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ASSESSING THE EFFECTS OF CLIMATE CHANGE AND VARIABILITY ON COCOA PRODUCTION IN THE BIBIANI-ANHWIASO-BEKWAI MUNICIPALITY

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DECLARATION

I, VINCENT AFFI-DONKOR, author of the thesis **"ASSESSING THE EFFECT OF CLIMATE CHANGE AND VARIABILITY ON COCOA PRODUCTION IN THE BIBIANI-ANHWIASO-BEKWAI MUNICIPALITY",** hereby declare that this submission is my work towards the Master of Science (MSc.) Degree in Global Development 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 Mrs. Joyce Achiaa Asare and Ohenewaa Abena Pokua Donkor

ACKNOWLEDGEMENT

I am grateful to God for the strength given me, without which the successful completion of this thesis would not have been possible. I also thank my supervisor, Prof. Jens Bernt Aune, for his support, encouragement, and guidance towards completing this thesis. My appreciation also goes to my mother, Lydia Ackah for her support and the love they showed me in times of need. I also wish to thank the Ghana Cocoa Board personnel whose invaluable inputs and immense support made this possible. I am grateful to them all. Finally, I am also grateful to all my friends, especially Prince Asante, for their invaluable contributions to completing this work.

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ABSTRACT

Climate change is rapidly increasing the vulnerability of agricultural systems, particularly food production. One crop that is susceptible to climate change is cocoa (*Theobroma cacao*). Though there are extensive studies on the effect of climate change and variability on cocoa production in Ghana, little empirical research has been carried out in Bibiani-Anhwiaso-Bekwai municipality. Therefore, the study sought to assess the effects of climate change and variability on cocoa production in the Bibiani-Anhwiaso-Bekwai municipality. The study used multi-stage sampling techniques to purposely select 120 cocoa farmers in six (6) communities in the municipality for primary data collection. In addition, ten (10) key personnel from the Ghana Cocoa Board were interviewed to give experts insight into the study. Also, secondary data was sourced from Ghana Statistical Service, Ghana Meteorological Agency, and academic journals, which comprised data on climate trends and cocoa production. The study found that 68.3% of cocoa farmers said their cocoa yield was reduced compared to the previous years. They claimed that increased temperature and low rainfall have led to high mortality of young seedlings and mature trees, causing reduced fruit-bearing and low yield. However, data from the Ghana Meteorological Agency showed that rainfall in the study area has increased. Also, the study found that most of the farmers have adopted the use of fertilizer and pesticides, removal of mistletoes, and pruning as a measure to offset the shocks of climate change. These practices may not be effective in reducing the vulnerability to climate change in cocoa yield. However, a few farmers in the municipality have adopted new measures such as improved varieties and artificial pollination. In addition, 65.0% of cocoa farmers said they were unaware of any policy undertaken by the government to address the menace of climate change on cocoa production. On the other hand, the Ghana Cocoa Board personnel stated that the government has implemented a policy called Production Enhancement Programme (PEP's) that includes pruning, artificial pollination, and Cocoa Disease and Pest Control Programme (CODAPEC), among others which are geared towards addressing climate change effects on cocoa production. Only 24.2% of the farmers in the study area are aware of this programme. The study concludes that policies are required to address the challenges faced by climate change and variability to increase the productivity of cocoa farmers.

LIST OF ABBREVIATIONS AND ACRONYMS

BABDA	Bibiani Anhwiaso Bekwai District Assembly
BABM	Bibiani Anhwiaso Bekwai Municipality
CHED	Cocoa Health and Extension Division
CHTP	Cocoa Hi-Technology Programme
COCOBOD	Ghana Cocoa Board
CODAPEC	Cocoa Disease and Pest Control Programme
CRIG	Cocoa Research Institute of Ghana
ECOWAS	Economic Community of West African State
ERP	Economic Recovery Program
GDP	Gross Domestic Product
GFC	Ghana Forestry Commission
GMA	Ghana Meteorological Agency
GSS	Ghana Statistical Service
ICO	International Cocoa Organization
IPCC	Intergovernmental Panel on Climate Change
MoFA	Ministry of Food and Agriculture
NCRD	Norwegian Centre for Research Data
NGO	Non-Governmental Organization
PEP	Production Enhancement Programme
SPSS	Statistical Package for Social Sciences
UNCTAD	United Nations Conference on Trade and Development
UNFCCC	United Nations Framework Convention on Climate Chang

CHAPTER ONE: INTRODUCTION

1.0 Introduction

In Africa, the agricultural sector is one of the most vulnerable to climate change and variability, as it is heavily reliant on rainfall and other climatic variables such as temperature, sunshine, and relative humidity (Müller-Kuckelberg, 2012; IPCC, 2014). In most subtropical countries, the most detrimental consequences of climate change are increased environmental damage, frequent drought, increased rural-urban migration, increased infestation of crops by pests and diseases, increased biodiversity loss, depletion of household assets, among others. However, depending on the location, the magnitude of these impacts will ultimately be experienced differently (IPCC, 2007).

Temperature and rainfall changes in subcontinents are rapidly and uncertainly increasing the vulnerability of food production (Harris and Consulting, 2014). This is likely to intensify in the future with climate change affecting staple food crops in tropical regions (Nelson et al., 2009; Porter et al., 2014). Climate change is a significant driver of changes in crop yield and threatens crop production and its stability (Witjaksono, 2016). According to Agbongiarhuoyi et al. (2013) and Lawal and Emaku (2007), one crop susceptible to climate change is cocoa. Cocoa flourishes well at temperatures ranging from 18ºC to 21ºC as minimum temperatures and 30ºC to 32ºC as maximum temperatures (Anim-Kwapong and Frimpong, 2004). Furthermore, cocoa grows well in areas with annual rainfall ranging from 1500mm to 2000mm (Nair, 2010). This indicates that any decline below the mean minimum or rise above the mean maximum will negatively impact cocoa output and other factors such as fertilizer and pesticides application. Also, changes in rainfall patterns often affect cocoa production (Ehiakpor et al., 2016). The objective of this Ms.Sc thesis is to assess the effects of climate change and variability on cocoa production in the Bibiani-Anhwiaso-Bekwai Municipality of Ghana and to study the measures in place to address this problem.

1.1 Background of the Study

Cocoa is an important cash crop for the economies of the producing countries and the countries of consumption. It is one of West Africa's principal agricultural exports generating foreign currency for countries such as Côte d'Ivoire, Ghana, Nigeria, and Cameroon. The production in Côte d'Ivoire alone accounts for 40% of the market share worldwide and averages 1.2 million tonnes a year (UNCTAD, 2009), with Ghana and Nigeria contributing 20.98% and 6.70% respectively to the world market (Ofori-Boateng and Insah, 2014). Overall, 70% of the world's cocoa production originates from the West African sub-region (ECOWAS, 2007). The cocoa industry in the world now relies largely on West African cocoa because of the sheer amount of cocoa produced and the abundance of high-quality bulk cocoa, which cannot easily be replaced by cocoa produced in other regions.

In Ghana, cocoa plays a significant role in the socio-economic development of farmers and the country at large. The cocoa industry is central to job creation, education, health, foreign exchange and road construction. In 2002, cocoa contributed up to 22.4% of Ghana's total foreign exchange earnings (Parry, 2015). Despite the contribution of cocoa as the engine of growth to the Ghanaian economy, the yield of cocoa in Ghana is lower compared to major cocoa-producing countries like Cote d’ Ivoire, Indonesia, and Malaysia. Research has shown that Ghanaian cocoa farmers can produce an estimated 1000 kg/ha or more cocoa bean yield, but currently, the national average yield is estimated at 400 kg/ha (Aneani et al., 2007). The relatively low yield is attributed to factors such as climate change and variability, decreased soil nutrients, high incidence of pests and diseases, insufficient financial capital, weak institutions, and limited access to knowledge in agricultural practices. Among the above factors, the effects of climate change and variability on cocoa production is one of the greatest challenges in the cocoa industry.

Cocoa planting is highly determined by the start of the rain, and drought often reduces the survival of cocoa seedlings. In the case of mature plants, drought can lead to reduced yield by reducing the size of the bean. Too much rainfall, however, triggers infestations of the black pod, which is one of the serious diseases of cocoa. It is caused by *Phytophthora Palmivora,* a soil-borne fungus prevalent during the rainy season (Oluyole et al., 2013). Therefore, the disease is worse in heavy rainfall areas. Seedlings and tree leaves are attacked and destroyed under extreme disease conditions following long periods of cool and rainy weather. The disease causes the rotting of pods. Black pod disease losses vary from place to place and from variety to variety (Oluyole et al., 2013). Sunshine normally improves the quality of cocoa beans. In general, climate changes are important factors that affect crop yields, production, soil utilization, and conservation.

Despite the burgeoning studies on the impact of climate change on cocoa production and adaptation of cocoa to climate change, there has not been much research on the effects of climate change and variability on cocoa production in the context of the Bibiani-Anhwiaso-Bekwai Municipality in the Western North Region of Ghana. Although Kumi and Daymond (2015) have done a study in this area, the focus was on farmers' perception on the effectiveness of Cocoa Disease and Pest Control Programme (CODAPEC) in Ghana and its effects on poverty reduction. Therefore, this work aimed at filling this lacuna by assessing the effect of climate change and variability on cocoa production in the Bibiani-Anhwiaso-Bekwai Municipality in the Western North Region of Ghana. The study sought to address the following research questions:

1. How has climate change and variability affected cocoa yield in the Bibiani-Anhwiaso-Bekwai municipality?
2. What are the adaptation strategies used by cocoa farmers to improve cocoa yield in the municipality?
3. What are the effects of the adopted strategies on cocoa yield and economic returns?
4. What are the government policies in place to address the effects of climate change and variability on cocoa production?

1.2 Objectives of the Study

The main objective of this study is to assess the effects of climate change and variability on cocoa production in the Bibiani-Anhwiaso-Bekwai municipality.

The specific objectives of the study are to:

- Assess the effect of climate change and variability on cocoa yield in the Bibiani-Anhwiaso-Bekwai Municipality.
- Identify adaptation strategies used to improve the output of cocoa in the Bibiani-Anhwiaso-Bekwai Municipality.
- Examine the effect of the adopted strategies on cocoa yield and economic returns.
- Identify government policies adopted to address the effect of climate change and variability on cocoa production.

1.3 Justification for the Study

It is an undeniable fact that cocoa is the most important cash crop in the economy of Ghana. An increase in farmers' productivity means a rise in the country's export earnings and Gross

Domestic Product. Every country aims to achieve the highest possible growth and development to improve people's overall wellbeing and living standards. However, as the cocoa sector in Ghana is plagued with high exposure to droughts and temperature extremes and other ecological problems (Dormon et al., 2004; Onyeiwu et al. 2011), yields are on average 350 kg/ha, which is far below major cocoa-producing countries such as Cote d'Ivoire and Malaysia with yield averaging 800 kg/ha and 1700 kg/ha respectively (Danso-Abbeam et al., 2012).

This study is critical, particularly at a time when the global cocoa sector is investing in productivity gains through sustainable agriculture as one of the major pipelines for higher income and sustainability of cocoa (Witjaksono, 2016).

The aim of this research is to assess the effects of climate change on cocoa production. The findings may also assist policymakers in updating and making policies in the cocoa industry to increase yield.

1.4 Organisation of the Study

The study is organized into six chapters. The first chapter gives the background, the research questions, the objectives, the justification, and the organisation of the study. Chapter two presents a literature review on climate change and variability on cocoa production and the conceptual approach. Chapter three introduces the research methodology with a description of the study location, followed by the research design, data collection and analysis, ethical consideration, and limitation of the study. Chapter four presents the results and discussion in relation to the objectives. Finally, chapter five outlines the conclusions and recommendations for policy and proposes future research.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Climate change caused by anthropogenic factors has changed temperature and precipitation patterns. Global agricultural yields, especially cocoa, are expected to be reduced because of these new trends (Schroth et al., 2016). As a result, the prospect that climate change may affect the amount of cocoa produced in Ghana is worth studying. This chapter addresses the following main themes: cocoa and development in Ghana, cocoa cultivation and productivity in Ghana, climate trends and projection in Ghana and Bibiani-Anhwiaso-Bekwai Municipality, the impact of climate change on cocoa production in Ghana, adaptability to climate change by farmers in Ghana and the conceptual approach.

2.1 Cocoa and Development in Ghana

Cocoa is an important cash crop in the global economy. It serves as a source of livelihood for millions of smallholder farmers in 50 countries across the region of Africa, Latin America, the Caribbean, and Asia (Parry, 2015). Parry (2015) shows that in West Africa, it is essentially a small-scale crop grown on 1.2 to 1.5 million farms ranging from 1.2 to 2.8 hectares in size and employing over 10 million people. Until the 1970s, Ghana was the world's leading producer of cocoa. Cocoa was Ghana's highest foreign exchange earner accounting for about 45% even as far back as the 1960s. Even until the 1990s, cocoa accounted for about 35% of the country's total export earnings annually (Essegbey et al., 2012).

Ghana is currently the world's second-largest producer of cocoa in the world with an average total annual output of around 800,000 metric tons (Asamoah and Owusu Ansah, 2017). The crop is second only to gold in foreign exchange earnings, contributing over half of Ghana's total agricultural export revenue. In 2012, cocoa accounted for approximately 30% of Ghana's overall export earnings, 19% of agricultural GDP, and 3.0% of the national GDP (Quarmine et al., 2012; GSS, 2013). For cocoa farmers in Ghana, it is estimated that the cocoa sector contributes between 70% to 100% to annual household earnings and employs about 3.2 million workers representing 60% of the national labour force in the agricultural sector (Anang et al., 2013). Asamoah and Owusu Ansah (2017) further showed that cocoa accounts for over 67% of household income in Ghana's cocoa-producing areas. This is an indication of the significance of cocoa to smallholder farmers and poverty reduction. According to Kolavalli and Vigneri

(2011), a household survey showed that poverty among cocoa-producing households dropped to 23.9% in 2005, down from 60.1% in the early 1990s. Other stakeholders such as chemical companies, input distributors, and licensed cocoa buying companies also largely depend on cocoa for markets for their products, income, and employment (Asamoah and Baah, 2003).

Cocoa occupies a special role in the economy of Ghana. It has long played an essential role in Ghana's economic development and remains a significant source of rural employment. It remains the country's most important agricultural export product (Parry, 2015).

2.2 Cocoa Cultivation and Productivity in Ghana

According to Parry (2015), there has been a slow technological development in cocoa production. However, farmers have started to use hired labour to weed and purchase pesticides to control pests and diseases. Mawutor (2018) shows that cocoa production in Ghana is labour and capital-intensive and is strictly market-oriented. Furthermore, he indicates that cocoa is heavily reliant on rain, and as such, it is predominantly found in the forest region of Ghana.

Growth in cocoa production became evident from 2001 (Kolavalli and Vigneri, 2011). According to Kolavalli and Vigneri (2011), cocoa production in Ghana has had four distinct phases. These phases are: "introduction and exponential growth (1888–1937); stagnation followed by a brief but rapid growth following the country's independence (1938–64); near collapse (1965–82); and recovery and growth or expansion, starting with the introduction of the Economic Recovery Program (ERP) (1983 to present)". Osei (2017) indicates that the implementation of the ERP increased the price paid to Ghanaian cocoa farmers relative to those paid in neighbouring countries. Furthermore, farmers were paid for the destruction of trees infested with the swollen shoot virus and the planting of new cocoa trees. This resulted in many farmers planting higher-yielding cocoa varieties created by the Cocoa Research Institute of Ghana (CRIG).

Changes have taken place in the country's cocoa production technology in the past years. Kolavalli and Vigneri (2011) highlight that there has been an increased use of fertilizer, the adoption of hybrid cocoa varieties, and the use of better pest and disease control systems. Again, Osei (2017) posits that initiatives by the Government of Ghana through the mass spraying scheme and HI-TECH subsidy packages have encouraged the implementation of a higher and more regular fertilizer application since the 2001/2002 growing season. Moreover, combined with a dramatic rise in world cocoa prices, the Cocoa Diseases and Pests Control programme (CODAPEC) has encouraged more farmers to increase their yield. From the onset, these measures saw a massive rise in national cocoa production in the 2002/2003 cocoa-growing season (Baah *et al.,* 2011). The impact of climate variability on the development of cocoa makes these government initiatives ineffective. The hybrid cocoa variety that Ghanaian cocoa farmers are encouraged to grow only ensures a continuous higher yield with extensive fertilizer and pesticide application (Osei 2017). Farmers are unable to afford this in most situations, resulting in persistent low yields. Kolavalli and Vigneri (2011) have noted that cycles are intrinsic to cocoa production because cocoa is impacted by environmental factors such as forest land availability, erosion, disease outbreaks, and regional production shifts together with economic and social factors such as migration.

Cocoa productivity in Ghana is estimated at 313- 400 kg/ha (Aneani and Ofori Frimpong, 2013). Compared to annual yield rates of countries such as Cote d'Ivoire (600kg/ha) and Indonesia (1000kg/ha), annual yield rate of Ghana is very low considering that most of the land for agriculture is utilized for cocoa production (Appiah *et al*., 1992; Anim-Kwapong and Frimpong, 2004; Frenzen and Mulder, 2007). Several causes, such as volatile climate conditions, poor agricultural methods, seasonal bushfires, illicit mining operations, and insect infestations, have been attributed to the low productivity (Osei, 2017). Most of these factors are heightened by climate variability, especially rainfall and temperature (Osei. 2017).

According to Anim-Kwapong and Frimpong (2004), the most damaging disease impacting the growth and ripening of the cocoa pod is the extremely infectious black pod disease. The high incidence of black pod disease is due to high relative humidity in the morning across West Africa. According to Danso-Abbeam et al. (2014), factors such as the age of cocoa farmers, gender, household size, farmer-based association participation, educational achievement, and age of trees contribute to the productivity of cocoa farmers. Regarding the Western North region of Ghana, where the town of focus in this study is located, Mawutor (2018) concluded that technical and institutional factors influence the total productivity of cocoa in the area. He also indicated that adult cocoa farmers are more productive than youth cocoa farmers in the area.

Figure 2 shows cocoa production from the 2012/2013 crop season to the 2018/2019 crop season. The graphs indicate a fluctuation in cocoa productivity. Dorman et al. (2004) noted that this variability could be attributed to socioeconomic, biological factors, and policy directions.

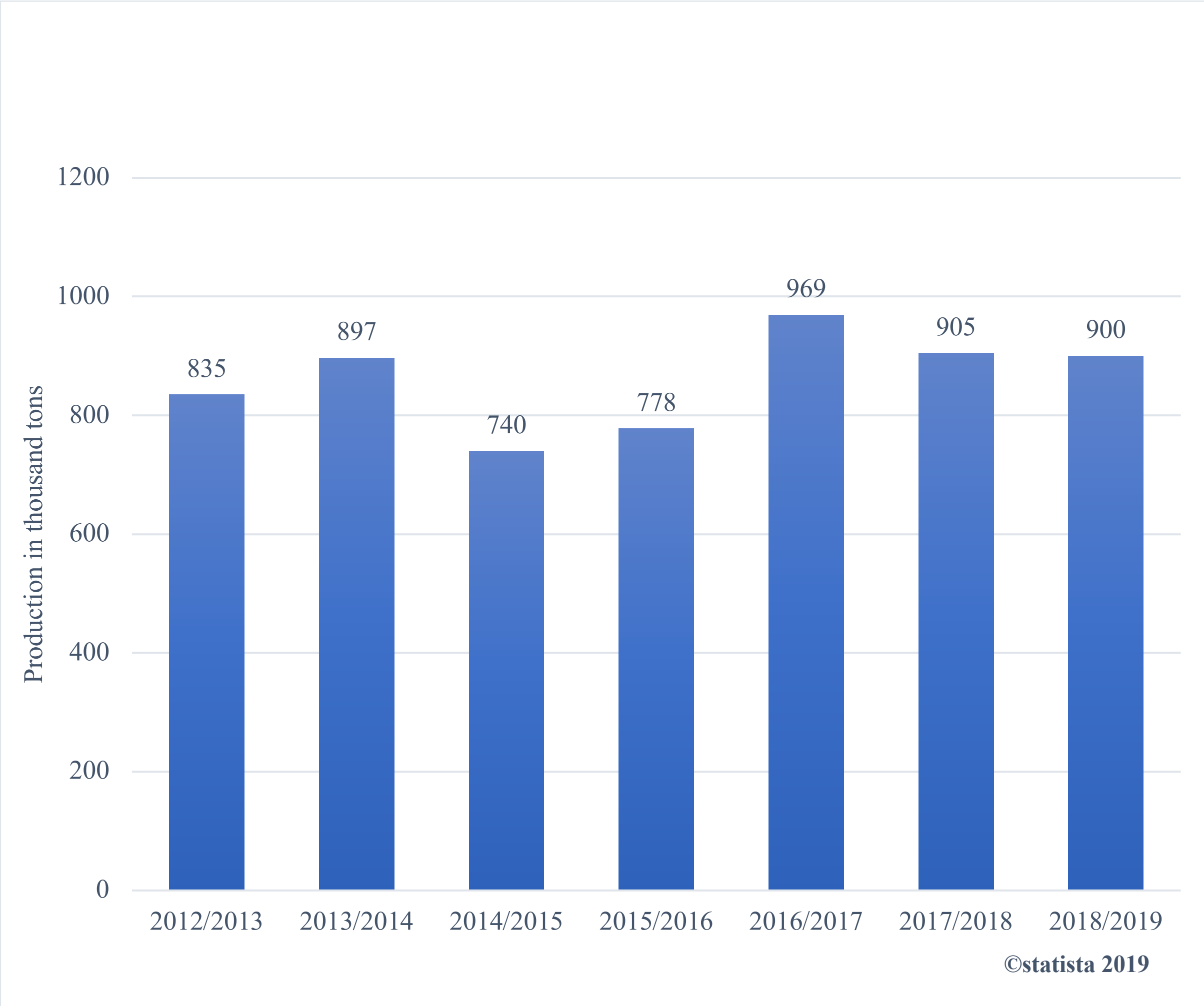

Figure 2: Production of cocoa beans in Ghana from 2012/2013 to 2018/2019 (in 1,000 tons)

Source: Statista.com (2019)

2.2.1 Conditions Necessary for Cocoa Cultivation

Cocoa is said to be a delicate and sensitive plant (cocoalife.org, 2021). Therefore, rainfall must be abundant and evenly distributed throughout the year for cocoa trees to thrive. For optimal yield, yearly rainfall levels of 1,500mm to 2,000mm are required. According to Ahenkorah (1981), the best soils for cocoa production have a pH of 5.6-7.2 in a 1:2.5 water, a C/N ratio of 10-12, organic carbon of not less than 3%, a base exchange capacity of 3-15 me/100g soil, availability of P more than 20ppm in the 0-5 cm layer and 15ppm in the 0-20 cm layer (using buffered 0.002N H_2SO_4 extractant), exchangeable potassium (K) not less 0.25/100g soil, and 8-13 me/100g soil (Ca + Mg). Moreover, rainforest trees to provide shade and protection from harsh sunlight and wind damage are also important to cocoa cultivation (cocoalife.org, 2021). Because cocoa trees are sensitive to climate, they can only thrive in areas located between 20 degrees north and south of the equator (cocoalife.org, 2021).

2.2.2 Factors Affecting Cocoa Productivity in Ghana

The importance of cocoa in Ghana's economy cannot be understated. Due to its contributions to overall Gross Domestic Product and status as the largest foreign exchange earner among all agricultural commodities, the cocoa subsector has been a major area of interest to policymakers. Amoah (2013) notes that except for the mid-1980s and early 1990s, output levels have not been consistent throughout time. Even though the yield appeared to be on track in 2000, it has had several inconsistencies. This has been attributed to several factors.

Anim-Kwapong and Frimpong (2004) show that cocoa producer price impacts productivity in Ghana. He indicates that farmers adjust the intensity with which they tend their fields in response to price changes. If prices are insufficient to cover regular variable expenditures like maintenance, the farmer's initial reaction will be to cut farm maintenance and halt new planting operations. Thus, harvesting will be low if prices are low. In contrast, farmers will enhance farm management if prices recover or exceed variable costs, which will lead to more harvesting.

Rainfall and drought are noted to be factors affecting cocoa productivity in Ghana. Anim-Kwapong and Frimpong (2004), who used multiple regression analysis to determine the effect of climate change on cocoa yield, indicates that per the analysis, “60% of the variation in dry cocoa beans could be explained by a combination of the preceding year’s total annual rainfall, total rainfall in the driest months, and sunshine duration”. Moreover, Oppong (2017) also shows that in times of drought, bush fires have become more widespread as a result of the actions of smokers, rat hunters, and farmers who adopt slash and burn farming methods. Normally, this results in a significant fire outbreak that destroys a large number of cocoa fields, which ultimately affects harvest.

The role of pests and diseases is also worth mentioning. Cocoa production is plagued by pests and diseases caused by a variety of insect species, as well as fungal and viral pathogens and rodents. Pests and diseases with a high occurrence have devastating impacts on production targets and economic value (Kumi and Daymond 2015). According to Kumi and Daymond (2015), Black pod (Phytophthora pod), Cocoa Swollen Shoot Virus, Witches Broom, Moniliasis pod rot, and Vascular-Streak Dieback are the five principal diseases that harm cocoa, while pests include insects such as Mirid, Mealy Bugs (Planococcus lilacinus), