021
	25	Male Famer Age 47	Local Farmer 34 years in cocoa farming	29th April 2021
	26	Male Famer Age 45	Local Farmer 20 years in cocoa farming	29th April 2021
Support from Agencies and / or business organizations	27	COCOBOD, Male 50	Government official 12 years in the cocoa industry	10th May 2012
	28	Cocoa Health and extension division (district) Male 61	Government official 30 years in the cocoa industry	15th May 2012
	29	Extension Community Agent Male 65	Government official 30 years in the industry	20th May 2012
	30	District Cocoa Officer, Male 52	Government official 25 years in the cocoa sector	20th May 2012
	31	Local Chief Male 72	Government official 38 years as an extension officer	8th June 2021
	32	COCOBOD Male 33	Government official (Officer) 6 years in the cocoa industry	8th June 2021
	33	COCOBOD Female 42	The Cocoa Research Institute of Ghana (CRIG) 18 years in the cocoa industry	8th June 2021
	34	NGO, Male 48 and Female 55	Ghana Cocoa, Coffee, and Sheanut Farmers Association (GCCSFA) 31 years in the cocoa industry	8th June 2021

	35	COCOBOD Female 58	The Seed Production Unit (SPU) Government official 32 years in the cocoa industry	8th June 2021
	36	Local authority Female 56	Government official 30 years in the cocoa industry	10th June 2021

Appendix 3

Semi-Structured Question Schedule

List of key informant interviews

A. Farmers
B. Ministry of Food and Agriculture (MOFA) Officials
C. Ghana Cocoa Board (COCOBOD) Officials
D. Traditional Leader
E. Cocoa Health and Extension Officers
F. Cocoa Research Institute of Ghana Officials
G. Local Authority Officials
H. District Cocoa Office officials
I. Farmers Association (Ghana Cocoa, Coffee and Sheanut Farmers Association) members

Farmers

1. Gender?
2. Level of education?
3. Knowledge of technology use on the farm i.e., Drones
4. How much time do you spend on the farm?
5. When do you start growing cocoa? (season)
6. What is the cost to you in cocoa production and marketing? (labour, pesticides, seedlings, fertilizers)
7. How do you control or manage weeds, or apply fertilizers on your cocoa farm?
8. How much cocoa do you produce each season?
9. How much do you obtain from cocoa each season? (price, total income, any other sources of income)
10. Where do sell your cocoa? (local market, Ghana Cocoa Board (COCOBOD) or exporters)
11. How do you evaluate your relationship with the buyer(s)?

12. How many people do you employ or help with your cocoa farming business?
13. Do you face any challenges in the production and marketing of the cocoa?
14. How have you overcome these challenges?
15. What support do you receive from the Ministry of Agriculture?
16. How does the involvement of the Ministry of Agriculture or Ghana Cocoa Board improve your farm management?
17. Have you experienced any changes to your farming practice in the past?
18. To what extent will any new changes in farm management affect you, the community and your family?
19. If help is available, do you think being in a cooperation group would help to minimise the costs of farm management or improve the profitability of production? If yes, how?
20. Are you able to produce the required quality and quantity of cocoa during each season?
21. On a scale of -5 to 5 how do you rank the quality of your cocoa production?
22. Are you satisfied with the price offered to you by the cocoa board?
23. Do you think current governmental policies and regulations support you as a farmer?
24. Would you be happy to implement the use of drones on your cocoa farm for pest management or fertilizer application?

Stakeholder Questionnaire

Ministry of Food and Agriculture

1. What are your impressions about the use of UAV (UAVs) in cocoa farming in Ghana?
2. Is this technology new to the ministry?
3. Has there been any government initiatives targeted at investment and advocacy of this technology?
4. How has private industry been engaged to enhance Public Private Partnership (PPP) investment into this technology for the cocoa industry?
5. Owing to the large investment in this technology, what credit support exist for farmers who are ready to own the technology?

Ghana Cocoa Board (COCOBOD)

1. Has your agency introduced any technologies for cocoa farming recently?
2. What has been the impact of this implementation?
3. What has been the response of the stakeholder community, especially farms, to this new technology?
4. What are you perceptions of precision farming, including the implementation of UAV (UAVs) for cocoa farming?
5. How do you think drone technology could benefit the cocoa sector in Nkawie?

Cocoa Health and Extension Division (CHED)

1. How often do you conduct sensitization campaigns in this district?
2. Does your education and training programmes have elements of modern technology in them? If so, which technologies?
3. Do you run practical technology sessions with the farmers?
4. Which are the most effective methods of instruction for the farmers?

District Cocoa Office (DCO)

1. What are some of the key activities you conduct to assist farmers in this district?
2. What are some of the opportunities this office creates to expose and expand farmers' knowledge?
3. How have farmers received insights from the UAV (UAVs) deployment on their farms?
4. How has the office attracted local drone companies into the district?

Cocoa Research Institute of Ghana (CRIG - Ghana)

1. Has your agency conducted research into the use of UAV (UAVs) in farming in general? Has there been any for cocoa farming?

2. From a research standpoint, what do you think will be some of the benefits of UAV (UAVs) to cocoa farming?
3. How do you think current research development will impact farmers and their households directly?

Local Authority

1. What are some of the activities the local assembly organises to develop the competencies of farmers?
2. Does the assembly have any initiatives that attract local drone companies into the region?
3. What do you think the impact is of drone technology to farming?

Farmers' Associations (Ghana Cocoa, Coffee and Sheanut Farmers Association) (GCCSFA)

1. Have you heard about drones and seen some being used for any activity?
2. Have your members experienced the use of drones on any farms other than cocoa?
3. During the practical test pilot, what would you say were some of the benefits of using drones for farming?

…………………………………………………………

Appendix 4

Business School

Participant information letter for

An analytical study into new technological implications to improve food productivity/security in Ghana, case insights into the use of drones in cocoa farming

Researcher: Samuel Boafo Afranie, PhD candidate,
University Business School,
University of Hull,
Cottingham Road,
Hull, HU6 7RX

I am a PhD candidate at Hull University Business School, University of Hull. As part of the degree, I am undertaking a research project involving an analytical study into new technological implications to improve food productivity/security in Ghana – case insights into the use of drones in cocoa farming.
This research will aim to investigate the implications of the adaptation of UAV (UAVs) and how they could improve food productivity in Ghana. The participants include local farmers and their stakeholders, such as middle-level stakeholders including regional boards, chambers of commerce, business associations, intermediaries, including wholesalers, Ministry of Agriculture officials such as the Ghana Cocoa Board, and top-level stakeholders.

The participants will be asked about their attitudes, opinions, and point of view towards the implementation of this new technological application upon cocoa farming. The participants will be observed in their natural setting, such as at the participants' working place, at their meeting activities, and during their business routines. Thus, this research may impact their personal privacy. However, the participants will be clearly informed of the research aim and processes before the interviews and observations, and their consents for the research interview and participant observation will be sought in advance.

