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The Impact of Climate Change on Cocoa Production and Adaptation Strategies Adopted by Cocoa Farmers in Amansie West District, Ghana.

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DECLARATION

I, **ISAAC OWUSU**, author of the thesis "**The Impact of Climate Change on Cocoa Production and Adaptation Strategies Adopted by Cocoa Farmers in Amansie West District, Ghana**.", hereby declare that this submission is my work towards the Master of Science (MSc.) Degree in International Environmental Studies. To the best of my knowledge, except where due acknowledgment has been made, it does not contain any material previously submitted by another person or material accepted for the award of any other degree by the University.

DEDICATION

This work is dedicated to my lovely Mother, Mrs. Yaa Akyaa (of blessed memory). Your wish was to see me achieve this success, but it could not happen due to your untimely death. You are gone but will forever remain in my heart.

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ABSTRACT

Climate change is one of the significant environmental challenges affecting the world. The extent of the effect of climate change is present in every country but it is expected to severely affect countries in Africa. The African agrarian economy is heavily reliant on climatic elements such as sunshine, increased temperature, and humidity as such it is expected to suffer the brunt of the effects of the climate change. Climate change is not a future phenomenon as the effects are expected to be present in most countries. In this light, this study seeks to study the impacts of climate change on cocoa production in Ghana and investigate the strategies adopted by cocoa farmers in the Amansie West district, Ghana. To get deeper and varied answers to the research questions, the study employs quantitative techniques to collect and analyze data. The study established that climate change had devastating effects on cocoa production in Africa and Ghana. In the Amansie West district, farmers reported increased sunshine, increasing temperature, and erratic rainfall and this has contributed to low cocoa yields as farmers reported that the cocoa trees wilted, delays in the maturity of the cocoa beans, and the reduction in the quality of the cocoa beans. Although the farmers adopted coping strategies to curb the influence of climatic changes, the results indicate that these coping mechanisms were generally ineffective. The study recommends the intensification of farmers' education on the appropriate means of dealing with the impact of climate variability in cocoa farming.

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LIST OF ABBREVIATIONS

CIAT	Centre for International Tropical Agriculture
COCOBOD	The Ghana Cocoa Board
CODAPEC	Cocoa Disease and Pest Control Programme
ECOWAS	Economic Community of West African States
ERP	Economic Recovery Programme
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GMOs	Genetically Modified Organisms
GIS	Geographic Information System
GSS	Ghana Statistical Service
ICCO	International Cocoa Organization
IPCC	Intergovernmental Panel on Climate Change
ITTA	International Institute of Tropical Agriculture
LAI	Leaf Area Index
LSP	Light Saturation Point
MoFA	Ministry of Food and Agriculture
PWD	Plant Water Demand
SDG	Sustainable Development Goal
SFL	Sustainable Food Lab
SPSS	Statistical Package for Social Sciences
UNCTAD	United Nations Conference on Trade and Development

UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WCF	World Cocoa Foundation

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

A major environmental issue presently affecting the human race is the changing climate across the globe (Datta, 2013). Climate change can be explained as the change in the variability of a climate's characteristics over a protracted time frame. Statistical tests can be used to determine if this change in the climate is the result of internal or external factors as well as anthropogenic activities (IPCC, 2014). Given that the phenomenon tends to influence the productivity of most agricultural crops, including cocoa, the impact of climate change cannot be understated (Kemausuor et al., 2011; Lee et al., 2012). The Intergovernmental Panel on Climate Change's Fifth Assessment Report (IPCC AR5, 2014) has made it abundantly clear that the effects of a changing climate are irrefutable and unparalleled, particularly in the twenty-first century. Research into the causes, effects, and necessity of creating coping or adapting techniques has been sparked by the magnitude of the effect of the changing climate.

The IPCC determined that the cumulative effects of human activity, including the release of greenhouse gases (GHG) into the atmosphere, are having an impact on the planet's climate. This position was established through its successive assessment reports, notably the Fifth Assessment Report (IPCC, 2014). Although many greenhouse gases, including nitrous oxide and methane, are recognized as major greenhouse gases in the atmosphere, the United Nations Framework Convention on Climate Change [UNFCC] (2007) claims that carbon dioxide is one of the most anthropogenically created greenhouse gases that warms the climate. Thus, as a result of the increased emissions of gases into the atmosphere, plant development and yield are impacted because they are vulnerable to changing weather patterns, such as unexpected rainfall and rising temperatures (Onyeneke *et al*., 2021).

According to the IPCC (2014) report Tropical Africa, which is the poorest and experiences the slowest technological improvement, is predicted to experience, particularly severe climate change. Although all economic sectors on the continent are impacted by climate change, agriculture is especially susceptible since it depends on other climatic factors including sunshine, relative humidity, and temperature (Müller-Kuckelberg, 2012; IPCC, 2014). Similarly, Schlenker & Lobell (2010) posit that Sub-Saharan Africa's agricultural industry and farmers' associated livelihoods will be particularly affected by climate change. Thus, a developing nation like Ghana, which experiences the slowest technical advancement and depends primarily on rainfall for its domestic agriculture, is predicted to have particularly severe effects from climate change (Barrios, Ouattara & Strobl, 2008; Dulal et al., 2010).

Cocoa is one of the major crops which are highly sensitive to changes in climatic conditions (Agbongiarhuoyi et al., 2013). Due to their enduring effects on a variety of socio-economic sectors (such as agriculture), including human comfort, rainfall and temperature are the most significant climate elements that are most investigated in climate research (Sayemuzzaman & Jha, 2014). As a result, rainfall and temperature have become important variables that can affect agricultural crops both directly and indirectly. Temperature rise, and unpredictable rainfall patterns, according to Datta (2013), are two key factors that have impacted the growth of crops like cocoa. Anim-Kwapong & Frimpong (2004) advance that temperatures between 18°C and 21°C at the minimum and 30°C to 32°C at the maximum are ideal for cocoa growth. Equally, for adequate cocoa output or yield, it is also necessary to have an annual rainfall between 1,100 and 3,000 mm, with a dry season that lasts no longer than three months and a minimum rainfall level of about 100 mm per month. Therefore, variations in temperature and rainfall beyond the required threshold (above the minimum and below the maximum means and averages respectively) may affect the cocoa yield. Data from the Ghana Meteorological Agency on the variation in Ghana’s climate between 1960 and 2000 show a significant decrease in rainfall and an increase in temperature in all agro-cultivating areas across the country, including the study area: Amansie West District (Boon & Ahenkan, 2011). This poses a serious threat to Ghana’s cocoa industry and livelihoods from cocoa production.

Cocoa is an essential crop for the economics of the growing countries as well as the consuming countries. It is a key agricultural export for West African countries such as Côte d'Ivoire, Ghana, and Nigeria as they earn foreign exchange from the sale of cocoa. Seventy percent of the world's total cocoa production is accounted for by the West African subregion (ECOWAS, 2007). According to UNCTAD (2009), Côte d'Ivoire alone holds 40% of the global cocoa market share, accounting for an average of 1.2 million tonnes annually. Ghana and Nigeria hold 20.98% and 6.70% of the cocoa market share, respectively (Asante-Poku & Angelucci, 2013; Ofori-Boateng & Insah, 2014). Due to the volume of cocoa produced and the availability of high-quality bulk cocoa, West African countries play an integral part in the cocoa industry.

As a significant contributor to Ghana’s economic growth and development, agriculture produces fifty-five percent of the country’s foreign exchange profits as well as accounting for forty percent of the country’s GDP. In Ghana, the socioeconomic status of farmers and the country at large is significantly influenced by cocoa. The cocoa business makes a considerable contribution to the development of roads, health, education, and foreign exchange. In 2002, an estimated twenty-two percent of Ghana’s total foreign exchange earnings came from the sale of cocoa (Parry, 2015). Nearly 60% of the nation’s agricultural workforce is employed in the cocoa subsector alone, and many farmers in cocoa growing regions like the Amansie West District rely primarily on this industry for their income (Asuming-Brempong et al., 2006). According to Tawiah (2015), an evaluation of the poverty levels of the households of cocoa farmers between the 1990s and 2005 indicates that the poverty levels decreased from sixty percent in the 1990s to twenty-four percent in 2005. This was primarily attributed to the favourable cocoa prices, higher yields, and increasing yields. Asante-Poku & Angelucci (2013) contend, that Ghana is the world's second-largest exporter of cocoa after Cote D'Ivoire as in 2010/2011 cocoa exports totalled 1,004,000 metric tons.

1.2 Problem statement

The significance of cocoa exports to the Ghanaian economy cannot be understated as the cash crop coupled with gold mining were the basis of the country's economy (Moss and Young, 2009). The Ghanaian government intends to boost cocoa production to make Ghana the number one cocoa-producing country in the world. This goal is in jeopardy of not being realized as the consequences of climate change have started manifesting in the agricultural activities in Sub-Saharan Africa (Kotir, 2011; Blanc, 2012). Interestingly, Mendelssohn et al., (2000) posit that climate change has varying influences on agrarian activities for each temperate zone. Countries in temperate and polar areas tend to have some economic advantage, an increase in warming will have a positive effect on their agriculture, whiles countries in the tropical and sub-tropical regions (including Ghana) will be disadvantaged because an increase in warming will affect their minimal water balance which will have a negative impact on their agricultural sector.

The changes in the climatic elements can have devastating consequences on cocoa production. These consequences include poor cocoa yield, post-harvest losses, and increased presence of cocoa pests and pathogens among others. These consequences are not limited to cocoa production alone, there are trickle-down effects on the socio-economic status of the farmers. The decreased cocoa production will affect the farmers' livelihood as the poor cocoa yield translates into low revenue generated from the cocoa sales. Persistent poor cocoa yield will affect the production of cocoa products and ultimately affect the foreign exchange Ghana gets from the cash crop. Despite the importance of climate change to cocoa production, there is limited attention on how climate change affects the cocoa sector, especially in the Amansie West District. Given the importance of cocoa production to the country, it is imperative that this influence is explored to appreciate the problem of climate change and highlight possible mitigation strategies to address the problem. This would guarantee that the livelihood of cocoa producers and their families will be sustainable, and the country in general through the foreign exchange generated by exporting cocoa.

1.3 Purpose of the study

The study's main purpose was to study the impacts of climate change on cocoa production in Ghana and investigate the adaptation strategies adopted by cocoa farmers in the Amansie West district, Ghana.

1.4 Research Objectives

The objectives of the study were to:

1) To review and analyze existing data on the impact of climate change on cocoa production in Africa in general, and Ghana in particular.
2) To investigate the impacts of climate change on cocoa production in the Amansie West district.
3) To establish the perception of cocoa farmers in the Amansie West district on the impacts of climate change on cocoa productivity.

4) To examine the strategies that have been adopted by cocoa farmers in the Amansie West district.

1.5 Research Questions

The following questions guided the study:

1) What are the existing data on the impact of climate change on cocoa production in Africa in general, and Ghana in particular?
2) What are the impacts of climate change on cocoa production in the Amansie West district?
3) How do cocoa farmers in the Amansie West district perceive the impact of climate change on cocoa productivity?
4) What adaptation strategies have been adopted by the cocoa farmers in the Amansie West district?

1.6 Significance of the study

The results of this study will advance the understanding of how climate change affects agriculture, particularly the production of cocoa. The study will be relevant for effective planning in the cocoa sector. Despite the various governmental policies to increase cocoa yield, there are reports of poor harvests, and this implies an opportunity to improve the cultivation and harvest of more cocoa trees. Understanding the impact of climate variability on cocoa production and the adaptation used by the farmers will help achieve the following:

(i) Aid all parties involved, especially the farmers, in determining how variations in climatic factors: temperature and rainfall affect their cocoa harvests.

(ii) In addition, reveal the various strategies farmers are using on their own to improve their production.

(iii) Finally, the study's findings will also serve as the foundation for appropriate interventions and opportunities for the COCOBOD and other stakeholder institutions to promote the adaptation strategies that were determined to be most crucial and to give farmers additional support in order to lessen their burden and boost their income.

1.7 Organization of the study

The study is structured into five chapters. The first chapter gives the background of the study, the problem statement, the research questions, and objectives as well as the significance of the study. Chapter two presents the conceptual and literature review on the influence of climate change on cocoa production. The next chapter, methodology, describes the study location and highlights the research design employed in carrying out the research. The chapter also details the techniques of data collection and analysis as well as the ethical concerns and the limitations of the study. In Chapter four, the results of the analysis are presented, and discussions are carried out in relation to the objectives. Finally, in Chapter five, the findings and policy recommendations are summarized, as are future research opportunities.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This section details the discussion of existing related studies on cocoa production and climate variability highlighting the conceptualization and review of previous studies. The review begins with the definition and conceptualization of climate change and proceeds to review related literature on the influence of climate on cocoa production in Ghana as well as existing climate adaptation strategies.

2.1 Conceptual Definitions

2.1.1 Climate change and variability

Per IPCC (2014), climate change can be explained as a natural, internal, external, or anthropogenic change in climatic conditions that continues for an extended period of time. Climate and weather are distinguished by the length of the elements. Climate lasts for a longer time than the weather, as a result, when variations last for a prolonged time frame, it can be considered that the climate has altered. Similarly, Arku (2013) advances that climate change can be classified as any alteration in the weather over time usually influenced by natural forces, human action, or both. A close analysis of Arku's (2013) definition demonstrates that there are other causes besides human activity that might contribute to climate change. He also emphasizes how climate change is influenced by a combination of both anthropogenic and natural elements. The causes of temperature change are also attributed in this report to internal natural processes such as variations in star cycles and volcanic eruptions, as well as external processes brought on by phylogenesis (human) changes in the atmosphere’s composition or in land usage. Thus, though knowledge about the natural causes of climate change is limited, the human-caused or anthropogenic factors have been given a lot of attention.

2.1.2 Climate change impact

The term 'impact of climate change' can alternatively be described as the effects of climate change on an individual level such as the effect on people's health and livelihoods as well as a societal level such as the effects on the economies, environmental ecosystems, infrastructure, and delivery of public services due to the interaction between climatic variables like temperature and rainfall occurring at irregular intervals of a particular fundamental quantity and also the vulnerability of a vulnerable society or system to the risk (IPCC,2014).