The interviews will be recorded by taking notes and via tape recording. Participants' activities will likewise be observed and recorded through note taking, tape recording, and photo taking with permission from participants. The participants are assured of the confidentiality of their data. The results will be used for research purposes and may be reported in scientific and academic journals. Individual results will not be released to any person except at the participants' request or on the participants' authorization. Participants are free to withdraw his/her consent at any time during the study and without adverse consequences, in which event his/her participation in the research study will immediately cease and any information obtained from him/her will not be used.

For further enquiries about this research project, please contact
the Researcher: Samuel Boafo Afranie.

University of Hull Cottingham Road,
Hull, HU6 7RX.
Email: S.B.Afranie@2017.hull.ac.uk

Supervised by Dr. Gunjan Saxena
University of Hull Cottingham Road,
Hull, HU6 7RX.
Email: G.Saxena@hull.ac.uk

Appendix 5

RESEARCH ETHICS COMMITTEE

FORM D – Staff, Post Graduate Students, and UG Dissertations

(Involving human participants)

Applications by members of Staff, by Post-Graduate students, and by UG students who write Dissertations. This form should be filled only if they are conducting research that involves human participants and/or animals:

SUBMISSION CHECKLIST

I have completed the Research Integrity module on the e learning portal https://hull.learnupon.com/dashboard Yes/[redacted]

Indicate with 'X' the documents that have been included with this application.

Fully completed application form	X
Completed risk assessment	
Recruitment materials – with date and version number) (e.g. poster or email used to invite people to participate)	
Consent form(s) – with date and version number (different version for each group of participants)	X
Letter or email seeking permission from gatekeeper/host	
Questionnaire(s) – with date and version number	
If conducting a student survey, confirm that it fits with University policy https://share.hull.ac.uk/Services/Governance/PolicyDocuments/Policy on Student Surveys.docx	
Interview questions / topic guide – with date and version number	X
Other (please specify)	
Data management plan (see section F2)	

Ethics reference number (for office use):	
WorkTribe project URL	

PART A: SUMMARY

A.1 Title of the research

AN ANALYTICAL STUDY INTO NEW TECHNOLOGICAL IMPLICATIONS TO IMPROVE FOOD PRODUCTIVITY / SECURITY IN GHANA – CASE INSIGHTS INTO THE USE OF DRONES IN COCOA FARMING

A.2 Principal investigator's contact details

Name *(Title, first name, surname)*	MR SAMUEL AFRANIE
Position	PhD STUDENT
Faculty/School	FBLP
Telephone number	07735043109
University of Hull email address	S.B.AFRANIE-2017@HULL.AC.UK
A.3 To be completed by students only	
Qualification working towards (e.g. Masters, PhD, ClinPsyD)	PhD
Student number	201720665
Supervisor's name (Title, first name, surname)	PROF. GUNJAN SAXENA
Faculty/ School	FBLP
Supervisor's telephone number	01482 46 3970
Supervisor's email address	G.SAXENA@HULL.AC.UK
A.4 Other relevant members of the research team (e.g. co-investigators, co-supervisors)	
Name *(Title, first name, surname)*	PROF. NISHIKANT MISHRA
Position	HEAD OF DEPARTMENT
Faculty/ School	FBLP
Telephone number	01482 46 3388
Institution	
Email address	NISHIKANT.MISHRA@HULL.AC.UK

A.5 Select from the list below to describe your research: (Mark with X all that apply)

X	Research on or with human participants
	Research working with data of human participants
	New data collected from observing individuals or populations
	Research using already published data or data in the public domain
	Research involving discussion of sensitive topics or topics that could be considered sensitive
	Research using confidential data
	Prolonged or frequent participant involvement
	Research involving members of the public in a research capacity (participant research)
X	Research conducted outside the UK
	Research involving accessing social media sites
	Research involving accessing or encountering security sensitive material
	Research involving accessing websites or material associated with extreme or terrorist communities
	Research involving storing or transmitting any material that could be interpreted as sympathetic, endorsing or promoting terrorist acts
	Research involving financial inducements for participants (other than reasonable expenses and compensation for time)

PART B: THE RESEARCH

B.1 Give a short summary of the research (max 300 words)

This section must be completed in language comprehensible to the lay person.

In plain English provide a brief summary of the aims and objectives of the research.

- The summary should briefly describe the background to the research and why it is important,
- the questions it will answer and potential benefits,
- the study design and what is involved for participants.

B.2 Proposed study dates and duration

Research start date (DD/MM/YY): _01.03.2021__ Research end date (DD/MM/YY): __01.06.2021__________

Fieldwork start date (DD/MM/YY): _01.03.2021__ Fieldwork end date (DD/MM/YY): ___01.06.2021________

B.3 Where will the research be undertaken? (i.e. in the street, on University of Hull premises, in schools, on-line etc.)

Do you have permission to conduct the research on the premises?

X	Yes			No

If no, please describe how this will be addressed.

B.4 Does the research involve any risks to the researchers themselves, or people not directly involved in the research? *E.g. lone working*

	Yes	X	No

If yes, please describe and say how these will be addressed (include reference to relevant lone working policies):

____

If yes, please include a copy of your completed risk assessment form with your application.

NB: If you are unsure whether a risk assessment is required visit the Health and Safety SharePoint site. Risk assessments are required for all fieldwork taking place off campus.

B.5 What are the main ethical issues with the research and how will these be addressed?
Indicate any issues on which you would welcome advice from the ethics committee

INDIVIDUAL PRIVICY WILL BE CONSIDERED, DATA COLLECTED WILL BE KEPT IN IN A WELL SECURED LAPTOP.

B.6 Does the research involve an international collaborator or research conducted overseas:

	Yes	X	No

If yes, describe any ethical review procedures that you will need to comply with in that country:

Describe the measures you have taken to comply with these:

Include copies of any ethical approval letters/ certificates with your application.

PART C: HUMAN PARTCIPANTS AND SUBJECTS

C.1 Who are the participants? FARMERS AND THEIR STALKHOLDERS

C.2 Are the participants expected to be from any of the following groups? (Mark with X as appropriate)

- [ ] Children under 16 years old. ***Specify age group:*** ____________________
- [ ] Adults with learning disabilities
- [ ] Adults with other forms of mental incapacity or mental illness
- [ ] Adults in emergency situations
- [ ] Prisoners or young offenders
- [ ] Those who could be considered to have a particularly dependent relationship with the investigator, e.g. members of staff, students
- [ ] Other vulnerable groups
- [X] No participants from any of the above groups

Include in Section D5 details of extra steps taken to assure their protection.

Does your research require you to have a DBS check?

[ ] Yes [X] No

It is the researcher's responsibility to check whether a DBS check (or equivalent) is required and to obtain one if it is needed. See also http://www.homeoffice.gov.uk/agencies-public-bodies/dbs

C.3 What are the potential benefits and/ or risks for research participants in both the short and medium-term?
Risks may include health and safety, physical harm and emotional well-being
PONTENTIAL BENEFITS INCLUDE THE IMPROVEMENT OF HIGH PRODUCTIVITY ON THEIR FARMS. THERE IS NO RISK TO HEALTH AND SAFETY,PHYSICAL HARM AND EMOTIONAL WELL BEING.

What will be done to avoid or minimise the risks?

C.4 Is there a potential for criminal or other disclosures to the researcher requiring action to take place during the research? (e.g. during interviews/group discussions, or use of screen tests for drugs?)

[ ] Yes [X] No

If yes, please describe and say how these will be addressed:

C.5 What will participants be asked to do in the study? *(e.g. number of visits, time involved, travel required, interviews)*
PARTICIPANT WILL BE ASK TO TAKE PART IN A SEMI STRUCTURED INTERVIEWS AT THEIR OWN LOCATIONS.

PART D: RECRUITMENT & CONSENT PROCESSES

How participants are recruited is important to ensure that they are not induced or coerced into participation. The way participants are identified may have a bearing on whether the results can be generalised. Explain each point and give details for subgroups separately if appropriate. Also say who will identify, approach and recruit participants. Remember to include all advertising material (posters, emails etc) as part of your application.

D.1 Describe how potential participants in the study be identified, approached and recruited and who will do this:

(i) identified: LOCAL FARMERS WITHIN THE SELECTED AREA/REGION

(ii) approached: THROUGH THEIR LOCAL ASSIOCIATION.

(iii) recruited: THROUGH THEIR LOCAL ASSIOCIATION.

D.2. Do you intend to identify participants by name? If yes, explain why

D.3 Will the research involve any element of deception?

	Y		X	N

If yes, please describe why this is necessary and whether participants will be informed at the end of the study.

D.4 Will informed consent be obtained from the research participants?

	Y		X	N

If yes, give details of how it will be done. Give details of any particular steps to provide information (in addition to a written information sheet) e.g. videos, interactive material. If you are not going to be obtaining informed consent you will need to justify this.

If participants are to be recruited from any of potentially vulnerable groups, give details of extra steps taken to assure their protection. Describe any arrangements to be made for obtaining consent from a legal representative.

Copies of any written consent form, questionnaire, written information and all other explanatory material should accompany this application. *The information sheet should make explicit that participants can withdraw from the research at any time, if the research design permits. Remember to use meaningful file names and version control to make it easier to keep track of your documents.*

D.5 Describe whether participants will be able to withdraw from the study, and up to what point (e.g. if data is to be anonymised). If withdrawal is not possible, explain why not.
Any limits to withdrawal, e.g. once the results have been written up or published, should be made clear to participants in advance, preferably by specifying a date after which withdrawal would not be possible. Make sure that the information provided to participants (e.g. information sheets, consent forms) is consistent with the answer to D6.
PARTICIPANT WILL BE ABLE TO WITHDRAW AT ANY POINT WITHOUT ANY OBILIGATIONS.

D.6 Will individual or group interviews/ questionnaires discuss any topics or issues that might be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures that require action (for instance, pertaining to child protection) could take place during the study (e.g. during interviews or group discussions)?
The information sheet should explain under what circumstances action may be taken.

	Y		X	N

If yes, give details of procedures in place to deal with these issues.

D.7 Will individual research participants receive any payments, fees, reimbursement of expenses or any other incentives or benefits for taking part in this research?

[ ] Y [X] N

If Yes, please describe the amount, number and size of incentives and on what basis this was decided.

PART E: RESEARCH DATA

Please read http://libguides.hull.ac.uk/researchdata

E.1 Explain what measures will be put in place to protect personal data. E.g. anonymisation procedures and coding of data. Any potential for re-identification should be made clear to participants in advance.

This will be ensured by using a unique id to allocate all records instead of personal details. It will be secured with strong password and all collected evidence will be anonymous.

E.2 Does the research involve sensitive topics or confidential data? If yes, explain.

E.3. What security measures are place to ensure secure storage of data at any stage of the research?

Provide details on where personal data will be stored, any of the following: (mark with X all that apply)

- [ ] University approved cloud computing services
- [ ] Other cloud computing services
- [ ] Manual files
- [ ] Private company computers
- [X] Portable devices
- [ ] Home or other personal computers (not recommended; data should be stored on a University of Hull server such as your G,T, X or Z: drive where it is secure and backed up regularly).

Please attach the data management plan in the appendices; for further information visit http://libguides.hull.ac.uk/researchdata

E.4 Who will have access to participant's personal data during the study?
THE RESERACHER

E.5 Where will the data generated by the research be analysed and by whom?
THE RESERACHER AND AT UNIVERSITY OF HULL

E.6 Who will have access and act as long term custodian for the research data generated by the study?
THE RESERACHER

E.7 Have all researchers that have access to the personal data that will be collected as part of the research study, completed the University (or equivalent) data protection training?

[X] Yes [ ] No

It is mandatory that all researchers accessing personal data have completed data protection training prior to commencing the research.
https://share.hull.ac.uk/Services/StaffDevelopment/SitePages/eLearning%20-%20Courses.aspx

E.8 Will the research involve any of the following activities at any stage (including identification of potential research participants)? (Select all that apply)

- [ ] Examination of personal records by those who would not normally have access
- [ ] Access to research data on individuals by people from outside the research team
- [ ] Electronic surveys, please specify survey tool: ____________________

Declaration by Principal Investigator

1 The information in this form is accurate to the best of my knowledge and belief.

2. I take full responsibility for the information I have supplied in this document.

3. I undertake to abide by the University's ethical and health and safety guidelines, and the ethical principles underlying good practice guidelines appropriate to my discipline.

4. I will seek the relevant School Risk assessment/COSHH approval if required.

5. If the research is approved, I undertake to adhere to the project protocol, the terms of this application and any conditions set out by the Faculty Research Ethics Committee.

6. Before implementing substantial amendments to the protocol, I will submit an amendment request to the Faculty Research Ethics Committee seeking approval.

7. If requested, I will submit progress reports.

8. I am aware of my responsibility to be up to date and comply with the requirements of the law and relevant guidelines relating to security and confidentiality of participants or other personal data, including the need to register when necessary with the appropriate Data Protection Officer.

9. I understand that research records/data may be subject to inspection for audit purposes if required in future.

10. I take full responsibility for the actions of the research team and individuals supporting this study, thus all those involved will be given training relevant to their role in the study.

11. By signing the validation I agree that the Faculty Research Ethics Committee, on behalf of the University of Hull, will hold personal data in this application and this will be managed according to the principles established in the Data protection Act (1998).

Sharing information for training purposes: Optional – please mark with X as appropriate:

X	I would be content for members of other Research Ethics Committees to have access to the information in the application in confidence for training purposes. All personal identifiers and references to researchers, funders and research units would be removed.

Principal Investigator

Signature of Principal Investigator:

(This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: ....SAMUEL AFRANIE............ Date: (dd/mm/yyyy): ...15.02.2021..........................

Reviewer

Signature of Reviewer:

(This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: .... Date: (dd/mm/yyyy): ....

Supervisor of UG and PG student research: I have read, edited and agree with the form above.

Supervisor's signature:..

(This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: .... Date: (dd/mm/yyyy): .... 15.02.2021...

Remember to include any supporting material such as your participant information sheet, consent form, interview questions and recruitment material with your application. Version control should be adopted to include the version number and date on relevant documents in the appendices. **These should be pasted as Appendices to this form.**

One copy of the form should be kept by the researcher, one copy should be retained by the Ethics Officer and one copy should be sent by email to
fblp-researchadmin@hull.ac.uk

Appendix 6

INTERVIEW TRANSCRIPTS

Farmers

1. Gender?
2. Level of education?
3. Knowledge of technology use on the farm i.e., Drones
4. How much time do you spend on the farm?
5. When do you start growing cocoa? (season)
6. What is the cost to you in cocoa production and marketing? (Labour, pesticides, seedlings, fertilizers)
7. How do you control or manage weeds, or apply fertilizers on your cocoa farm?
8. How much cocoa do you produce each season?
9. How much do you obtain from cocoa each season? (Price, total income, any other sources of income)
10. Where do sell your cocoa? (Local market, Ghana Cocoa Board (COCOBOD) or exporters)
11. How do you evaluate your relationship with the buyer(s)?
12. How many people do you employ or help with your cocoa farming business?
13. Do you face any challenges in the production and marketing of the cocoa?
14. How have you overcome these challenges?
15. What support do you receive from the Ministry of Agriculture?
16. How does the involvement of the Ministry of Agriculture or Ghana Cocoa Board improve your farm management?
17. Have you experienced any changes to your farming practice in the past?
18. To what extent will any new changes in farm management affect you, the community and your family?
19. If help is available, do you think being in a cooperation group would help to minimise the costs of farm management or improve the profitability of production? If yes, how?
20. Are you able to produce the required quality and quantity of cocoa during each season?
21. On a scale of -5 to 5 how do you rank the quality of your cocoa production?
22. Are you satisfied with the price offered to you by the cocoa board?
23. Do you think current governmental policies and regulations support you as a farmer?
24. Would you be happy to implement the use of drones on your cocoa farm for pest management or fertilizer application?

Respondent 1	Male Famer Age 53	Local Farmer 28 years in cocoa farming	7th April 2021

1. Male
2. Primary
3. I have not used any technology before
4. I go to my farm early in the morning around 6am and leave there 5pm
5. I've been in the cocoa farming for 28 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt, they cannot be trusted
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them (trust issue)
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free and available to students
23. To some extent it is good but can be improved to look after us
24. Yes if it will help us to reduce labour cost because we will pay more for people to spray

Respondent 2	Male Famer Age 39	Local Farmer 15 years in cocoa farming	7th April 2021

1. Male
2. No education
3. Technology is to me
4. I work all day on the farm with my family.
5. I have 15 years of cocoa farming experience
6. This is my biggest worry as the government do not help at alI get my fertilizer from the local office in this village. Sometimes the price is 300gh which is expensive. The fertilizer should be free, but they charge lots of money for it.
7. We put them in a spraying can on the cocoa farm and it's very difficult to spray it .we do that every year and it takes time. I wish we have technology to do it
8. I produce about 25 bags
9. 2500Gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We have good relationship, but the local authorities are very corrupt, and they don't give us the full price of our cocoa bags because they are very corrupt
12. I do not employ anyone I work on the farm with my wife
13. There is no accountability to farmers, we do not know what equipment the government is issuing to us at any time; all we hear is 'free farming equipment', yet we still have to pay for the items at the local authority.
14. We pour libation . The gods are very good, and they protect our farms
15. We don't receive support
16. They are supposed to give us fertilizers for farming and give us education
17. No improvement still the same old
18. It will help us to improve our farming and help us to get lots of money
19. Yes, we would be able to build on our family and our lives will be better through education
20. No because there are no fertilizer and modern tools to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free and fair to shareholders
23. It is okay but can be improved to look after my family
24. Yes because we will have to spend money for labour

Respondent 3	**Male Famer Age 47**	**Local Farmer 15 years in cocoa farming**	**7th April 2021**

1. Male
2. No education
3. no technology
4. I go to my farm early in the morning around 6am and leave there 6pm
5. I've been in the cocoa farming for 15 years now
6. I get my fertilizer from the local office in this village. Sometimes the price could shoot to 400gh which is expensive. The fertilizer should be affordable, but they charge lots of money for it.
7. Even though the application of drones would improve our cocoa farming, the local authority would be reluctant to accept it because the drone is a big machine to steal and hide in their home, so they could not make any money out of that
8. I produce about 30 bags
9. 3000Gh and this is what I use to make sure my family is okay
10. Ghana Cocoabod
11. We are in good relationship with them, but the local authorities are very corrupt, and they don't give us the actual price of our cocoa bags
12. I work on the farm with my wife and sometimes my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are very corrupt, and the prices of the fertilizers are too high
14. We pour libation and the goods protect our farms
15. We don't receive any help
16. They are supposed to educate us
17. No improvement as usual
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better through education
20. No because there are no fertilizers to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free and available to shareholders
23. It is not bad but can be improved to look after my family
24. Yes because we will have to spend more money for labour

Respondent 4	**Female Famer Age 36**	**Local Farmer 14 years in cocoa farming (Family Business)**	**7th April 2021**

1. Female
2. Primary
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been in the cocoa farming for 14 years now
6. I get my fertilizer from the local office in this village. Sometimes the price is 200gh . The fertilizer should be affordable, but they charge lots of money for it.
7. We use manual spraying and it's so difficult to spray it making our work more difficult. we do that every year and it takes time.
8. I produce about 30 bags
9. 2000gh and I take care of my family with it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are not good, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any aid
16. They are supposed to educate and train us
17. No improvement
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better
20. No because there are no fertilizers to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free and fair to shareholders
23. It is good but can be improved to look after my family
24. Yes because we will have to spend more money for labour work

Respondent 5	Female Famer Age 48	Local Farmer 20 years in cocoa farming	7th April 2021

1. Female
2. No education
3. No technology
4. I go to my farm in the morning around 9am and leave there 5pm
5. I've been in the cocoa farming for 20 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 25 bags
9. 2500gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. And also employed few people .
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and fair to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 6	Male Famer Age 55	Local Farmer 30 years in cocoa farming	9th April 2021

1. Male
2. Secondary
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I’ve been in the cocoa farming for 30 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it’s so difficult to spray it . We do that every year and it takes time.
8. I produce about 20 bags
9. 2000gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don’t give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I have not employed anyone
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don’t receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and available to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 7	Male Famer Age 54	Local Farmer 34 years in cocoa farming	9th April 2021

1. Male
2. Secondary
3. I have not used any technology before
4. I work from 6am and leave there 5pm a
5. I've been in the cocoa farming for 34 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all Although the government provides free farming equipment such as hoes during the planting session, I still need to pay for them at the local office in this district, and this money does not go back to government, but ends up in the local authority workers' pockets
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. I have never been in a school before, I can neither read nor write, so I am happy with what am doing on my far
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free and fair to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Respondent 8	Male Famer Age 51	Local Farmer 31 years in cocoa farming (Inherited from Father)	9th April 2021

1. Male
2. Secondary
3. no technology
4. I arrive at my farm early at 6am and depart 6pm
5. I've been producing cocoa for 31 days
6. The municipal office in this village is where I acquire my fertiliser. The price can occasionally jump to 400gh, which is exorbitant. The fertiliser ought to be inexpensive, but they charge a high price for it
7. We use manual spraying and it's so difficult to spray it making our work more difficult. We do that every year and it takes time.
8. I make roughly 30 bags
9. 3000 gh and i use this for my family's wellbeing
10. Ghana Cocoabod
11. We are in good relationship with them, but the local authorities are very corrupt, and they don't give us the actual price of our cocoa bags
12. I work on the farm with my wife and sometimes my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are very corrupt, and the prices of the fertilizers are too high
14. We pour libation and the goods protect our farms
15. We don't receive any help
16. They are supposed to educate us
17. No improvement as usual
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better through education
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free and fair to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Respondent 9	Male Famer Age 51	Local Farmer 20 years in cocoa farming	9th April 2021

1. Male
2. Primary
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been working in the cocoa farming for 20 years now
6. I get my fertilizer from the local office in this village. Sometimes the price is 200gh . The fertilizer should be affordable, but they charge lots of money for it.
7. We use manual spraying and it's so difficult to spray it making our work more difficult. we do that every year and it takes time.
8. I produce about 30 bags
9. 2000gh and I take care of my family with it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are not good, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any aid
16. They are supposed to educate and train us
17. No improvement
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better
20. No because there are no fertilizers to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free and given to shareholders
23. It is good but can be improved to look after my family
24. Yes because we will have to spend more money for labour work

Respondent 10	Male Famer Age 47	Local Farmer 27 years in cocoa farming	12th April 2021

1. Male
2. No education
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been in the cocoa farming for 27 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 20 bags
9. 2000gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I have not employed anyone
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and be given to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 11	Male Famer Age 46	Local Farmer 18 years in cocoa farming	12th April 2021

1. Male
2. No education
3. No technology
4. I work from 9am and leave there 5pm
5. I've been in the cocoa farming for 18 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 25 bags
9. 2500gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. And also employed few people .
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and available for shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 12	Male Famer Age 65	Local Farmer 40 years in cocoa farming (Family Business)	12th April 2021

1. Male
2. No education
3. I have not used any technology before
4. I go to my farm early in the morning around 6am and leave there 5pm
5. I've been in the cocoa farming for 40 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free
23. To some extent it is good but can be improved to look after us
24. Yes if it will help us to reduce labour cost because we will pay more for people to spray

Respondent 13	Male Famer Age 68	Local Farmer 47 years in cocoa farming (Family Business)	12th April 2021

1. Male
2. Primary
3. I have not used any technology before
4. I go to my farm early in the morning around 6am and leave there 5pm
5. I’ve been in the cocoa farming for 47 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it’s very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We’ve got good relationship, but the local authorities are corrupt, and they don’t give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don’t receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free and available to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Respondent 14	Male Famer Age 45	Local Farmer 25 years in cocoa farming	16th April 2021

1. Male
2. No education
3. I have not used any technology before
4. I begin 6am and end 5pm
5. I’ve been working in the cocoa farming industry for 25 years now
6. I get my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. The cocoa farm uses hand spraying, which is exceedingly challenging to do. But it takes time and we do it all year long. I wish there was technology for that.
8. I produce about 20 bags
9. About 2000gh and this is what i use for family’s wellbeing
10. Ghana Cocoabod
11. We’ve got good relationship, but the local authorities are corrupt, and they don’t give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don’t receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free and made known to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Respondent 15	Female Famer Age 60	Local Farmer 45 years in cocoa farming	16th April 2021

1. Female
2. primary
3. no technology
4. I go to my farm early in the morning around 6am and end 6pm
5. I’ve been in the cocoa farming for 45 years now
6. I get my fertilizer from the local office in this village. Sometimes the price could shoot to 400gh which is expensive. The fertilizer should be affordable, but they charge lots of money for it.
7. We use manual spraying and it’s so difficult to spray it making our work more difficult. We do that every year and it takes time.
8. I produce about 30 bags
9. 3000 gh and this is what I use to make sure my family is okay
10. Ghana Cocoabod
11. We are in good relationship with them, but the local authorities are very corrupt, and they don’t give us the actual price of our cocoa bags
12. I work on the farm with my wife and sometimes my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are very corrupt, and the prices of the fertilizers are too high
14. We pour libation and the goods protect our farms
15. We don’t receive any help
16. They are supposed to educate us
17. No improvement as usual
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better through education
20. “This is how it looks. This can affect the entire cocoa farm and you will make nothing from your farm. The virus is very dangerous and very difficult to control. It makes cocoa farming sometimes difficult to manage. If a new system can improve this for us, that would be great for every farmer within the district. Cocoa beans matter a lot in cocoa farming. It is the beans that we sell to make money. Most farms within this region suffer from swollen shoot virus, and it is very difficult to control this. In 1992, I did not make any money on my cocoa farm, as the cocoa beans were full of swollen shoot virus because this affected my cocoa trees. The regional office rejected all my cocoa beans. The main problem is that we need government support in tackling this virus. The government can give support by providing us with fertilizers and even machines to spray our cocoa farms instead of us using our manpower all the time
21. 3
22. No because we need more fertilizers, and it should be free and available to shareholders
23. It is not bad but can be improved to look after my family
24. Yes because we will have to spend more money for labour

Respondent 16	**Female Famer Age 47**	**Local Farmer 32 years in cocoa farming**	**16th April 2021**

1. Female
2. Primary
3. No technology
4. I go to my farm in the morning around 9am and leave there 5pm
5. I've been in the cocoa farming for 32 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 25 bags
9. 2500gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. And also employed few people .
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms, our traditional good is powerful
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

17 Respondent	**Female Famer Age 52**	**Local Farmer 35 years in cocoa farming**	**20th April 2021**

1. Female
2. No education
3. No technology
4. I begin 9am and end 5pm
5. I've been in the cocoa farming for 35 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 25 bags
9. 2500gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. And also employed few people .
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and available to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 18	Female Famer Age 68	Local Farmer 48 years in cocoa farming (Inherited from husband)	20th April 2021

1. Female
2. No education
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been in the cocoa farming for 48 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 20 bags
9. 2000gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I have not employed anyone
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high (trust)
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free and available to shareholders
23. It is good but we can help increase production
24. Once I can understand how to use a drone, then it would be good to use it on my farm. I would not have to pay more people to spray my farm manually. If a drone can do it for us in a day, that would be great, and it would save us money and time. For now, I have to pay labourers for three days to do that for me

Respondent 19	**Female Famer Age 48**	**Local Farmer 22 years in cocoa farming (Family own land)**	**20th April 2021**

1. Female
2. No education
3. I have not used any technology before
4. I go to my farm early in the morning around 6am and leave there 5pm
5. I've been in the cocoa farming for 22 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them (trust)
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes if it will help us to reduce labour cost because we will pay more for people to spray

Respondent 20	Male Famer Age 58	Local Farmer 33 years in cocoa farming	20th April 2021

1. Male
2. No education
3. I have not used any technology before
4. I go to my farm early in the morning around 6am and leave there 5pm
5. I've been in the cocoa farming for 33 years now
6. I buy my fertilizer from the local office in this village. Sometimes it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free to shareholders
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Respondent 21	Male Famer Age 55	Local Farmer 34 years in cocoa farming	29th April 2021

1. Male
2. Primary
3. There is no technology
4. I commence 8am and leave there 4pm
5. I've been working in the cocoa farming for 34 years now
6. I get my fertilizer from the local office in this village. Sometimes the price is 200gh . The fertilizer should be affordable, but they charge lots of money for it.
7. We use manual spraying and it's so difficult to spray it making our work more difficult. we do that every year and it takes time.
8. I produce about 30 bags
9. 2000gh and I take care of my family with it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are not good, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. Although I do reap a lot of cocoa during the harvest session, most of it goes to waste because of poor pest management, the reason being that the government does not support us enough in financial terms. We are unable to buy the insecticides for spraying on our farms; we need to apply by completing a lengthy form before money can be released for this. We still need to pay labourers to do this for us, and we are unable to afford all of this. The government in power needs to help us with money and even pay for the labourers spraying the entire farm. I do wish that the application of UAV was on the government's priority list, as this would reduce my costs and could save the cost of paying labourers, but again, I do not think the government can afford this technology
16. They are supposed to educate and train us
17. No improvement
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better
20. No because there are no fertilizers to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free to shareholders
23. It is good but can be improved to look after my family
24. Yes because we will have to spend more money for labour work

Respondent 22	Male Famer Age 51	Local Farmer 30 years in cocoa farming	29th April 2021

1. Male
2. No education
3. No technology
4. I go to my farm in the morning around 9am and leave there 5pm
5. I've been in the cocoa farming for 20 years now
6. Although the government provides free farming equipment such as hoes during the planting session, I still need to pay for them at the local office in this district, and this money does not go back to government, but ends up in the local authority workers' pockets
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 25 bags
9. 2500gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. And also employed few people .
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high (trust)
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free for shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent **23**	**Male Famer Age 44**	**Local Farmer 23 years in cocoa farming**	**29th April 2021**

1. Male
2. primary
3. no technology
4. I go to my farm early in the morning around 6am and leave there 6pm
5. I've been in the cocoa farming for 23 years now
6. I get my fertilizer from the local office in this village. Sometimes the price could shoot to 400gh which is expensive. The fertilizer should be affordable, but they charge lots of money for it.
7. We use manual spraying and it's so difficult to spray it making our work more difficult. We do that every year and it takes time.
8. I produce about 30 bags
9. 3000 gh and this is what I use to make sure my family is okay
10. Ghana Cocoabod
11. We are in good relationship with them, but the local authorities are very corrupt, and they don't give us the actual price of our cocoa bags
12. I work on the farm with my wife and sometimes my kids. I do not employ anyone
13. Yes, we face challenges because the local authorities are very corrupt, and the prices of the fertilizers are too high
14. We pour libation and the goods protect our farms
15. We don't receive any help
16. They are supposed to educate us
17. No improvement as usual
18. It will help us to improve our farming and help us to look after our family
19. Yes, we would be able to make our lives better through education
20. No because there are no fertilizers to help us control pests
21. 3
22. No because we need more fertilizers, and it should be free to shareholders
23. It is not bad but can be improved to look after my family
24. Yes because we will have to spend more money for labour

Respondent 24	Male Famer Age 42	Local Farmer 30 years in cocoa farming	29th April 2021

1. Male
2. No education
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been in the cocoa farming for 34 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 20 bags
9. 2000gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I have not employed anyone
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free for shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent **25**	**Male Famer Age 47**	**Local Farmer 34 years in cocoa farming**	**29th April 2021**

1. Male
2. No education
3. There is no technology
4. I go to my farm in the morning around 8am and leave there 4pm
5. I've been in the cocoa farming for 34 years now
6. I get my fertilizer from the local office in this village. the price is 200gh which is expensive, but they charge lots of money for it.
7. We put them on spraying can and it's so difficult to spray it . We do that every year and it takes time.
8. I produce about 20 bags
9. 2000gh and my family depends on it
10. Ghana Cocoabod
11. We have a good relationship with them, but the local authorities are very corrupt, and they don't give us the real price of our cocoa bags
12. I work on the farm with my wife and my kids. I have not employed anyone
13. Yes, we face challenges because the local authorities are corrupt, and the prices of the fertilizers are too high (trust)
14. We pour libation and the gods protect our farms
15. We don't receive any help
16. They are supposed to teach us
17. No improvement
18. It will help us to increase our farming activities and help us to look after our family
19. Yes, it will enable us to make our lives greater.
20. No because there are no fertilizers to help us control pests
21. 3
22. No because fertilizers are needed, and it should be free to shareholders
23. It is good but we can help increase production
24. Yes because we will have to spend more money for labour work

Respondent 26	Male Famer Age 45	Local Farmer 20 years in cocoa farming	29th April 2021

1. Male
2. No education
3. I have not used any technology before
4. I commence 6am and depart 5pm
5. I've been with the cocoa farming industry for 20 years now
6. I get my fertilizer from the local office in this village. However, it costs me 200gh. The fertilizer should be free, but they charge lots of money for it. The governments are not helping at all
7. We use manual spraying on the cocoa farm and it's very difficult to spray it .However we do that all year round and it takes time. I wish we have technology to do it
8. I produce about 20 bags
9. About 2000gh and this is what I use to feed my family
10. Ghana Cocoabod
11. We've got good relationship, but the local authorities are corrupt, and they don't give us full price of our cocoa bags because they are very corrupt
12. This is a family business so my kids, my wife and my nephew work on it
13. Yes, we face challenges because the local authorities are very corrupt, and they sell the fertilizers to us at a very high price, and we do not have enough modern tools to do the farming. They keep everything in the city and sell them
14. We pour libation and the gods help us
15. We don't receive support because they do not care about us
16. They are supposed to supply fertilizers and tools for farming and educate us which they do sometimes
17. All is the same nothing has changed
18. It will help us to improve our farming and help us to get lots of money
19. Yes, because of education and training we would be able to improve our family and our lives will be better
20. No because there is lack of fertilizers and lack of modern tools to help us control pests
21. 3
22. No because we need more training and more fertilizers, and it should be free but we cannot trust other stakeholders.
23. To some extent it is good but can be improved to look after us
24. Yes because we will have to spend more money for labour work

Ghana Cocoa Board (COCOBOD)

6. Has your agency introduced any technologies for cocoa farming recently?
7. What has been the impact of this implementation?
8. What has been the response of the stakeholder community, especially farms, to this new technology?
9. What are your perceptions of precision farming, including the implementation of UAV (UAVs) for cocoa farming?
10. How do you think drone technology could benefit the cocoa sector in Nkawie?

Respondent 27	**COCOBOD, Male 50**	**Government official 12 years in the cocoa industry**	**10th May 2012**

1. The organisation has been working incredibly hard to advance technologies in order to improve farmer life in general. Drone technology has been highlighted multiple times as a component of the organization's initiative. As innovative technology for growing cocoa seedlings at nursery sites, we have introduced the usage of cocopeat and receptacles. The programme is a part of the Board's efforts to streamline its essential operations in keeping with best practises for environmental preservation and protection.
2. This has enhanced plant health during the nursing process and encouraged confidence and a positive outlook on agricultural output.
3. Stakeholders' attitudes toward this strategy have been generally supported and encouraged with regard to the production of cocoa
4. All agricultural sectors, especially those that use UAVs for pest management in cocoa farming and contemporary agricultural practises like seed plantations, need to be encouraged to undertake precision farming.
5. This will be seen by many as a benefit for the Nkawie cocoa industry. for instance, to save labour costs, maintain pest management effectiveness, and boost productivity

Respondent 28	**COCOBOD Female 58**	**The Seed Production Unit (SPU) Government official 32 years in the cocoa industry**	**8th June 2021ov**

1. **Yes cocopeat and receptacles have been introduced.** The two media are not only ecologically-friendly, but also provide good conditions for the proper growth of the seedlings. The cocopeat promotes high water retention, ensures good germination, and rapid seedling emergence. The receptacles, on the other hand, have holes underneath which ensure good drainage and guarantee the formation of intact and healthy roots. Again, removing seedlings for transplanting from receptacles is achieved with minimum disturbance to the young plant, and these qualities are essential for a high survival rate of seedlings
2. It has been a great impact because it has helped to increase cocoa yields **.** The next phase of cocoa farming will be about who is able to leverage technology for cocoa growth. Our neighbours Cote D'Iviore, who are the highest producers and exporters of cocoa in the world, are using drones; this is providing significant benefits such as effective disease and pest control as well as testing the viability of seeds and trees grown. What is stopping us here in Ghana from applying this technology if we are serious about wanting to overtake Cote D'Iviore?
3. In general there have been a positive attitutes towards stakeholders involvement and engagement
4. All agricultural sectors, especially those that use UAVs for pest management in cocoa farming and contemporary agricultural practises like seed plantations, need to be encouraged to undertake precision farming.
5. The Nkawie cocoa sector will undoubtedly benefit from this, according to many. For example, to reduce labour expenses, keep pest management effective, and increase productivity . To enhance cocoa production in Nkawie, there is now a need to invest more in technology to help our farmers who struggle all year round. We are in talks with stakeholders to support us in establishing a clear initiative which will make this happen. As part of the COCOBOD budget, we have now factored in the purchase of new farming technology such as drones for use by farmers on their farms. There is no doubt that investing in technology will serve as a massive benefit for our cocoa farmers and the entire cocoa production, as we are seeing in Cote D'Ivoire

Respondent 29	**COCOBOD Female** **58**	**The Seed Production Unit (SPU)** **Government official 32 years in the cocoa industry**	**8th June 2021**

1. Yes (twin technology)
2. It has helped in farming practices especially cocoa
3. With regard to cocoa production, stakeholder attitudes toward this method have typically been welcomed and supported.
4. Precision farming needs to be fostered in all agricultural sectors, particularly those that use UAVs for pest management in cocoa farming and modern agricultural practises like seed plantings.
5. Many people will view this as advantageous for the Nkawie cocoa sector. For example, to reduce labour costs, maintain pest management effectiveness, and increase productivity

Cocoa Health and Extension Division (CHED)

5. How often do you conduct sensitization campaigns in this district?
6. Does your education and training programmes have elements of modern technology in them? If so, which technologies?
7. Do you run practical technology sessions with the farmers?
8. Which are the most effective methods of instruction for the farmers?

Respondent 30	Cocoa Health and extension division (district) Male 61	Government official 30 years in the cocoa industry	15th May 2012

1. Very often within the district
2. Yes recently we have been educating and training farmers of good farming skills on youtube. Watching YouTube videos on drone technology for farming was integral in psychologically preparing farmers for the practical test sessions, which were influential in providing them with a 'teaser' of what the technology can do for them on their farms. The farmers' knowledge of what the technology really is, and how it can improve their crop performance and farming practices was rendered visual through the video sessions which including practical test sessions
3. Yes we recently did the drone test session and during the drone test sessions organized for stakeholders, they were excited to see how drone technology was working effectively with the images of the farm it captures, including how the spraying of the fertilizer onto the crops is carried out
4. Video exhibitions and practical test sessions

District Cocoa Office (DCO)

5. What are some of the key activities you conduct to assist farmers in this district?
6. What are some of the opportunities this office creates to expose and expand farmers' knowledge?
7. How have farmers received insights from the UAV (UAVs) deployment on their farms?
8. How has the office attracted local drone companies into the district?

Respondent 31	**Extension Community Agent Male 65**	**Government official 30 years in the industry**	**20th May 2012**

1. Instead of depending on health and extension officers' visits to organize workshops and training sessions for our farmers and their workers, we sometimes take it on ourselves to offer that service and support for the farmers so that they do not fall behind in the matter of what new farming practices are being applied elsewhere.
2. We have an information system established to link farmer production to market information so that both investors and farmers can be given up to-date information on the conditions of their cocoa plant, but because we still have to resort to the use of manual processes, we are not able to provide timely and accurate information. Conducting laboratory tests to assess soil and plant conditions can be cumbersome and time-consuming at the same time. When I visited a pineapple farm, I was surprised to see their system, which uses drones which are small, Unmanned Aircraft which provide feedback information on crop health, performance and yield estimates and then relay this through a mobile phone platform linking farmers to extension agents, markets and other
3. Acquahmeyer is now working with 8,000 farmers, who pay USD$5 to USD$10 per acre, approximately six times a year, to assess their crops and soil and apply pesticides. Each drone costs USD$5,000 to USD$15,000 to build, and can spray 10,000 acres annually. Acquahmeyer's strategy of training locals to pilot and repair the aircraft is helping to fuel interest in the company and its growth, says Nelson. He says: "In every farming community we have ambassadors for our company who are pilots, and we are creating jobs. We want to make sure that technology and agriculture becomes an exciting job
4. It is attracted soo many private companies and they are willing to come into the district

Respondent 32	**District Cocoa Officer, Male 52**	**Government official 25 years in the cocoa sector**	**20th May 2012**

1. We occasionally take it upon ourselves to provide that service and support for the farmers in order to ensure that they do not lag behind in the matter of what new farming practises are being implemented elsewhere, instead of relying on health and extension officers' visits to organise workshops and training sessions for our farmers and their workers.
2. We have a system in place to link farmer production to market data, allowing us to give investors and farmers the most recent information possible about the state of their cocoa plant. However, because we still rely on manual processes, we are unable to deliver fast and accurate information. It might be difficult and time-consuming to conduct laboratory tests to evaluate the health of the soil and plants. When I went to a pineapple farm, I was astonished to see their system, which makes use of drones—small, unmanned aircraft—to provide feedback on crop health, performance, and yield estimates. This information is then relayed through a mobile phone platform that connects farmers to extension agents, markets, and other stakeholders.
3. . Each drone can spray 10,000 acres annually for between US$5,000 and US$15,000 to develop. According to Nelson, Acquahmeyer's strategy of teaching locals how to fly and maintain the aircraft is boosting interest in the business and its expansion. He claims: "We have pilot advocates for our business in every farming community, and we're also producing jobs. We want to ensure that working in technology and agriculture is exciting.
4. A lot of private enterprises have been drawn to it and are prepared to move into the neighbourhood.

4. Has your agency conducted research into the use of UAV (UAVs) in farming in general? Has there been any for cocoa farming?
5. From a research standpoint, what do you think will be some of the benefits of UAV (UAVs) to cocoa farming?
6. How do you think current research development will impact farmers and their households directly?

Respondent 33	**Local Chief Male 72**	**Government official 38 years as an extension officer**	**8th June 2021**

1. Yes the implementation of drones in cocoa farming is long overdue; trust me when I tell you that the implementation of this technology in cocoa farming will restore investors' confidence in the sector. This is because we will be able to project yields and returns for investors by telling them the number of cocoa plants on the farms which are disease- and pest-free, as well as telling them about the measures we are taking on the diseases which affect plants and/or seeds to make sure that they do not lose out in the long run. These drones will also assist smallholder farmers with relevant and real-time information on which parts of their farm and plantations are doing well, as well as soil conditions. It will help to prevent post-harvest loses and reduce the perceptions investors and stakeholders have about cocoa being a high-risk venture, especially the banks and financial institutions who fear granting loans to c÷//÷'farmers. We will be able to support farmers' loan applications with digitized data and research results, which will help banks to make informed decisions based on live information and updates on farm conditions. The Unmanned Aerial Vehicle technology will improve the reliability of information which can be fact-checked based on the farmers' own land and crops, yields and even the quality of the seeds produced"
2. It will benefit in controlling pest . it will hep reduce labour cost and it will optimize productivity
3. It will improve their households and enhance them to learn modern farm practices

Local Authority

4. What are some of the activities the local assembly organises to develop the competencies of farmers?
5. Does the assembly have any initiatives that attract local drone companies into the region?
6. What do you think the impact is of drone technology to farming?

Respondent 34	**Local authority Female 56**	**Government official 30 years in the cocoa industry**	**10th June 2021**

1. We have been to these workshops organised by the company and have seen what the drones can do, but it is better if we bring them to the district for the farmers to see them for themselves, so that it does not become 'reported speech'. There is already a perception of corruption amongst public officials in the minds of these farmers, so when they see the illustrations live and hear from the horse's mouth, they will see and believe that the benefits and prospects of using drones to farm bring many advantages. From where I sit, drones help labour on the farms and decrease their costs, also guaranteeing high yields. The reason why Ghana was the first country to receive the COVAX vaccine is that it had the strongest application; this is because they can guarantee the delivery of this vaccine to any health facility or hospital in the country via Unmanned Aerial Application which comes at a low cost and very high reliability rate

2. The speedy nature of drone delivery helps with the challenges posed by 'cold chain logistics'. There is no need to worry about traffic delays in the sky, he says, and the drones, which travel at 100 km/h, take only 30 to 40 minutes on average to complete each delivery
3. It will help optimize productivity

Respondent 35	**Local authority Female 56**	**Government official 30 years in the cocoa industry**	**10th June 2021**

1. We've attended the workshops the firm organised and seen what the drones are capable of, but it would be best if we brought them to the district so the farmers could see them for themselves in order to prevent "reported speech." These farmers already believe that public officials are crooked, so when they see the examples in person and hear it directly from the source, they will see and believe that the prospects for employing drones to farm bring numerous benefits. From where I am standing, drones guarantee good harvests while reducing labour expenditures on farms.
2. Drone delivery is quick, which helps with the problems that "cold chain logistics" poses. He asserts that there is no need to be concerned about traffic jams in the sky and that each delivery is often completed in 30 to 40 minutes by the drones, which travel at a speed of 100 km/h.
3. It will increase productivity.

Farmers' Associations (Ghana Cocoa, Coffee and Sheanut Farmers Association) (GCCSFA)

4. Have you heard about drones and seen some being used for any activity?
5. Have your members experienced the use of drones on any farms other than cocoa?
6. During the practical test pilot, what would you say were some of the benefits of using drones for farming?

Respondent 36	**NGO, Male 48 and Female 55**	**Ghana Cocoa, Coffee, and Sheanut Farmers Association (GCCSFA) 31 years in the cocoa industry**	**8th June 2021**

1. We have heard of the drone technology and have visited the farmers and other friends who are involved in vegetable growing. In fact, I led the cocoa farmers on a tour during a pilot of one of the drones on a maize farm, and what we saw with our own eyes was amazing. My members themselves came to tell me that they wish we had this technology, but I was told it would be very expensive for us due to the features associated with a drone for cocoa, especially with the kind of analysis it can perform on seeds and cocoa plants. We have engaged with our members, and they are ready to accept it, if we can have access to it
2. No but they had a test scction
3. Its rapid and accurate

Key Themes within respondents.

- Social Relationships with Stakeholders,
- Benefits Provided by Agencies,
- Stakeholders' Activities, Farmers' and Stakeholders'
- Motivations,
- Traditional Practices,
- Traditional Belief Systems,
- Positive And Negative Attitudes Towards Technology,
- Positive And Negative Attitudes Towards Cocoa Productivity,
- Trust,
- Corruption, And Its Negative Impacts on Cocoa Farming.