2.1.3 Climate change adaptation

The IPCC (2014) contends that adaption to climate change is simply responding to the existing or anticipated climate and its effects. This is as natural as it is for the human nature to adapt to reduce injury or take advantage of favourable chances. This involves adopting programs and tactics intended to lessen the susceptibility of the human population and nature to the present or anticipated effects of climate change. Sagun (2009) adds to the definition by explaining that climate adaption is the modification of existing human actions as well as natural resources in reaction to present or anticipated climatic shocks or impacts to avoid harm or enhance benefits.

Contrarily, Fussel & Klein (2002) adopt a different definition of climate adaptation, describing it as any alteration to the original orientation of any structure or institution to mitigate the negative consequences of climate change on that structure or institution. Thus, climate adaptation refers to a structure or institution's capacity to adjust to climate change (including extreme weather events) in order to mitigate potential harm, seize opportunities, or cope with its repercussions. This indicates that people have a wide range of options and chances to adjust to these erratic climatic conditions. This position is congruent with Pinto et al., (2012)' s definition of climate change adaptation, which categorizes them as actions made in response to actual or anticipated erratic climate conditions that have detrimental impacts on people, communities, and the economy.

2.2 Climate Change and Cocoa Production

The production of cocoa flourishes in warm regions due to the suitable temperature and soil types found in these regions such as the West African coasts, Brazil, Indonesia, and other tropical locales. Ivory Coast, Ghana, Nigeria, Cameroon, and Cameroon together collectively produce almost 70% of the world's total cocoa (Schroth et al., 2016).

2.2.1 Cocoa Production and Development in Ghana

Between 1995 and 2014, Ghana's cocoa production saw a steady rise from 300,000 tons to 900,000 tons/per year. The cocoa production in the country was at its peak in the 2016/2017 cocoa season with a total of 969,000 tons (Buxton, 2018). Asante-Poku & Angelucci (2013) posit that the primary reason for the increase in cocoa production is a result of the supportive measures put in place by the state-owned cocoa marketing board COCOBOD. The COCOBOD is an institution charged by the Government of Ghana with the responsibility to supervise the activities of cocoa in the country. The responsibilities of the COCOBOD include agricultural research into cocoa, exportation and internal sale of the cocoa beans, seed hybridization, sale of seeds, provision of agricultural support services to farmers, approval of fertilizers, pesticides, and fungicides, and quality control services. Though there have been fluctuations in the volume of cocoa beans produced in Ghana, the existence of the institution (COCOBOD) overtime has translated into sustainable growth in the cocoa industry when compared with some world-leading producers like the Ivory Coast and Indonesia. Osei (2017) classifies Ghana's cocoa production into four different phases:

1. From 1888 to 1937, characterized by the introduction and expansion of cocoa production.
2. From 1938 to 1964, distinguished by a period of inactivity after which a fleeting but quick rise after the country gained independence.
3. From 1965 to 1982, characterized by a near collapse phase of the cocoa production industry.
4. From 1983 – till date, characterized by the recovery and expansion of the cocoa production industry through the introduction of the Economic Recovery Program (ERP).

The recovery and expansion phase that followed the introduction of the Economic Recovery Programme (ERP) was effective for the following reasons: farmers received compensation for destroying swollen-shoot virus-infected trees and planting new trees in their stead. Many farmers planted the new cocoa varieties developed by the Crop Research Institute and expressed their satisfaction with the high yield from harvest. In addition, Ghanaian farmers have gotten better prices for their cocoa yields than their competitors in nations like the Ivory Coast and Nigeria (Osei, 2017).

Over the past few years, Ghana's cocoa-producing technology has seen a lot of advancements. Kolavalli & Vigneri (2011) advance that the cocoa industry has seen greater fertilizer use, hybrid cocoa variety production, and enhanced pest and disease management methods. Since the 2001–2002 cocoa season, heavier and more frequent fertilizer applications have been made as a result of other government initiatives including the mass spraying of cocoa and HI-TECH subsidy packages. The Cocoa Diseases and Pests Control program (CODAPEC) has encouraged cocoa farmers to boost their harvests through the pest and disease management techniques in order to earn the appropriate price for their cocoa on the global market. Baah et al., (2011) explained that these measures led to a dramatic growth in the volume of cocoa produced beginning from the 2002/2003 cocoa season. However, these government policies are unable to be effectively manifested due to the threat posed by the impact of climate change. Also, Buxton (2018), posits that the hybrid Cocoa variety cultivated by Cocoa farmers requires extensive fertilizer and pesticide application for it to continuously produce higher yields. But most farmers are not able to acquire these fertilizers and pesticides as a result of a lack of capital, hence, they record lower yields. Cycles are inherent in the production of cocoa since it is impacted by natural factors like erosion, disease outbreaks, availability of forest areas, and regional production shifts as well as economic and social reasons like migration (Kolavalli & Vigneri, 2011).

Ghana's highest Cocoa output was recorded in the 2016/2017 season with a total of 969,000 tons (statista.com, 2019). The national output has since been reduced with a total output of 905,000 and 900,000 tons for the 2017/2018 and 2018/2019 seasons respectively. Ghana generates barely 50% of what countries like Cote d'Ivoire and Indonesia produce annually on a national scale. Because a more significant portion of agricultural land in the country is being used for Cocoa production, the national productivity is therefore considered very low. However, the low productivity within the sector has been attributed to several factors including poor farming practices, unfavourable climatic conditions, illegal mining, seasonal bushfires, and pests and diseases invasion and smuggling of Cocoa beans. Osei (2017) posits that the root cause of these factors is climate change and variability, especially rainfall and temperature.

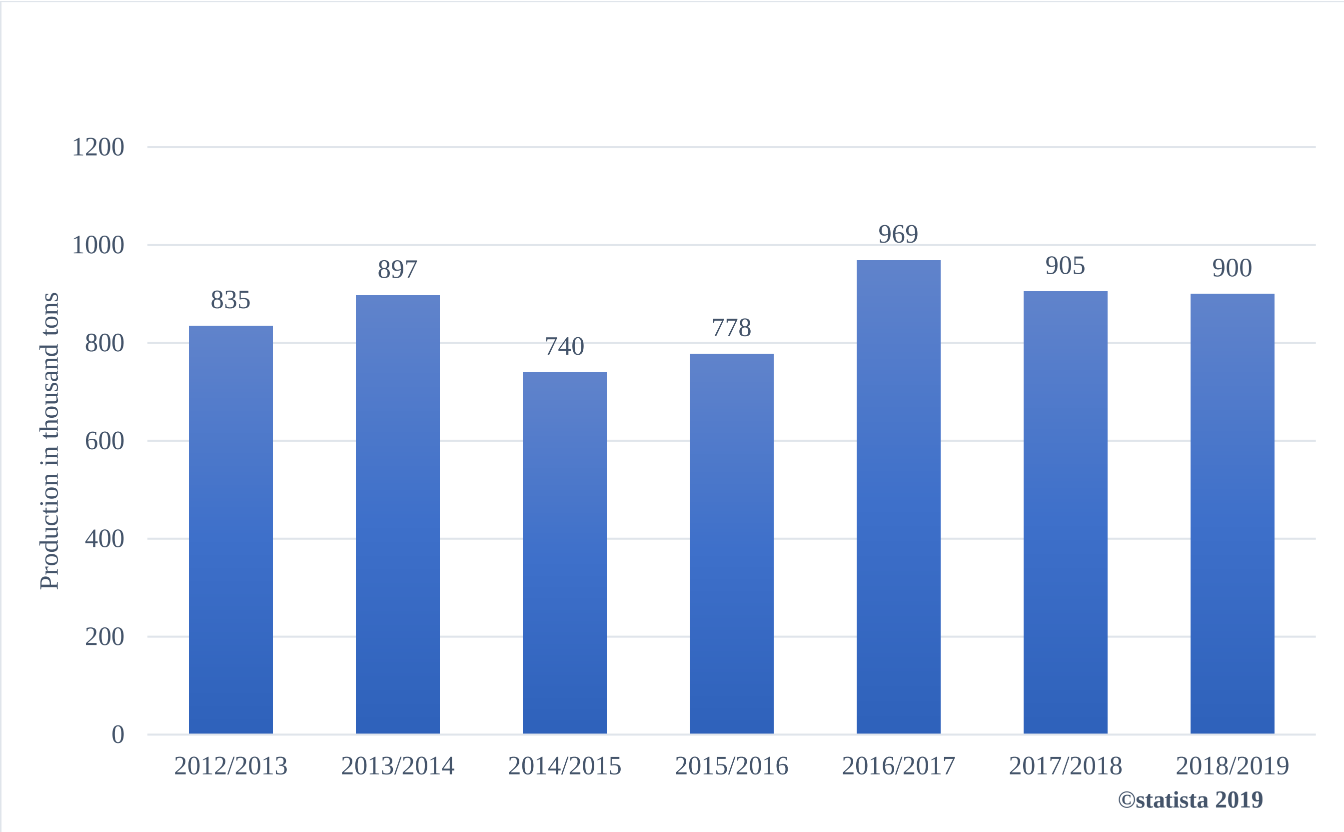


Figure 1: Volume of production of Cocoa beans in Ghana (in 1,000 tons)
Source: Statista.com (2019)

2.2.2 Factors affecting cocoa production in Ghana

It is impossible to overestimate the importance of cocoa to Ghana's economy. Because of its contributions to the overall GDP and position as the top agrarian product concerning foreign exchange earnings, the cocoa subsector is of major interest to policymakers. Amoah (2013) observes that, with the exception of the mid-1980s and early 1990s, there have been fluctuations in the country's cocoa output levels. Though output increased slightly in 2000, there were several inconsistencies. In the following sections, we will look at the factors that have contributed to these inconsistencies.

2.2.2.1 Farmers' financial situation and the cost of buying cocoa

The ability and desire of Ghanaian cocoa farmers to make investments in their cocoa farms in response to high world prices depend on their income levels. Due to their low wages and the fact that the bulk of their trees are getting older, cocoa farmers find it increasingly challenging to pay for labour, frequent spraying, fertilizers, and other expenses. According to Buxton (2018), the international market determines the price paid for Ghana's cocoa. As a result, Ghana enters the global cocoa market as a price taker. As a result, global cocoa supply and price conditions have a greater impact on Ghana's cocoa industry. Cocoa supply is mostly dependent on producer price even with limited immediate cultivation capabilities, weather conditions can still alter the volume of yields to be realized. Cocoa farmers have an incentive to enhance their output through good husbandry methods when the price of cocoa beans rises. For instance, fertilizers are utilized to promote good yields in expectation of a favourable buying price if credit is available. The same conditions allow for the hiring of labourers to weed the cocoa farms.

Cocoa producer prices affect Ghanaian productivity as farmers modify the amount of care they provide their farms in reaction to fluctuations in prices. In instances where there are low prices to meet regular farm maintenance costs, farmers will stop new planting and cut farm maintenance. Therefore, if prices are low, harvesting will be reduced. Similar to this, in situations where the cost increase or exceed expenses, farmers will improve the administration of their farms, resulting in more harvesting (Anim-Kwapong &Frimpong, 2004).

2.2.2.2 Climatic factors

Climate is one of the major determinants of Cocoa production from cultivation to post-harvest. This session details the major climatic elements which have significant effects on Cocoa production.

Rainfall

Due to its vulnerability to drought, cocoa is greatly influenced by the distribution of rainfall. The amount of cocoa produced is significantly correlated with unpredictable pre-harvest rainfall. A high rainfall year in Ghana is found to translate into high crop yield, albeit this is not always the case (Buxton, 2018). Similarly, Wiah (2017) discovered that rainfall correlated positively and negatively with crop yield in Ghana during particular months. Ghana's cocoa is affected by numerous variables, including the soil characteristics (structure and quality), shading available in the farm, air circulation, volume and distribution of active roots, root depth as well as the age and strength of the cocoa trees (Nair, 2021). Buxton (2018) advances that the pace at which the soil releases its available water to the tree is more significant than the total amount of soil moisture when determining whether the soil is suitable for cocoa production.

Temperature

As a tropical crop, cocoa must be grown in conditions with mean maximum temperatures of 30–32 degrees Celsius, mean minimum temperatures of 18–21 degrees Celsius, and absolute minimum temperatures of 10 degrees Celsius (Parry, 2015). The relationship between temperature and light consumption efficiency has been established, with temperatures below 24 degrees having a negative impact on the rate of light-saturated photosynthesis (Anim-Kwapong & Frimpong, 2004). Temperatures below 10 degrees lead to an extreme halt in the process of photosynthesis. The stomata of cold leaves never open in contrast to warm plants. In other words, stomatal resistance is influenced by leaf temperature, with greater temperatures reducing resistance. However, the effect of temperature may be negated because rising temperatures are typically accompanied by increasing vapor pressure deficits (Buxton, 2018). Flushing has been seen in

Ghana to occur during a time of high temperatures (when the maximum and minimum temperatures vary the most).

Solar Radiation

According to Woittiez et al. (2017), crop cultivation and production are typically reliant on the full amount of solar energy collected throughout the growing season where elements like temperature, water, and soil nutrients, and destruction of crops from pests and diseases can be controlled. According to experiments conducted in West Africa, reducing permanent shade (which blocks 30–50 percent of incident radiation) can increase prospective cocoa yields by double when fertilizers are used (Anim-Kwapong & Frimpong, 2004). In other words, the amount of sunlight received by a cocoa tree will determine its growth and output (Ojo & Sadiq, 2010). Cocoa's maximal photosynthetic rate at light saturation is just 7 mg dm-1 h-1 and it has a low light saturation point (LSP) of 400 E m-2 s-1 (Hutcheon, 1981 cited in Buxton, 2018). If cocoa is exposed to intense sunshine levels above 60%, its rate of photosynthetic growth decreases. While continued exposure to sunshine in cocoa impacts the leaves' capacity for photosynthetic activity, low light exposure intensities prevent the growth of flowers. The production of cocoa will be significantly depressed by these two processes (Challinor & Wheeler, 2007).

Genetic Factors

The existence of good varieties is a primary component of the sustained cultivation of any crop. However, it has been determined that only about thirty percent of the total cocoa cultivation area is made with the approved cocoa varieties (Fowler & Coutel, 2017). These varieties are primarily bi-parental crosses (hybrids) of native and introduced types. The majority of non-selected cultivated Cocoa varieties are native breeds; Amelonado Trinitario and F3 Amazon as well as open-pollinated populations descended from selected hybrid varieties. In the last 25 years, the majority of high-yielding Cocoa varieties with effective disease resistance have been discovered. In other crops, genetic modification has been used to benefit both farmers and consumers.

Nearly ninety-four percent of farmers in the Amansie West District, according to Osei (2017), have embraced the usage of enhanced cocoa types like the hybrid “Abrewa bedi”. This is due to the fact that hybrid cocoa varieties mature faster, usually in three to four years, as opposed to Amazonia varieties, which take five to six years. In the view of Aneani & Ofori-Frimpong (2013), hybrid varieties are high-yielding and produce cocoa pods all year. Furthermore, unlike the Amazonia, which is highly susceptible to excessive sunlight and diseases, the hybrid cocoa variety is resistant to both climate (sunlight) and disease, allowing for a higher yield with little or no shade. Similarly, Buxton (2018) discovered that farmers had adopted a new hybrid cocoa variety called “akokra bedibi”, which most farmers were using, though some were still using the old variety. Forty percent of the farmers have reported changing the type of cocoa they cultivate.

Of the 179 farmers, 162 (91%) said that a change in the climate was to blame for their decision to alter the type of cocoa they grew. The improved varieties will produce a higher yield, allowing cocoa farmers to earn enough money from the sale of their crops to improve their livelihood while mitigating the influence of climate change. The majority of current applications of hybrids are only concerned with fixing agricultural genetic defects that are regulated by one or a few gene-based genetic flaws such as vulnerability to pests, diseases, or stress conditions. Given this, a successful genetic transformation system is required for Cocoa’s long-term breeding prospects. However, any such study must be done in conjunction with suitable investigations into how genetically modified organisms (GMOs) affect the environment, considering farmers’ comments (Buxton, 2018).

Land Tenure Systems

Bugri (2008) explains land tenure as the acquisition of farming land and access to land resources. Given that most production gains come from the expansion of the cocoa area, it can be claimed that access to land has had an effect on the cocoa industry. Ghanaian migrant cocoa producers can buy land in one of three ways. These are gifts, outright purchases, and sharecropping (the "abunu" and "abusa" systems). The "abunu" system divides the output into two parts and distributes it equally between the owner of the land and the farmer. The "abusa", on the other hand, is where the yield is divided into three parts, with the farmers taking two and the landowner taking one, depending on their agreements.

There is little question that increased investment in the cocoa industry would be encouraged by the security of land tenure. Operating in locations more beneficial to the cocoa plant will be important at a time when some traditional cocoa-growing regions are anticipated to be sensitive to the impacts of climate change (Buxton, 2018; Osei, 2017). Even in likely new areas, unfavourable land tenure issues will have an impact on cocoa farmers' activities, and thus the cocoa sector. If cocoa is to continue serving as one of the main pillars of the Ghanaian economy, concerns linked to land acquisition and all other issues related to land acquisition in the cocoa sector in Ghana must be addressed with the seriousness the issues require.

Pests and Diseases

Another crucial aspect to consider is how illnesses and pests affect cocoa yields. Production of cocoa is impacted by rodent infections, fungal, viral, and viral diseases as well as pests and diseases brought on by different insect species. The prevalence of pests and illnesses has an adverse effect on economic value and production goals (Kumi & Daymond 2015). According to the authors, the five main diseases that threaten cocoa are Cocoa Swollen Shoot Virus; Witches

Broom; Black pod (Phytophthora pod); Vascular-Streak Dieback; and Moniliasis pod rot. According to Kongor et al. (2018), the black pod disease is the most hazardous of all the ailments that harm developing or ripening cocoa pods worldwide. Equally, insects and pests that threaten cocoa trees include the red borer (Zeuzera coffeae); Cockchafer Beetle (Leucopholis spp.); Mealy Bugs (Planococcus lilacinus); and Mirid. Striped Squirrels (Funambulus tristriatus), a non-insect pest, also pose a threat to cocoa trees.

The two main Phytophthora species that cause Cocoa disease in Ghana, according to Parry (2015), are ‘P. megakarya and Phytophthora palmivora’. Parry (2015) claims that sucking insects called capsid pests (Miridae) harm the developing stems of the cocoa tree by puncturing the young shoots with their mouthparts, adding deadly saliva, and then sucking liquid sustenance out of the wound resulting in the death of the impacted shoots. In addition, Mistletoe, a parasitic shrub that grows on cocoa plants, is a component of sucking insects that affect cocoa trees (Oppong, 2017). The cocoa trees with the young branches are harmed if they are not quickly removed. To stop mistletoe from affecting the other parts of the tree, mistletoe-infested regions of the tree are totally removed.

Smuggling of Cocoa and government policies

The smuggling of Cocoa from Ghana to nearby countries especially Cote D’Ivoire has been a major setback to the Ghanaian Cocoa sector. This is because smuggling is capable of rendering projections of cocoa beans production inaccurate. Aneani & Ofori-Frimpong (2013) contend that rather than improvements in the Ghana cocoa supply chain, the present rise in Ghana cocoa exports is the result of the elimination of pricing incentives to smuggle Ghana cocoa to Cote D'Ivoire. The Ghana Cocoa Board claims that 5–10% of Ghana's harvested cocoa was illegally exported to Côte d'Ivoire (COCOBOD, 2007). As a result, the Ghanaian government has implemented anti-smuggling policies over the years.

Among these initiatives are an increase in farmers' prices, an active initiative to control pests and diseases, payments of bonuses, a high-tech program, and replanting of denuded areas, all of which will allow the agrarian sector to meaningfully contribute to the growth and development of the country with an increased share in GDP through the sale of cocoa products for foreign exchange earnings as well as the creation of job opportunities and subsequent alleviation of poverty levels (Naminse, Fosu, & Nongyenge, 2011). Ghana has recently emerged as a significant cocoa exporter and this can be attributed to the implementation of a price stabilization system; fertilizer credits; increased producer prices; partial internal marketing liberalization; the privatization of input distribution; government-sponsored rehabilitation programs, advancements in farming extension systems as well as mass spraying programs (ICCO, 2007).

2.2.3 Effects of Climate Change on Ghana's Cocoa Cultivation

Climatic conditions including temperature, sunshine, rainfall, and humidity have all been identified as having an interconnected impact on Cocoa growth and production in Ghana (Owoeye & Sekumade, 2016). However, temperature and rainfall are the determinants of Cocoa growth and production (Afrane & Ntiamoah). For instance, Hutchins et al., (2015), in their study found that the respondents mentioned changes the in the rainfall pattern and temperature as the main challenges they are experiencing as cocoa farmers. Changes/variability in these climatic elements, especially long periods of drought have a greater consequence on Cocoa production. This is because, whiles Cocoa seedlings cannot flourish during prolonged drought, it also becomes extremely difficult to establish new Cocoa farms (Hutchins et al., 2015). Equally, prolonged drought has also been established to contribute to a reduction in the leaf area index (LAI) which in turn results in a decline in cocoa yield (Adjei-Nsiah & Kermah, 2012).

Temperature fluctuations have a variety of effects on cocoa crops, including changing the crop flowering period, which results in fewer seeds and increased evapotranspiration (Challinor &Wheeler, 2007). According to Schroth et al. (2016), increases plant water demand (PWD), which stresses the cocoa crop during drought conditions, particularly during the dry seasons. Changing climate and variability have an impact on the cycles and levels of development of cocoa pests and diseases. They also have an impact on host resistance as well as the physiology of host-pathogen or pest interactions (Oyekale, 2015). These have a negative impact on cocoa yields and harvest losses, as well as on socioeconomic conditions such as the earned income of the farmer, the farmer's decision-making ability, the ability to sell the cocoa, and, most importantly, the livelihoods of the farmers (Ojo & Sadiq, 2010).

Again, variability in climatic elements (rainfall and temperature) impacts the drying and processing of the harvested cocoa beans. Though increased rainfall is very necessary for higher productivity, Oyekale (2015), argued that excessive rainfall and longer periods of wet season slow Cocoa processing, which diminishes the quality of the cocoa beans with a resultant surge in the processing costs. However, heat from the sun after the harvest of cocoa pods aids in drying the cocoa beans. The water content in the seeds is reduced by the heat, making them easier to process. This raises the value of the cocoa beans while decreasing processing costs. This suggests that timely and moderate rainfall distribution is necessary for the efficient harvesting and processing of cocoa. This is so because cocoa is so susceptible to harsh weather conditions. Additionally, Oyekale (2015) opines that cocoa growers frequently alter the usual times they spray cocoa pods to offer maximum protection due to the unpredictable nature of rainfall patterns.

2.3 Adaption strategies used to address climate change in farming

The concept of climate change adaptation has been defined or explained in various ways by different Scholars. The IPCC (2014) contends that adaption to climate change is simply responding to the existing or anticipated climate and its effects. According to Codjoe et al. (2013), adaptation also entails improving adaptive capability and implementing strategies to mitigate the experience of the unpredictability and extremes of climatic conditions. Similarly, Berhe (2016) described adaptation as any reactionary actions to a new set of circumstances, whether purposefully or accidentally, to respond to specific threats to the wellbeing of people posed by the unpredictable climatic conditions. Adaptation is utilized to lower a person's degree of susceptibility while enhancing their adaptive capability.

Berhe (2016) claims that a number of elements, including the availability of alternative livelihood options, both indigenous and contemporary institutions, and available resources all have a substantial impact on adaptation. This is to allow farmers to adjust to climate change as their decisions about how to allocate resources are influenced by the resource available at their disposal, and the social environment. To be effective, however, different measures must be implemented in different areas based on their specific needs. That is, it must consider people's beliefs about climate change, their understanding of the variations in climatic conditions, and their understanding of current and future technology (Kurukulasuriya & Rosenthal, 2003).

2.3.1 Forms Adaptation Strategies used in Cocoa Production

Adaptation measures employed in Cocoa production can be categorized into macro-adaptation and micro-adaptation based on the decisions and the implementation bodies (Osei, 2017). The national level of macro-adaptation measures involves farmers' decision-making. That is, it considers agricultural production at both regional and national levels, as well as its interactions with domestic and international policies. Macro-adaptation policies used in Ghana include establishing a price stabilization system; partially liberalizing; raising producer prices; internal marketing; privatizing input distribution; mass spraying campaigns; strengthening extension networks, fertilizer credits; and government-backed rehabilitation programs. (ICCO, 2007). On the other hand, judgments made using micro-adaptation strategies are made purely for the advantage of the farmer. They are referred to as individual adaptation measures with farmers primarily motivated by their own interest and the fundamental goal of maximizing agricultural income. The following are the major micro-adaptation strategies used in Ghanaian cocoa production:

2.3.1.1 Growing of shade plants and trees

Osei (2017) advances that farmers introduce shading to protect the seedlings. By growing shade trees like plantains, farmers are able to provide a protective cover for their new cocoa field and shade their cocoa seedlings from too much sunlight. These plantains are planted a year before the cocoa seedlings are introduced onto the farms. Up until the cocoa bears fruit, plantains feed the family and supplement their income. Contrarily, illegal mining and chainsaw use discourage the complete and effective use of this method because they commonly ruin cocoa fields by removing these shade trees.

2.3.1.2 The use of improved varieties

One of the adaptation strategies utilized by cocoa farmers in Ghana is the use of enhanced varieties of cocoa or seed hybridization. To create the hybrid variety of cocoa produced by the majority of cocoa farmers today, the Cocoa Research Institute of Ghana, for instance, began hybridizing cocoa seeds in 1984 (Kolavalli & Vigneri, 2011). This is because the new varieties are more sun tolerant, can withstand pest and disease attacks, mature in advance, and produce greater yields than the previously cultivated Amelonado and Amazonia types. For example, Buxton (2018) discovered that farmers had adopted a new hybrid cocoa variety called 'akokra bedibi,' which most farmers were using, though some were still using the old variety. Around 40% of farmers have switched to a different type of cocoa. A hundred and sixty-two of the farmers representing ninety-one percent of the total one hundred and seventy-nine farmers confirmed that climate change accounted for their decision to grow a different cocoa variety. According to Osei (2017), the “abrewa bedi” cocoa variety was the popular hybrid of choice for most farmers in the district as this hybrid matures at a faster rate than the Amazonia varieties, which take 5 to 6 years.

2.3.1.3 Fertilizer application

According to Kolavalli & Vigneri (2011), cocoa fields from the nation’s major cocoa-producing districts show a remarkable increase in fertilizer use over the 1990s, with applications rising from 9 percent in 1991 to 47 percent in 2003. This is due, in part, to the cultivation of new and improved cocoa varieties, which necessitate the use of a large amount of fertilizer and other chemicals in order to achieve maximum productivity. Even though the use of chemical fertilizers has skyrocketed and continues to skyrocket, Cudjoe et al. (2013) argued that a significant number of cocoa farmers are interested in using non-fertilizer strategies such as mulching to improve soil fertility because they are less expensive. Buxton (2018) found that 357 farmers (or 80%) of those surveyed claimed they utilized fertilizer in their fields, with 356 farmers employing inorganic fertilizer, with only one farmer using chicken droppings as organic fertilizer.

2.3.1.4 Regular spraying

Another important micro-adaptive measure that has been used by cocoa farmers in Ghana is regular spraying of their Cocoa farms. Farmers have adopted the use of pesticides and fungicides to spray their Cocoa farms to prevent the attack from diseases and pests such as the deadly black pod. Studies by Osei (2017) and Buxton (2018) across the major Cocoa growing areas in the country revealed that most farmers are into this adaptation strategy. This is because farms growing hybrid Cocoa varieties must spray frequently. It was discovered that cocoa farmers on average, sprayed their farms four (4) times during the growing season (August, September, October, and December), but due to climate change, they occasionally apply fertilizers six more times per year on their cocoa farms. Spraying assists in dealing with the effects of diseases and reduces the invasion of pests caused by climatic changes, thereby increasing cocoa production.

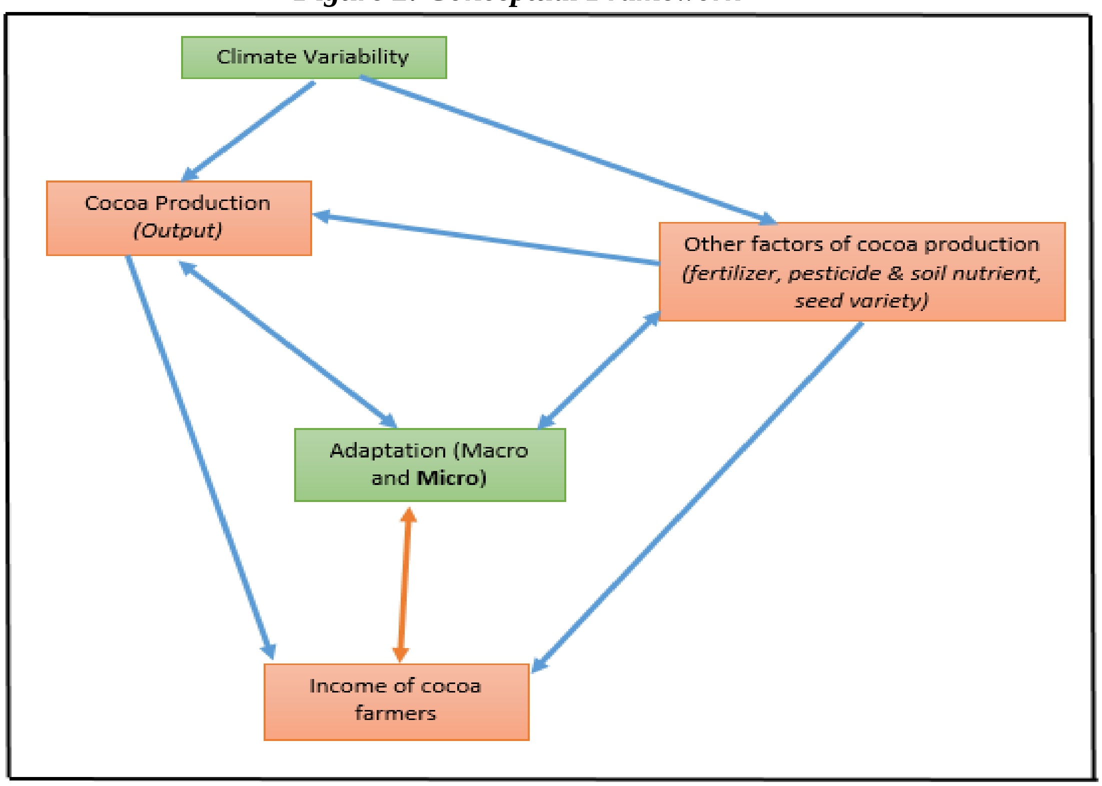
Though these strategies adopted by the farmers help in minimizing the influence of the changing climatic conditions on cocoa farming, a major constraint to this is the unavailability of financial resources. As farmers adapt and cultivate the hybrid varieties of Cocoa, they have to increase fertilizers and pesticides application as well, since the varieties require them to thrive. For instance, Osei (2017) that, about 73% said they would adopt this adaptation to the use of fertilizers and regular spraying if they had enough money.

2.4 Conceptual Framework: Impact of Climate Variability, Cocoa cultivation, other factors of Cocoa Production, Adaptation Measures, and Farm Income.

The diagram (Fig 2) shows that climate change is a significant but unavoidable influence on cocoa production. It affects the development of cocoa pods, insects, and pathogens, resulting in a decrease in yield and eventually affecting farmers' income (Agbongiarhuoyi et al., 2013). Variations in temperature as well as unpredictable rainfall patterns have directly impacted the development of the cocoa tree and fruits (Challinor & Wheeler, 2007). The excessive temperature during the flowering stage of the Cocoa leads to a reduction in the number of seeds. Factors such as fertilizer and pesticide application, soil moisture and nutrient, seed varieties, and farming methods are indirectly affected by the changes in climatic variables. All these are shown to influence the total output.

As a result of potential reductions in cocoa yield due to changes in climatic elements, cocoa farmers implement initiatives to help them address the growing influence of climate change on their cocoa outputs. These adaptation measures have an impact on the quantity and use of other cocoa production factors. These include using pesticides to lessen the prevalence of black pod or capsid, the spread of new diseases; adding additional fertilizer to the soil to boost its nutrients planting as well as using improved cocoa varieties. The majority of these adaptation measures are designed to improve other aspects of production. Fertilizer application, cultivation of improved varieties, and regular spraying are examples of micro-adaptation strategies used by farmers. Government-backed rehabilitation programs; increased producer prices; the implementation of a price stabilization system; partial internal marketing liberalization; privatization of input distribution; mass spraying programs, fertilizer credits, and enhanced extension systems are just a few of the government-provided adaptation measures (ICCO, 2007).

Figure 2: Conceptual Framework



Source: Adopted from Osei, (2017).

Therefore, the farmer's capacity to adjust well to the climatic variations depends on his/her level of income, because fertilizers, pesticides, and purchasing of improved seeds require money or capital. The total amount of money or income the farmers receive from their cocoa farms is influenced by the volume of crop harvested as well as the costs involved in the techniques employed to address the influence of the climatic conditions on their cocoa yield. This implies that, when the adaptation strategies employed by the farmer become successful, he/she will record higher yields, which will result in the farmer receiving more money from the cocoa sales. Given this, the cocoa farmer will continue employing such adaptation strategies. On the contrary, the farmer will incur losses as a result of low yield when the adaptation strategies are not successful. Therefore, the farmer will stop using such adaptation strategies.

Little research has been done on the impact of climate change or variability on cocoa cultivation in the Amansie West District in Ghana's Ashanti Region. This is despite the global statistics on the impact of climate change on cocoa production. Although other researchers have conducted some studies on cocoa production, none have examined the relationship between climate change and cocoa production. Adjei (2017), for example, conducted a study in the Amansie West District focusing on the effects of illegal mining (galamsey) on cocoa cultivation and the livelihood of cocoa farmers. Similarly, Quaye et al. (2015) investigated the current land tenure arrangements in Ghana in the Amansie West District as an incentive to adopt environmentally sustainable cocoa production practices. Given this, this research intends to fill this lacuna by evaluating how climate change and variability affect cocoa output and adaptation tactics in Amansie West District. This is because the cocoa output is significantly influenced by climate change and provides a significant portion of the revenue for cocoa farmers and their families.

CHAPTER THREE

METHODOLOGY

3.0 Philosophical Foundation

Table 1; Shows the research objectives, key theoretical perspective used, methodology, and key references.

Research Objectives	**Key THEORY/Philosophical foundation used (Main theoretical perspectives)**	**Methodology**	**Key reference**
1. To review and analyze existing data on the impact of climate change on cocoa production in Africa in general, and Ghana in particular.	Natural factors/climatic factors Anthropogenic/ human factors	Literature review. Content analysis WordCloud	Arku (2013) IPCC (2014)
2. To investigate the impacts of climate change on cocoa production in the Amansie West district.	Natural/Climatic factors Rainfall Temperature Solar Radiation	Literature review. Quantitative: data collected using surveys and analyzed using SPSS	Buxton (2018) Challinor & Wheeler (2007) Owoeye & Sekumade (2016) Woittiez et al., (2017) Anim-Kwapong & Frimpong, 2004
3. To find the perception of cocoa farmers in the Amansie West district on the impacts of climate change on cocoa yields.	Drought and Leaf Area Index (LAI). Evapotranspiration and Plant Water Demand (PWD.)	Literature review. Quantitative data collection (Questionnaire).	Oyekale (2015) Ojo & Sadiq (2010). Schroth *et al., (*2016), Challinor &Wheeler (2007).

Research Objectives	Key THEORY/Philosophical foundation used (Main theoretical perspectives)	Methodology	Key reference
	Physiology of host-pathogen or pest interaction. Harvest losses.	SPSS for analyzing the data	Adjei-Nsiah &Kermah (2012). Hutchins *et al.,* (2015),
4. To examine the adaptation strategies employed by cocoa farmers in the Amansie West district.	Macro-adaptation Micro-adaptation	Literature review. Quantitative data collection (Questionnaire). SPSS for analyzing the questionnaire.	Osei (2017) Kolavalli & Vigneri (2011) Buxton (2018) Codjoe *et al.,* (2013) ICCO (2007)

3.1 Description of the Study Area.

The Amansie West District Assembly is part of the forty-three MMDAs in the Ashanti Region, including the (Ghana statistical service, 2021). Legislative Instrument (L. I.) 1403, which was passed in 1988, created the district as part of Ghana's decentralization initiative to bring government to the people's homes. The district, with Manso Nkwanta as its capital, was created in 1988 from the former Amansie District. Ahwerewa; Pakyi Nos. 1 and 2; Datano; Antoakrom; Agroyesum; Apono; Moseaso; Aponoapono; Watreso; Nipankyeremia; Manso Adobea; Ankam; Esuowin; Keniago; Esaase; Odaho; Datano Abore; and Kumpese, are a few of the bigger communities. The district makes up about 5% of the Ashanti Region's total land area, covering an equal land area of 1,364 sq. kilometers.

The district is home to 109,416 residents, catering for about three percent of the total population in the Ashanti Region. There are 56,048 males and 53,368 females in the district (Ghana statistical service, 2021). The district is bordered by Amansie Central, Obuasi Municipal, and Bekwai Municipal, on the east; by Atwima Mponuah and Atwima Nwabiagya on the west; Atwima Kwanwoma as well as Upper Denkyira and Bibiani on the north and the south respectively.

Figure 3: Map of the Amansie West District Source

Ghana Statistical Service, GIS (2014)

The district's climate is classified as Wet Semi-Equatorial (MoFA & AWDADU, 2010). It has a two-season rainfall regime: a heavy rainy season and a minor rainy season. The minor season falls between the period of September to November whilst the heavy rains are reported from the period of March to July. The average yearly rainfall is between 855 and 1,500 millimeters. The annual average number of wet days is between 110 and 120. The weather is normally dry from

December to March, with rising temperatures, early morning mist/fog, and cold temperatures. Temperatures are normally hot throughout the year, with a mean monthly temperature of around 27°C (Amansie-West District Assembly Profile, 2010).

The people of Amansie West District are predominately farmers specifically, crop production. That is, about 99% of the farmers are involved in crop farming (GSS, 2014). Maize, plantain, cassava, yam, and cocoyam are the popular staple crops that are cultivated. Other popular crops are garden eggs and tomatoes. The Amansie West District ranks third as the principal cocoa growing area in Ghana (MoFA, 2010).

3.2 Research Design

Bryman (2012) postulates that research design is the process of gathering and analysing data. Because the Amansie West District of Ghana is the study area for this research, a case study design was employed in answering the research questions. The goal of using this research design was to subject cocoa farmers to a thorough examination and gain access to their knowledge on the perceived impact of climate change on cocoa cultivation in the Amansie West District. According to Yin (2013), a case study design is appropriate when research topics necessitate an exhaustive and "in-depth" examination of a social phenomenon. Furthermore, this study was conducted using quantitative data collection and analysis techniques.

3.3 Sampling Technique and sample size

A population is essentially a larger collection of research units targeted for a particular study (Bryman, 2012). According to Bryman (2012), sampling denotes the procedure of selecting a representative set of cases from a much larger set. Since it is practically impossible to interview all the Cocoa farmers in the community, respondents would be carefully sampled for the survey. The targeted population for the study were cocoa farmers in the Amansie West District. The stratified sampling technique would be used for the respondents from the target population. Creswell (2014) asserts that the use of stratified sampling ensures that the sample appropriately depicts the percentage of the population that has individuals with various characteristics. Thus, the study had a sample of 100 farmers.

3.4 Sources of data

Data for this study was sourced from primary and secondary. The primary data were sourced from the cocoa farmers through structured questionnaires whilst the secondary data for the study were sourced from various literature published in reports, scholarly journals and books, newspapers, and various committee reports on unpredictable climatic conditions and existing measures to address these conditions in Ghana. The utilization of different data was to provide an in-depth understanding and help to address the research questions more comprehensively and flexibly (Bryman, 2012).

3.5 Data Analysis

The analysis of the data collected was conducted using Statistical Package for Social Sciences (SPSS). The data was analysed using descriptive statistical techniques specifically exploring the frequency distribution of the variables reflecting the research questions. The results were presented in frequency tables, pie charts, and bar graphs.

3.6 Pre-Testing and Training

A pre-test of the survey instrument was conducted to assess the validity of the instruments before the data collection exercise. A pre-test is a brief examination of individual components of a research instrument that is used primarily to inspect the instrument’s mechanical construction (Sarantakos, 2005). Pre-testing is utilized to address concerns such as respondent burden, interest, and comprehension in addition to interviewer tasks, questionnaire problems, sample, and coding and analytic challenges (Czaja, 1998). The pre-testing was used to train three assistants who assisted with the administration of the questionnaires. This pre-test population was chosen from cocoa growers in the Amansie Central District. This Cocoa district was chosen because its features are similar to those of the areas chosen for the main study. A total of twelve (12) Cocoa farmers were carefully chosen to participate in the pilot testing to get a sense of what to expect in the field. The pre-test was conducted over three days.

3.7 Ethical Considerations

Every study project requires a high level of ethical consideration. The study of actual people in real situations is common in social science research, which poses ethical concerns about the researcher's interaction with the respondents. The validity of social science research may be questioned if care is not taken when performing it. As a result, the researcher must assume responsibility for all project procedures and ethical considerations. The study must be carried out to ensure that the integrity of respondents is preserved, and undesirable side effects that could limit future research opportunities are circumvented. Furthermore, the research must be carried out as a scientific project with no bias. Informed permission, anonymity, and confidentiality were all considered in the study.

For this purpose, all of the study's field assistants were chosen from among agricultural extension agents with prior experience working with farmers. They were instructed in all of the study's methods and assisted in the pre-testing of the equipment. The investigation adhered strictly to local conventions, and guidelines. The appropriate guidelines were observed for entering the community. At the district, and neighbourhood levels, consent to carry out the research was sought from the appropriate authorities. All research issues were discussed during visits to the chief cocoa farmer in each village. Local traditions, such as days when farming was prohibited, were observed.

There was no needless interference with the respondents' lives. As a result, no questions regarding the farmers' private lives were asked, and they were free to decline to answer any questions they found to be intrusive. The wellbeing of the informants was given top priority, and their interests, dignity, and privacy were all protected. Only convenient times for the respondents were used for the distribution of the questionnaires, and every effort was made to keep normal activities out of the way. The respondents were questioned in their own language, and their written responses were shown to them thereafter to prevent comments from being misinterpreted.

All information was kept completely confidential, and participants were kept anonymous. Anonymity safeguards privacy by withholding a participant's identity after the data has been collected. As a result, the survey did not include the respondents' names. Farmers were assured of their anonymity and that the information they submitted would only be used for the academic project for which it was intended. Participants had access to the study's findings, which were presented in a way and language they could understand. The research findings were made available to participants in a format and language that they could understand. All parties were made aware of the results' limitations in terms of reliability and applicability. Finally, both unpublished and published publications by other scholars that were included in the study were properly recognized.

3.8 Limitations of the study

Though the study sampled 100 respondents and solicit information through the use of questionnaires coupled with an interview with 10 key informants. The results of this research cannot be generalized considering the sample size and the selection of one community for the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

In this chapter, the results of the data collected from the 100 respondents from the Amansie West district on issues of climate change and cocoa production are presented, interpreted, and discussed. The chapter begins with the demographic characteristics of the respondents. This includes subsequent subsections focused on results relating to the impacts of climate change/variability on cocoa production, the perception of cocoa farmers on the relationship between climate change and cocoa yields as well as the strategies adopted by cocoa farmers in addressing the issues of climate change in the Amansie West district.

4.1 Demographic Characteristics

The demographic characteristics of the sample are presented in Table 1. The data collected showed that of the 100 respondents, 76% of them were male while 24% were female. That is, the sample consists of significantly a greater number of male farmers than females. This may also be suggestive that there was male dominance or more male cocoa farmers within the study area than there were females. The majority of respondents were male because, due to customary practices in the community, men have easy access to farmland than their female counterparts. It could also be because cocoa farming is more labour-intensive and requires more physical strength. Therefore, women may lack the needed effort to cultivate Cocoa. Also, of the 100 respondents who responded to the questionnaires, most of them (that is 54%) were 36-50 years old. Only 5% and 15% of the farmers were 18 – 25 and 26 - 35 years respectively. This shows that only 20% of the farmers fell within the category of youth. Even though 26% of the farmer were above 51+ years of age, the data shows that the ages of the farmers skewed towards the upper age categories.

On the education levels of the respondents, it was interesting to find that even though 19% and 3% of the 100 respondents did not attend any form of school (formal or informal), the remaining 78% of the respondents had some form of formal education. Specifically, 36%, 30%, and 12% of the respondents respectively had Basic, Secondary, and Tertiary education. The statistics above show a high literacy level among Cocoa farmers in the Amansie West District. When compared to farmers who rely on their experience, educated farmers are more efficient in production and more willing to welcome innovations (Martey et al.,2013). This implies that with their high literacy, farmers in the Amansie West District are appreciative of the devastating effects of climate change. A significant number of the farmers (80%) were married with only 5% of them being single. Notably, however, 14% of the respondents were widowed with only 1% of them divorced.

Table 2: Demographic Characteristics of Respondents

Demographic Characteristic	**Frequency(**f)	**Percentage (**%)
Gender		
Female	24	24
Male	76	76
Age		
18 – 25	5	5
26 – 35	15	15
36 – 50	54	54
51 and above	26	26
Educational Status		
No education	19	19
No formal education	3	3
Basic	36	36
Secondary	30	30
Tertiary	12	12
Marital Status		
Single	5	5
Married	80	80
Divorced	1	1

Demographic Characteristic	**Frequency(**f)	**Percentage (**%)
Widowed	14	14
Years of Cocoa Cultivation		
Less than 5 years	7	7
5 – 10 years	19	19
11 – 20 years	49	49
21 - 30 years	15	15
31 years and above	10	10
Size of Cocoa Farms		
Less than a hectare	4	4
1 hectare	22	22
2 hectares	56	56
3 hectares	8	8
4 or more hectares	10	10
Average Cocoa Yield		
Less than a ton	7	7
1 – 2 tons	76	76
3 – 4 tons	14	14
5 or more tons	3	3
Type of labour		
Family	10	10
Hired labour	11	11
Both Family and Hired Labour	79	79
Owner of the Farm		
Myself	82	82
Family	15	15
Rent	3	3
	N = 100	

(Source: Fieldwork, 2022)

On characteristics of the respondents which related directly to their farming activities, the results highlighted that 49% of the 100 farmers have worked as cocoa cultivators for 11 – 20 years. That is, almost half of the respondents have been working as cocoa farmers for over 10 years and up to 20 years. Also, it was ascertained that 7% of the farmers have been in cocoa cultivation for less than 5 years while 19% of them have been in it for 5 - 10 years. Another 15% of the respondents have also worked as cocoa farmers for 21-30 years. The data further shows that 10% of the farmers being the most experienced category of cocoa farmers have been in the business for over 31 years.

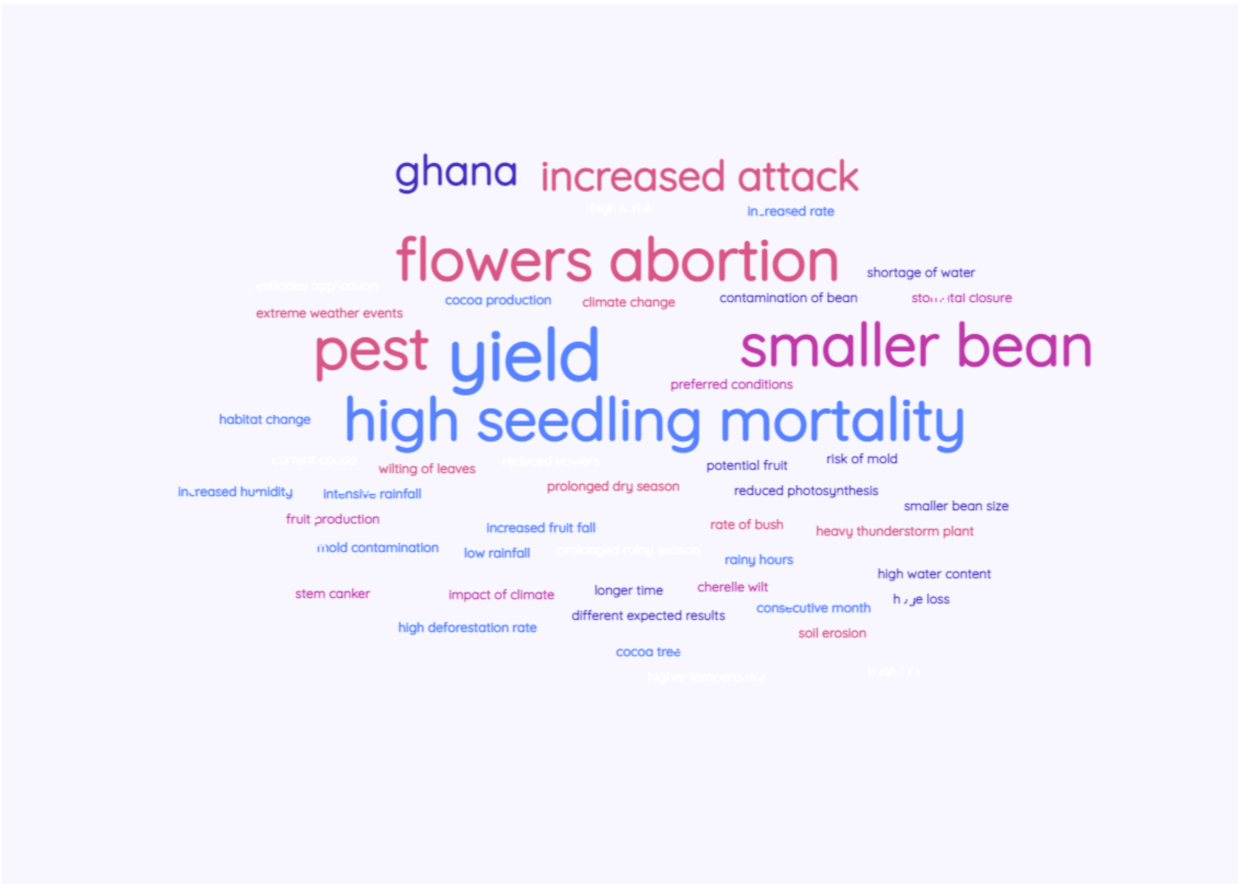
Most of the farmers (56%) worked on 2 hectares of cocoa farms. Also, 8% and 10% of the respondents worked on 3 hectares and 4 or more hectares of cocoa farms respectively. While 22% of them worked on 1-hectare farms, 4% of them had less than 1-hectare-sized cocoa farms. Almost 80% (specifically 76%) of respondents harvested only 1-2 tons of cocoa yield. Of the remaining respondents, 14% and 3% realized 3 – 4 tons and 5 or more tons respectively. Only 7% of the respondents reported receiving less than the normal cocoa yield from their farms. The main form of labour relied upon by cocoa farmers in this study is a combination of family and hired labour, as was shown in the 79% of the farmers who reported using that form of labour. It must be noted however that 10% and 11% of the farmers respectively reported relying on Family only and Hired labour only for their farm work. The results showed that 82% of the respondents worked on self-owned farms, 15% on family farms, while 3% worked on rented cocoa farms.

4.2 Impact of climate change on cocoa production in Africa in general, and Ghana in particular.

Figure 4 details the results of the content analysis on the impact of climate change on cocoa production in Africa and Ghana. The word cloud shows that high seed mortality, smaller bean, increased attack of pests, and flower abortion are the visible consequences of climate change on cocoa production in Africa. The incidence of Cherelle wilt, increased diseases such as stem canker, black pod, pink disease, stomatal closure, and reduced photosynthesis or photochemistry also impact cocoa production in Africa (Afrane & Ntiamoah, 2011; Kimengsi & Tosam, 2013; Wessel & Quist-Wessel, 2015). Climate projections predict that the areas suitable for cocoa farming in

Africa will shrink. The increased occurrence and intensity of extreme climatic events such as intensifying temperatures as well as erratic rainfall patterns are expected to increase the presence of pests and the incidence of diseases on cocoa farms. In West Africa, climate estimates show that many cocoa-growing zones in both Côte d'Ivoire and Ghana will be unsuitable for cocoa production by 2050 (Läderach et al., 2013; Kroeger et al., 2017).

Figure 4: Word cloud on the impact of climate change on cocoa production in Africa and Ghana



Two-thirds of the world’s supply of cocoa comes from Africa, with the majority coming from Côte d’Ivoire and Ghana. Cocoa production has increased in both Côte d’Ivoire and Ghana, providing a boost to both economies. For these reasons, both countries’ governments consider the cocoa sector to be of vital economic, social, and environmental importance. However, growing fears about climate change have raised alarms about the continuing feasibility and sustainability of cocoa production in Africa. Climate change exacerbates the existing problems of cocoa tree pests and disease; an aging tree stock; a lack of training and support for cocoa farmers; poor tree and soil management as well as underinvestment in the maintenance of cocoa farms (Kroeger, 2017).

Actors in the cocoa industry, including the World Cocoa Foundation (WCF), the International Institute of Tropical Agriculture (IITA); Rainforest Alliance; the Sustainable Food Lab (SFL); Root Capital; and USAID International Center for Tropical Agriculture (CIAT) have joined forces to include climate change in their plans for West Africa and to put in place climate-smart practices that are advantageous for the social, environmental, and economic spheres. This climate-smart cocoa strategy includes practices, oversight frameworks, and/or tactics that increase cocoa output, enhancing farm resilience while also reducing the effects of climate change (Rosenstock et al., 2016; Kroeger et al., 2017; Akrofi-Atitianti et al., 2018).

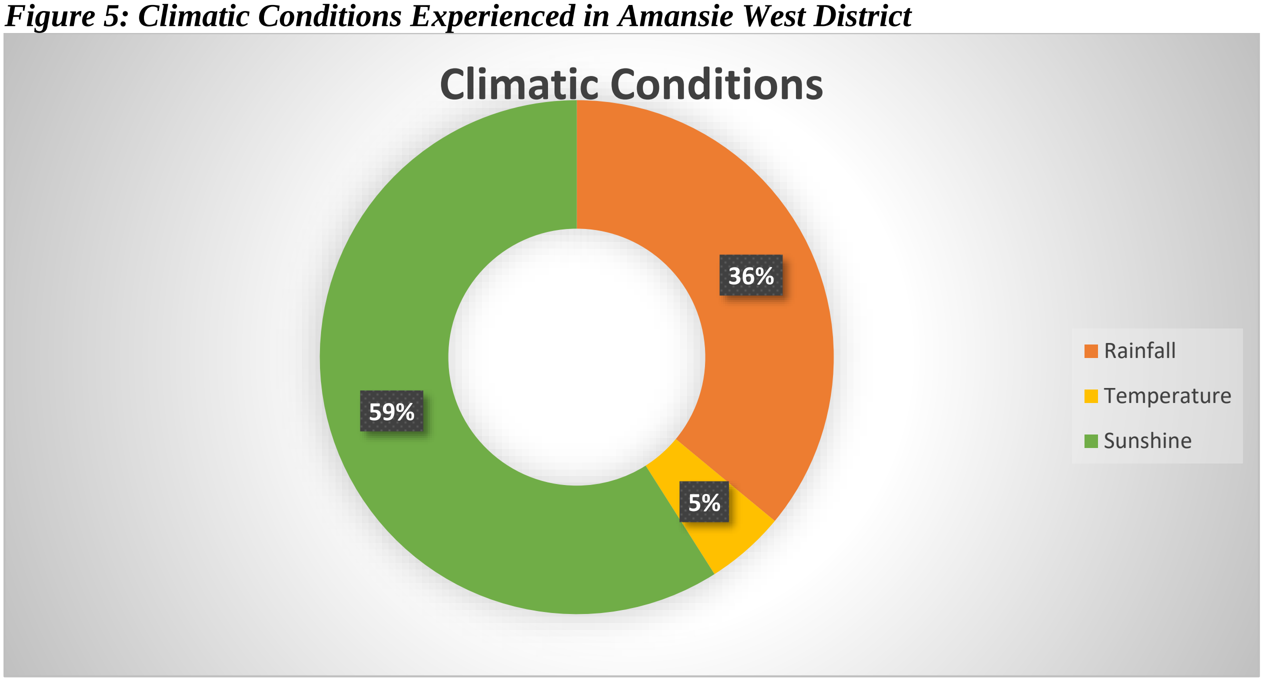
Practical examples of climate-smart cocoa include:

1) In Ghana’s Western Region, Touton has launched a climate-smart cocoa effort that completely complies with the World Cocoa Foundation's farmer training programs.
2) Hershey’s new $500 million sustainable cocoa strategy, “Cocoa for Good,” aims to conserve forests and climates by investing in shade-grown cocoa while simultaneously emphasizing production. It also focuses on zero deforestation and increasing agroforestry.
3) Mars “Sustainable in a Generation,” which fights deforestation and climate change with data-driven evidence.

4.3 The impacts of climate change on cocoa production in the Amansie West district.

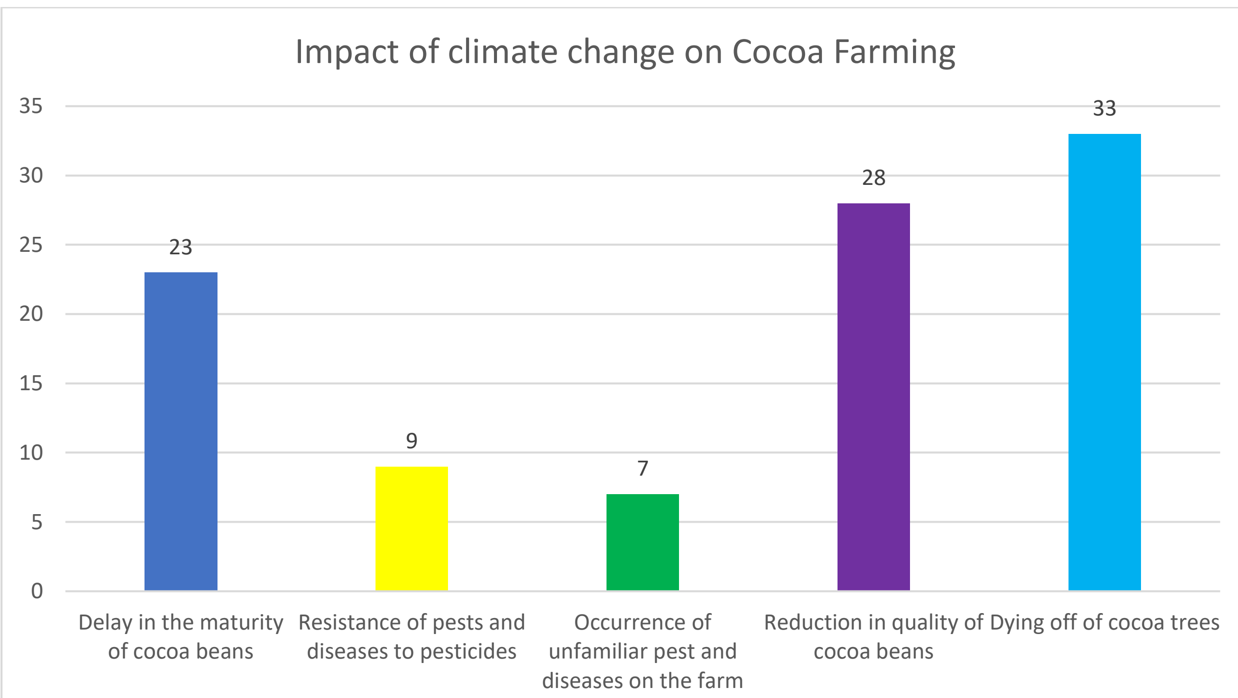
In this section, the climatic conditions experienced by the farmers in the district were analysed and presented. The results showed that sunshine (59%) was the dominant climatic condition experienced by the farmers in the district followed by rainfall (36%) and then temperature rises (5%). These climatic conditions are suitable for cocoa-growing areas (Afrane & Ntiamoah, 2011; Owoeye & Sekumade, 2016; Schroth et al., 2016). However, their variability may pose threats to cocoa farming and productivity from cocoa farms. The ramifications of climate change are manifested in the health and livelihood of the individual whilst simultaneously affecting the economy, infrastructure, and ecosystem of the community. This is attributed to the interaction within the variability of the climatical components like temperature and precipitation (IPCC, 2014) which makes it necessary to consider the influence of climate change on cocoa farming.

Figure 5: Climatic Conditions Experienced in Amansie West District



In examining the impact of climate change on cocoa cultivation, it can be observed from the figure (6) below that 33% had their cocoa trees dying off while 28% of the respondents experienced a reduction in the quality of cocoa beans. It was further ascertained that 23% experienced delays in the maturity of cocoa beans while 9% of the farmers experienced pest and disease resistance against pesticides and 7% of the farmers also experienced an attack from unfamiliar pests and incidence of diseases on the farm. In general, farmers faced the dying off of their cocoa trees, reduced cocoa beans quality, and delays in the maturity of cocoa beans possibly due to climate change and climate variability in the Amansie West district. That is, climate change and variability could threaten both the income and food security of cocoa farmers who work in a single-sector agrarian economy.

Figure 6: The impacts of climate change/variability on cocoa production



The finding of this study that climate variabilities result in reduced quality of cocoa beans adds to the evidence within the literature that prolonged drought also leads to a reduction in the Leaf Area Index (LAI) which in turn results in a decline in Cocoa yield or output (Adjei-Nsiah & Kermah, 2012; Hutchins *et al.*, 2015; Ojo & Sadiq, 2010). Also, the finding that climate change accounts for the delay in maturity of cocoa beans corroborates the existing knowledge that temperature variations affect cocoa crops by changing the crop flowering period, resulting in a decline in seed numbers and high loss of water from the soil (Challinor & Wheeler, 2007; Schroth *et al.*, 2016). Even though the resistance of pests and disease to pesticides was not prevalent among the cocoa farmers studied in this work, it substantiates the work of Oyekale (2015) that prolonged drought alters host resistance and physiology of the host-pathogen as well as their interaction with the pests.

4.4 Cocoa farmers' perception of the impacts of climate change on cocoa yields in the Amansie West district

Table 3 details the impacts that climate change has on cocoa yields as perceived by the cocoa farmers. It can be observed that farmers perceive that climate change has negatively impacted their cocoa yields. Ninety-three (93) farmers reported that increased sunshine has led to decreased cocoa yields. Similarly, on their perception of temperature changes, 87 farmers also advanced that the increasing temperature exacerbated by the deteriorating climate conditions accounted for their decreasing cocoa yields. Equally, with regards to changes in rainfall pattern, 33 farmers attributed the uneven distribution of rainfall to their decreasing crop yield and 44 farmers advanced that the unpredictability of the rain had a similar effect on their crop yield.

Table 3: Farmers' Perception of The Impacts of Climate Change on Cocoa Yields

Variables		**Cocoa Yields**	
Changes in Sunshine	Increased	Decreased	No Change
Increased Sunshine	3	93	1
No Change	1	2	0

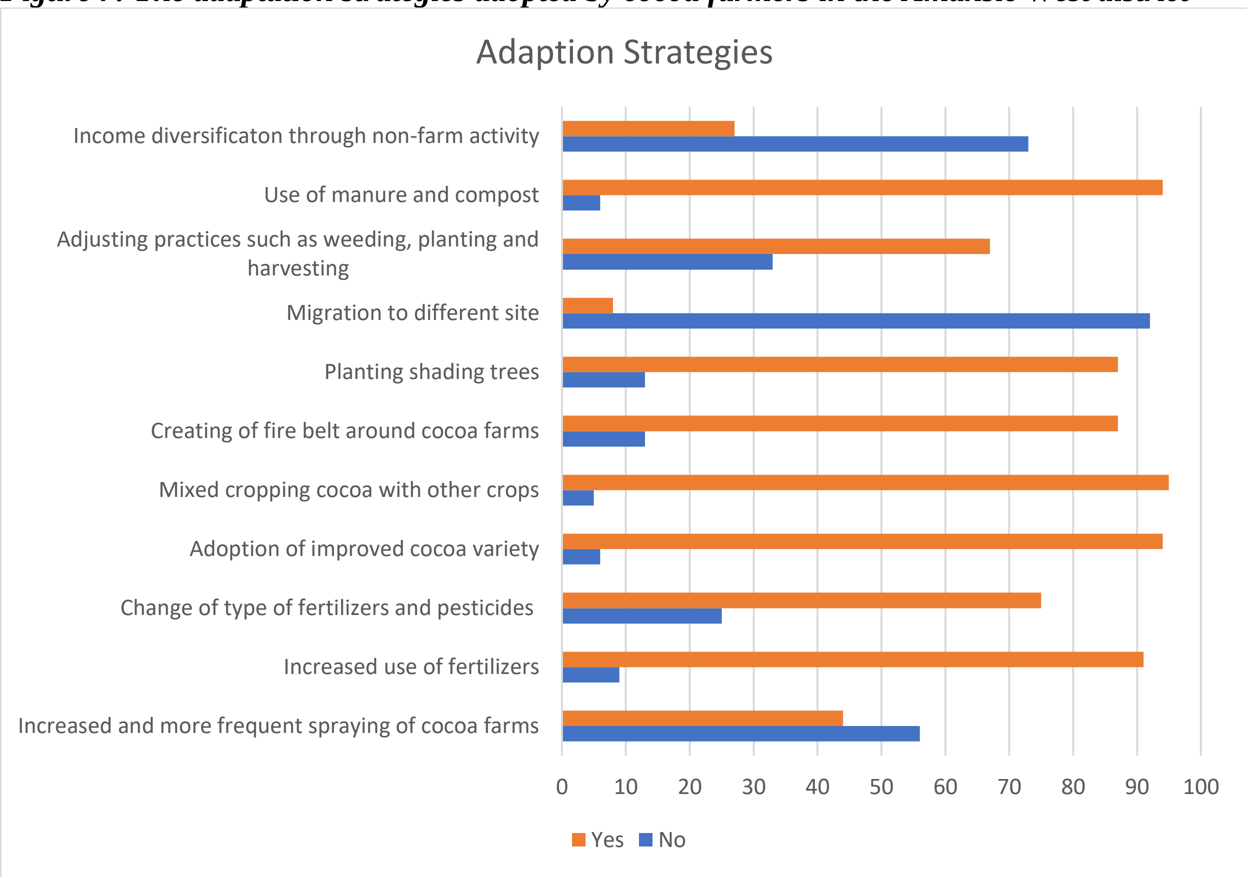
Changes in Temperature			
Temperature rise	4	87	1
Low temperature	0	2	0
No change	0	6	0
Changes in Rainfall			
Increase rainfall	1	4	0
Decrease rainfall	2	10	0
Late onset of rain	0	4	0
uneven distribution of rainfall	0	33	1
Unpredictability of the rain	1	44	0

Cocoa production like any other farming activity requires the right temperature, sunlight, and adequate rainfall in addition to the regular crop maintenance such as applying fertilizers, weeding, and others. Climate change has a direct effect on these climatic conditions and subsequently affects cocoa production in the district. The perceptions of the farmers generally agreed with the literature on the effect of climate change on cocoa production (Adjei-Nsiah & Kermah, 2012; Challinor & Wheeler, 2007; Hutchins *et al.*, 2015; Ojo & Sadiq, 2010; Schroth *et al.*, 2016). There is largely agreement between the observation of the farmers on the relationship between climate change and their cocoa yield when matched against what is within the literature.

4.5 The adaptation strategies employed by cocoa farmers in the Amansie West district

In ascertaining the strategies adopted by farmers to adapt to the effects or impact of climate change, the respondents were required to respond to various adaptions identified from the literature. As such, they responded to the items using “yes” and “no “response categories. The results are presented in Figure 7. Over 90% of the farmers relied on manure use, increased fertilizer use, mixed cropping cocoa with other crops, and the use of improved cocoa varieties as adaptation strategies. This agreed with the work of Kolavalli & Vigneri (2011) that the cocoa industry has seen greater fertilizer use, hybrid cocoa variety production, and enhanced pest and disease management methods. This finding further confirms the work of Osei (2017) that "abrewa bedi" is the popular cocoa variety used by farmers in the region. These varieties of cocoa are deemed better options because they mature earlier than the Amazonia type, 5 to 6 years (Aneani & Ofori-Frimpong, 2013; Buxton, 2018; Kolavalli & Vigneri, 2011; Osei, 2017).

Figure 7: The adaptation strategies adopted by cocoa farmers in the Amansie West district



About 80% of farmers also reported that they planted shading trees and created fire belts to adapt to the climate variabilities' impact on their cocoa farms. The importance of shading in cocoa productivity substantiates the finding of Nair (2021) that under field conditions, conditions defining the maximum soil moisture levels for cocoa cultivation during Ghana's dry season vary and depend on several elements, including volume and distribution of active roots; shading, soil texture and structure; root depth; age and strength of the cocoa tree as well as the air movement. In a similar study by Osei (2017) shade trees were used by about 83% of cocoa farmers to protect cocoa plants.

Over 60% of the farmers also said that they adjusted their planting, weeding, and harvesting practices. It was interesting to find however that, over 90% of the farmers did not migrate to different sites as an adaptative strategy. This may be explained by land tenure arrangements such as sharecropping and gifts (Quay *et al.,* 2015) which may become barriers to easy access to land for farming in new locations. Again, because the land is generally communally owned, and that cocoa is a perennial crop means moving during short periods for new land during climate variabilities. Also, over 70% of farmers could not diversify income through non-farm activities to cope with the impact of climate variabilities and over 50% of the farmers could not increase the frequency of spraying their farms as a way of coping with the impact of climate variabilities. This contradicts the existing literature on spraying farms as a means of adaptation to climate variability (Buxton, 2018; Osei, 2017). With practices such as increased fertilizer use, the cost of production is expected to increase for farmers, thus reducing their profit margins from their work.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Introduction

This last chapter of the work presented conclusions based on the data analysis and findings. The conclusions made on the issue of climate change and cocoa production within the Amansie West district in Ghana are presented in a summarised conclusion. Recommendations to reduce the impact of climate variability on cocoa production are then proffered before further recommendation for future research is made.

5.1 Conclusion

- The study explored the impact of climate change on cocoa production in Africa and Ghana. Using content analysis and presenting the results with a word cloud, the results indicate that high seed mortality, smaller bean, increased attack of pests, and flowers abortion are the visible consequences of climate change on cocoa production in Africa. According to climate predictions, Africa's cocoa-growing areas would become smaller. Farms will be exposed to unpredictable rainfall as a result of rising temperatures, changing precipitation, and an increase in the occurrence and intensity of extreme climatic events. By 2050, several regions in Ghana and Côte d'Ivoire will not be suitable for cocoa farming according to West African climate forecasts. This has inspired reactions by stakeholders in the cocoa production sector on the African continent to implement socially, environmentally, and economically beneficial climate-smart practices in cocoa farming in Africa.
- Focusing specifically on the impacts of climate change/variability on cocoa production in the Amansie West district, the results indicate that sunshine was the dominant climatic condition experienced by the farmers in the district. Though this condition is suitable for

cocoa growing areas, their variability poses threat to cocoa farming and productivity from cocoa farms. The farmers experienced their cocoa trees dying off, reduced cocoa beans quality, and delays in the maturity of cocoa beans due to climate change and climate variability in the Amansie West district. The effect of this variability could threaten both the income and food security of cocoa farmers as they depend heavily on the agrarian economy.

- Also, the study established that farmers perceived that climate change has a negative impact on their cocoa yields. The farmers reported that increased sunshine, increasing temperature, and erratic rainfall have contributed to decreased cocoa yields. On this, it can be concluded that farmers perceive threatened by the climate variabilities. This implies that the realization of the Sustainable Development Goal 2.4 (ensuring sustainable food production systems among cocoa farmers) within the Amansie district is in jeopardy.
- Finally, concerning the strategies adopted to address the impact of climate change, the farmers advanced that they used manure and fertilizers as well as innovative farming techniques such as the use of improved cocoa varieties and mixed cropping cocoa with other crops. Also, the farmers complemented these practices with the planting of shading trees and creating fire belts. Interestingly, however, most of these farmers could not diversify their livelihoods or incomes through non-farm incomes as a way of dealing with the situation. Notably, about half of the cocoa farmers could not increase the frequency of spraying their farms in response to the impact of climate variabilities. In sum, even though farmers adopted some coping strategies, the impacts of climate variabilities are seen in reduced yields and lowered beans quality, and trees dying show that these coping mechanisms were generally ineffective.

5.3 Recommendations

The following measures are proffered as recommendations:

1. Based on the finding that the farmers experience high temperatures, unpredictable rainfalls, and uneven distribution of rainfalls across the season, it is recommended that the Ghana Meteorological Agency, the Ministry of Agriculture, and the Ghana Cocoa Board collaborate to ensure that data-based extension services are delivered to farmers in a timely manner. This would help farmers to make informed decisions on planting times and the specific times to make particular farm practice decisions to forestall the impact of climate variability on cocoa production.
2. It is further advised that there must be a multi-stakeholder effort within the agriculture sector to ensure that technological tools and platforms provided by organizations such as Farmerline Ghana and other Agritech organisations are adopted to improve access to needed farm information and knowledge required to make effective farm decisions are adopted. This when done would keep farmers within the information loop regularly and make their farm work more effective and give them the needed resilience to the impact of climate change.
3. Again, considering that farmers realised low yields as a result of climate variabilities in spite of their coping mechanisms, there is a need to further intensify farmer education on appropriate and more current ways of dealing with the impact of climate variability in cocoa farming. This would ensure that the livelihoods of cocoa farmers are not threatened by climate variabilities.
4. It is further recommended that beyond national-level fertilizer and cocoa farm input distributions, efforts be made to ensure effective on-the-ground monitoring to ensure that

these services reach the intended beneficiaries. This would ensure that regularity and frequency of farm spraying and fertilizer application can be done to improve the resilience of crops against the effects of climate change.

5. There is a further need to ensure that farmers are trained to identify and maximise context-specific alternative income options. This would allow them to find and own relevant alternative livelihood options so that they can be able to quickly diversify their livelihoods through non-farm income in the event that climate variabilities threaten their major income source. This would improve food security and the general economic wellbeing of cocoa farmers in Ghana.
6. Again, there is a need for further research by agronomists and other related researchers in Ghana to ascertain the extent and actual correlations between climate variability and reduced pest resistance, crop yields, and quality of beans within the cocoa sub-sector. These kinds of studies would help to identify the exact situation as pertains to Ghana and proffer the needed context-specific technical remedies to deal with pest resistance, lowered beans quality, and reduced crop yields which happen because of climate variabilities. This would go a long way to ensure that better varieties of crops are identified for the Ghanaian setting.
7. Considering that this current study was limited in its scope, there is a need for a broader study that engages more districts, and multiple stakeholders within the sector to arrive at a conclusive sector finding on how climate variabilities impact cocoa production in Ghana. These studies would serve as the informed basis for policies for improved cocoa farming interventions.

REFERENCES

Adjei, A. (2017). *The impact of illegal mining (Galamsey) on cocoa production and livelihood_a case study of Amansie West District* [(Doctoral dissertation,]. University of Education.

Adjei-Nsiah, S., & Kermah, M. (2012). Climate Change and Shift in Cropping System: From Cocoa to Maize Based Cropping System in Wenchi Area of Ghana. *British Journal of Environment and Climate Change*, *2*(2), 137–152. https://doi.org/10.9734/BJECC/2012/1220.

Afrane, G., & Ntiamoah, A. (2011). Use of pesticides in the cocoa industry and their impact on the environment and the food chain. Pesticides in the modern world risks and benefits. *InTech*, *51–68*.

Agbongiarhuoyi, A. E., Abdulkarim, I. F., Fawole, O. P., Obatolu, B. O., Famuyiwa, B. S., & Oloyede, A. A. (2013). Analysis of farmers' adaptation strategies to climate change in cocoa production in Kwara State. *Journal of Agricultural Extension*, *17*(1), 10–22.

Akrofi-Atitianti, F., Ifejika Speranza, C., Bockel, L., & Asare, R. (2018). Assessing climate smart agriculture and its determinants of practice in Ghana: A case of the cocoa production system. *Land*, *7*(1), 30.

Amoah, S. K. (2013). Factors affecting cocoa production in Upper Denkyira West District. *Unpublished Doctoral dissertation of University of Ghana*.

Aneani, F., & Ofori-Frimpong, K. (2013). An Analysis of Yield Gap and Some Factors of Cocoa (Theobroma cacao) Yields in Ghana. *Sustainable Agriculture Research*, *2*(4), 117–127. https://doi.org/10.5539/sar.v2n4p117.

Anim-Kwapong, G. J., & Frimpong, E. B. (2004). Vulnerability of Agriculture to Climate Change- Impact of Climate Change on Cocoa Production. *Vulnerability and Adaptation Assessment Under the Netherlands Climate Change Studies Assistance Programme Phase 2*, *2*, 2.

Arku, F. S. (2013). Local creativity for adapting to climate change among rural farmers in the semi-arid region of Ghana". *International Journal of Climate Change Strategies and Management*, *5*(4), 418–430.

Armah, E. S. (2008). Explaining Ghana's good cocoa karma: A smuggling incentive- reversal argument. "Paper prepared for presentation at the Center for the Study of African Economies (CSAE. *Conference on Economic Development in Africa 16th*.

Asante-Poku, A., & Angelucci, F. (2013). *Analysis of incentives and disincentives for cocoa in Ghana*. Technical notes series.

Asuming-Brempong, S., Sarpong, D. B., Asenso-Okyere, K., & Amoo, P. (2006). *Labour practices in cocoa production in Ghana* (pilot survey).

Baah, F., Anchirinah, V., & Amon-Armah, F. (2011). Soil fertility management practices of cocoa farmers in the eastern region of Ghana. *Agriculture and Biology Journal of North America*, *2*(1), 173-181.

Barrios, S., Ouattara, B., & Strobl, E. (2008). The impact of climatic change on agricultural production: Is it different for Africa? *Food Policy*, *33*(4), 287–298.

Berhe, M., Hoag, D., Tesfay, G., Oniki, S., & Kagatsume, M. (2016). Effects of adaptation to climate change on income of cattle owners in the pastoral and agro-pastoral communities of Northern Ethiopia. *2016 AAAE Fifth International Conference*.

Blanc, E. (2012). *The impact of climate change on crop yields in Sub-Saharan Africa*.

Boon, E., & Ahenkan, A. (2011). Assessing Climate Change Impacts on Ecosystem Services and Livelihoods in Ghana: Case Study of Communities around Sui Forest Reserve. *18th Commonwealth Forestry Conference*.

Bugri, J. T. (2008). The dynamics of tenure security, agricultural production and environmental degradation in Africa: Evidence from stakeholders in north-east Ghana. *Land Use Policy*, *25*(2), 271–285.

Buxton, D. N. B. (2018). *Vulnerability of cocoa production to climate change: A case of the Western and Central Regions in Ghana* [(Doctoral dissertation,]. University of Cape Coast.

C.O.C.O.B.O.D. (2007). *Production and price statistics*.

Challinor, A. J., & Wheeler, T. R. (2007). Crop yield reduction in the tropics under climate change: Processes and uncertainties. *Agricultural and Forest Meteorology*, *148*(3), 343–356.

Climate Change-UNFCCC, U. N. F. C. (2007). Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries". In *Bonn, Climate Change Secretariat, Development and Strategy Governance Division, IFPRI, Ghana Strategy Support Program (GSSP* (Vol. 19, pp. 1–9).

Codjoe, F. N. Y., Ocansey, C. K., Boateng, D. O., & Ofori, J. (2013). Climate Change Awareness and Coping Strategies of Cocoa Farmers in Rural Ghana. *Journal of Biology, Agriculture and Healthcare*, *3*(11), 19–29.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approach.* Sage publications.

Datta, S. (2013). Impact of climate change in Indian Horticulture—A review". *International Journal of Science, Environment and Technology*, *2*(4), 661–671.

Dulal, H. B., Brodnig, G., Thakur, H. K., & Green-Onoriose, C. (2010). Do the poor have what they need to adapt to climate change? A case study of Nepal. *Local Environment*, *15*(7), 621–635.

ECOWAS (2007). *Atlas on Regional Integration in West Africa*. ECOWAS-SWAC/OECD. http://www.oecd.org/regional/atlasonregionalintegrationinwestafrica.htm.

Ehiakpor, D. S., Danso-Abbeam, G., & Baah, J. E. (2016). Cocoa Farmer's Perception on Climate Variability and its Effects on Adaptation Strategies in the Suaman District of Western Region, Ghana. *Cogent Food & Agriculture*, *2*(1).

Fowler, M. S., & Coutel, F. (2017). *Cocoa beans: From tree to factory. Beckett's industrial chocolate manufacture and use* (pp. 9–49).

Fussel, H. M., & Klein, R. J. T. (2002). Vulnerability and Adaptation Assessments to Climate Change: An Evolution of Conceptual Thinking". *UNDP Expert Group Meeting*.

Ghana Statistical Service. (2021). *Population and Housing Census*, National Analytical Report.

Ghana Statistical Service. (2014). GIS. *District map of Amansie West*.

Hutchins, A., Tamargo, A., Bailey, C., & Kim, Y. (2015). *Assessment of Climate Change Impacts on Cocoa Production and Approaches to Adaptation and Mitigation: A Contextual View of Ghana and Costa Rica*. International Development Studies.

International Cocoa Organization (2007). World Cocoa Market: An Analysis of Recent Trends and of Prospects to the Year 2006/7, *ICCO Publication.*

I.P.C.C. (2007). *Climate Change 2007: Impacts, adaptation and vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

I.P.C.C. (2014). Summary for policymakers. *Climate Change*, 1–32.

Kemausuor, F., Dwamena, E., Bart-Plange, A., & Kyei-Baffour, N. (2011). Farmers" perception of climate change in the Ejura-Sekyedumase District of Ghana". *ARPN Journal of Agricultural and Biological Science*, *6*(10), 26–37.

Kimengsi, J. N., & Tosam, J. N. (2013). Climate variability and cocoa production in Meme Division of Cameroon: Agricultural development policy options. *Greener Journal of Agricultural Sciences*, *3*(8), 606–617.

Kolavalli, S., & Vigneri, M. (2011). *Cocoa in Ghana: Shaping the success of an economy. Yes, Africa can: Success stories from a dynamic continent* (pp. 201–218). https://doi.org/10.1596/978-0-8213-8745-0

Kongor, J. E., Steur, H., Walle, D., Gellynck, X., Afoakwa, E. O., Boeckx, P., & Dewettinck, K. (2018). Constraints for future cocoa production in Ghana. *Agroforestry Systems*, *92*(5), 1373–1385.

Kotir, J. H. (2011). Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security. *Environment, Development and Sustainability*, *13*(3), 587–605.

Kroeger, A., Koenig, S., Thomson, A., & Streck, C. (2017). *Forest-and Climate-Smart Cocoa in Côte d'Ivoire and Ghana*.

Kumi, E., & Daymond, A. J. (2015). Farmers' perceptions of the effectiveness of the Cocoa Disease and Pest Control Programme (CODAPEC) in Ghana and its effects on poverty reduction. *American Journal of Experimental Agriculture*, *7*(5), 257–274.

Kurukulasuriya, P., & Rosenthal, S. (2003). *Climate Change and Agriculture: A Review of Impacts and Adaptations, World Bank Climate Change Series* (Vol. 91). World Bank Environment Department. https://doi.org/10.1017/CBO9781107415324.004

Lee, J., Nadolnyak, D., & Hartarska, V. (2012). *Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study"*. Department of Agricultural Economics and Rural Sociology, University of Auburn.

Mendelssohn, R., Dinar, A. & Dalfelt, A., (2000). Climate change impacts on African agriculture, Mimeo, *Yale University*.

Moss, T. J., & Young, L. (2009). *Saving Ghana from its oil: The case for direct cash distribution*.

Ministry of Food and Agriculture & Amansie West District Agricultural Development Unit (2010). *Assessment of development in the Amansie West District*.

Ministry of Food and Agriculture (2010). Agriculture in Ghana, Facts and Figures (2009). *Ministry of Food and Agriculture –Statistics, Research and Information Directorate (MOFA-SRID)*. Ghana.

Müller-Kuckelberg, K. (2012). Climate change and its impact on the livelihood of farmers and agricultural workers in Ghana. In *Preliminary Research Results. General Agricultural Workers' Union of GTUC. Friedrich Ebert Stiftung* (pp. 1–47).

Nair, K. P. (2021). *Cocoa (Theobroma cacao L.). The agronomy and economy of important tree crops of the developing world* (pp. 131–180).

Naminse, E. Y., Fosu, M., & Nongyenge, Y. (2011). *The impact of mass spraying programme on cocoa production in Ghana*.

Ofori-Boateng, K., & Insah, B. (2014). The impact of climate change on cocoa production in West Africa. *International Journal of Climate Change Strategies and Management*.

Ojo, A. D., & Sadiq, I. (2010). Effect of climate change on cocoa yield: A case of cocoa research institute (CRIN) farm, Oluyole local government Ibadan Oyo State. *Journal of Sustainable Development in Africa*, *12*(1), 350–358.

Onyeneke, R. U., Amadi, M. U., Njoku, C. L., & Osuji, E. E. (2021). Climate Change Perception and Uptake of Climate-Smart Agriculture in Rice Production in Ebonyi State, Nigeria. *Atmosphere*, *12*(11).

Oppong, S. (2017). *Trend and Factors Affecting Cocoa Production in Ghana: A Case Study of Sefwi- Wiawso District*. University of Ghana.

Osei, E. M. (2017). *Climate Variability and Cocoa Production: The Implications of Micro-Adaptation Measures on Cocoa Farmers' Income*. University of Ghana.

Owoeye, R. S., & Sekumade, A. B. (2016). Effect of climate change on cocoa production in Ondo State, Nigeria. *J Soc Sci Res*, *10*, 2014–2025.

Oyekale, A. S. (2015). Climate change-induced occupational stress and reported morbidity among cocoa farmers in South-Western Nigeria. *Annals of Agricultural and Environmental Medicine*, *22*(2), 357–361.

Parry, V. (2015). *Assessment of the sustainable livelihoods of rural cocoa farmers in the Atwiima Mponua District of Ghana,1-138*. University of Ghana.

Pinto, D. A., Demirag, U., Haruna, A., Koo, J., & Asamoah, M. (2012). Climate Change, Agriculture, and Food crop Production in Ghana". In *International Food Policy Research Institute (IFPRI)*.

Quaye, W., Ampadu, R., Onumah, J., & Titiati, A. (2015). Does the current land tenurial arrangement in Ghana incentivise adoption of environmentally sustainable cocoa production practices? A case study of four selected cocoa growing districts in Ghana. *African Journal of Science, Technology, Innovation and Development*, *7*(4), 265–275.

Rosenstock, T. S., Lamanna, C., Chesterman, S., Bell, P., Arslan, A., Richards, M. B., & Zhou, W. (2016). The scientific basis of climate-smart agriculture: A systematic review protocol. In *CCAFS Working Paper*.

S.A.G.U.N. (2009). Climate Change Impacts on Livelihoods of Poor and Vulnerable Communities and Biodiversity Conservation: A Case Study in Banke, Bardia, Dhading and Rasuwa District of Nepal". In *Strengthened Actions for Governance in Utilization of Natural Resources Program* (p. 56).

Sayemuzzaman, M., & Jha, M. K. (2014). Seasonal and annual precipitation time series trend analysis in North Carolina, United States. *Atmospheric Research*, *137*, 183–194.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*, 014010. https://doi.org/10.1088/1748-9326/5/1/014010.

Schroth, G., Läderach, P., Martinez-Valle, A. I., Bunn, C., & Jassogne, L. (2016). Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. *Science of the Total Environment*, *556*, 231–241.

Tawiah, A. (2015). [Cocoa Commodity Report, 1–16.]. https://www.modernghana.com/print/621813/1/2014?2015?cocoa?commodity?report.html

Trade, U. N. C. & Development. (2009). *Responding to the global crisison climate change mitigation and development – trade and development report UNCTAD Secretariat"* (pp. 978-92-1-112776-8 0255-4607).

United Nations Conference on Trade and Development (2009*). Responding to the global crisis on climate change mitigation and development – trade and development report UNCTAD Secretariat*", ISBN978-92-1-112776-8ISSN0255-4607. New York and Geneva.

Wessel, M., & Quist-Wessel, P. F. (2015). Cocoa production in West Africa, a review and analysis of recent developments. *NJAS: Wageningen Journal of Life Sciences*, *74*(1), 1–7.

Wiah, E. N. (2017). Impact of climate change on cocoa yield in Ghana using vector autoregressive model. *Ghana Journal of Technology*, *1*(2), 32–39.

Witjaksono, J. (2016). Cocoa farming system in Indonesia and its sustainability under climate change. *Agriculture, Forestry and Fisheries*, *5*(5), 170.

Woittiez, L. S., Wijk, M. T., Slingerland, M., Noordwijk, M., & Giller, K. E. (2017). Yield gaps in oil palm: A quantitative review of contributing factors. *European Journal of Agronomy*, *83*, 57–77.

Yin, R. K (2013). Case study research: Design and methods. Thousand Oaks, CA: Sage. *The Canadian Journal of Action Research*, *14*(1), 69-71.

APPENDIX

A. Survey Instrument

Dear Participant,

I am a master's student researching 'the impact of climate change and variability on Cocoa production and possible adaptation measures in Ghana, particularly the Amansie West District'. The study is being supervised by Professor Bishal K. Sitaula. This study is for academic purposes only and any information and material obtained shall be treated strictly confidential. This questionnaire is designed to collect data for academic research as part of the requirements for the award of MSc. International Environmental Studies degree. The information provided will be treated with the utmost confidentiality and used for the intended purpose only. The responses will be analyzed in aggregates and no one will be directly identified. You are at liberty to withdraw your participation at any point in time you feel uncomfortable continuing. You are kindly entreated to answer the questions as honestly as possible, but you may skip any question that you do not feel comfortable answering. However, answering all questions will help increase knowledge of the subject matter. I appreciate you for taking the time to complete this set of questionnaires.

Thank you.

Farmer's Background Information

Please provide give a response that reflects your situation. Tick [√] where appropriate response.

Name of Community…………………………… …………………………………….

1. Gender

   (a) [ ] Male (b) Female [ ] (c) Other [ ]

2. Age

   (a) 18-25 [ ] (b) 26-35 [ ] (c) 36-50 [ ] (d) 51-60 years [ ] (e) 60 years and above [ ]

3. Educational status

   (a) Basic [ ] (b) Secondary [ ] (c) Tertiary [ ] (d) Non formal Education [ ] (e) No education [ ]

4. What is your marital status?

   (a) Married [ ] (b) Single [ ] (c) Divorced [ ] (d) Widowed [ ]

5. How many years have you been cultivating cocoa?

   (a) Less than 5 years [ ] (b) 5-10 years [ ] (c) 11-20 years [ ] (d) 21-30 [ ] (e) 30 years + [ ]

6. What is the size of your cocoa farm?

(a) less than 1 hectare [ ] (b) 1 hectare [(c) 2 hectare (d) 3 hectares [ ] (e) 4 hectares or more [ ]

7. What is the average yield of your cocoa farm?

(a) less than a ton [ ] (b) 1-2 tonness [ ] (d) 3-4 tonnes [ ] (e) 5 and above tonnes [ ]

8. What type of labor is employed?..................

(a) Family [ ] (b) hired laborers [ ] (c) both family and hired laborers [ ]

9. Who is the owner of the land you are farming on? ……………………………

(a) Myself [ ] (b) Family [ ] (c) A friend [ ] (d) Am renting [ ]

Perception and knowledge of farmers about Climate Change/ Variability

10. Have you heard of climate variability and change before?

(a) Yes [ ] (b) No [ ]

11. If yes, from which of these sources do you obtain information about farming?

(a) Extension officers [ ] (b) Friends [ ] (c) Media [ ] (d) Fellow farmers [ ]

(e) Farmers Association [ ](f) Other (Specify)…………………………………

12. Have you noticed any change/variability in the weather patterns of this area? ……….

(a) Yes [ ] (b) No [ ]

13. If yes, how long have you realized these changes in the weather? ……………….

(a) 1-5 years [ ] (b) 6-10 years [ ] (c) 11-15 years [ ] 16-20 years [ ] 21years & above [ ]

14. Which climatic element(s) have/has a greater influence on your cocoa farming?

Rainfall [ ] Temperature [ ] Sunshine amount [ ] Wind [ ] Humidity [ ]

15. Which changes have you identified in these climatic variables in this area?

Temperature

(a) Temperature rise [ ] (b) Low temperature [ ] (c) No change [ ]

Rainfall

(a) Increase rainfall [ ] (b) Decrease rainfall [ ] (c) Late onset of rain [ ] (d) uneven distribution of rainfall [ ] (e) Unpredictability of the rainfall [ ] (f) No change [ ]

Sunshine

(a) Increased sunshine [ ] (b) Decreased sunshine [ ] (c) No change [ ]

16. What do you think could be the cause of this variability in the climate in the area?.........

(a) Deforestation [ ] (b) Burning of firewood [ ] (c) Land degradation [ ]

(d) God's punishment to humankind [ ] (e)Caused by nature or God [ ]

(f) Other (specify) …………………………………………………

17. Have you ever received any expert advice from any stakeholders of agriculture (such as MoFA) on the effects of this variability on your cocoa farming? Yes [ ] No [ ]

If yes, which stakeholder organization and what kind of advice did they give you?.............

....

....

Impacts of Climate Variability on Cocoa Production

18. What are the impacts of these climatic variables on your cocoa farm?............

(a) Delay in the maturity of cocoa beans [ ]

b) Resistance of pests and diseases to pesticides [ ]

c) Occurrence of unfamiliar pests and diseases on the farm [ ]

d) Reduction in quality of cocoa beans [ ]

e) Dying off of cocoa trees [ ]

(f) Other (Specify)……………… …………………………………….

19. Have these impacts in any way affected your Cocoa yields? Yes [ ] No [ ]

20. What changes have you noticed in yield with regards to these impacts of climate change/variability?...

a) Increased in cocoa yield [ ]

b) Decreased in cocoa yield [ ]

c) No change in cocoa yield [ ]

21. Apart from these direct impacts of climate change/variability which other factors have affected your Cocoa yields?...

a) Increases in pest and disease [ ]

b) Difficulty in weed control [ ]

c) Wildfires [ ]

d) Inability to effectively spray cocoa farm [ ]

e) Inadequate fertilizer application [ ]

f) Other (Specify)… ……………………………

Adaptation Measures or Strategies Used in Cocoa Farming

22. Do you know/have heard about adaptation strategies used in Cocoa farming? Yes [ ] No [ ]

If yes, what do you know about it?..

23. Which medium/source did you hear about these adaptation measures?...................................

(a) Extension officers [ ] (b) friends [ ] (c) radio [ ] (d) fellow farmers [ ]

(e)farmers association [ ](f) Other (Specify)…………………………………………………

24. Have you been using these adaptation measures?..........Yes [ ] No [ ]

How long have you been using these adaptation measures?...............

a) 2 years b) 3 years c) 4 years d) 5 years and above

Which of the following adaptation measures have you been using on your Cocoa farm?...

	Adaptation measures	Yes	No	I do not know
25	Increased and more frequent spraying of the cocoa farm			
26	Increased use of fertilizer			
27	Change of type of fertilizer and pesticides used on the farm			
28	Adoption of improved Cocoa variety			
29	Mixed cropping Cocoa with other crops			
30	Creating of fire belt around cocoa farms			
31	Planting shading trees or plants as a protective cover for seedlings			
32	Migrating to different sites			
33	Adjusting practices such as weeding, planting, and harvesting			
34	Creating of fire belt around cocoa farms			
35	Use of manure and compost			
36	Income diversification through non-farm activity			
37	Others (Specify)…………………………………………			

38. What are/is the reason(s) why you have been using the chosen adaptative measure?...

....

....

....

39. Have you planned of changing the adaptation measure(s) you are using now? Yes [ ] No[ ]

Why?..

....

....

40. Do you sometimes face some challenges in implementing these adaptation measures?

Yes [ ] No [ ]

41. If yes, what are these challenges?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

42. If you do not use any of these adaptation measures, what has been the barrier(s) to adopting any of these measures?...

a) Traditional belief [ ]

b) Lack of information on climate variability and adaptation [ ]

c) Lack of finance to help cope with changes in the climate [ ]

d) Lack of labor force [ ]

e) Other (Specify)……………………… ……………………………………………….

43. What have been the effects of the chosen adaptation measure(s) on your Cocoa yield?

(a) Increased in cocoa yield [ ]

(b) Decreased in cocoa yield [ ]

(c) No change in cocoa yield [ ]

44. Do you know any government policy/policies put in place to mitigate the impact of climate change on cocoa yield? (a) Yes [ ] (b) No [ ] (c) Don't know any [ ]

45. If yes, which policy/policies do you know?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………..

B. Letter of Recommendation

NORWEGIAN UNIVERSITY OF LIFE SCIENCES (NMBU),
FACULTY OF LANDSCAPE AND SOCIETY (LANDSAM)
DEPARTMENT OF INTERNATIONAL ENVIRONMENT AND DEVELOPMENT STUDIES, NORAGRIC
UNIVERSITETSTUNET 1, TIVOLI, 1432 ÅS, NORWAY
DATE: 12TH APRIL 2022

Letter of official confirmation

This is to confirm that Mr. Isaac Owusu is currently enrolled as a full-time student in the two-year study program: Master of Science in International Environmental Studies, at the Faculty of Landscape and Society (LANDSAM) at the Norwegian University of Life Sciences (NMBU). Students in this program are encouraged to go for fieldwork to conduct their research and data collection for their Master's thesis.

Isaac Owusu's research will address the following topic: **'the impact of climate change and variability on Cocoa production and possible adaptation measures in Ghana, particularly the Amansie West District'**. According to his research proposal, the fieldwork will be conducted in Amansie West District in May 2022. His research proposal is approved by the Department of International Environment and Development Studies (Noragric) and his thesis will count toward 30 credits (ECTS) of his 120 credit Master's degree. His supervisor is Professor Bishal K. Sitaula.

We kindly ask you to assist our student where necessary and appreciate your facilitation of his fieldwork. If you have any questions, don't hesitate to contact the study administration at LANDSAM.

Sincerely, yours

Professor Bishal Sitaula, PhD

Leader of the Climate Change and Agriculture Development Cluster, Noragric, LANDSAM, NMBU

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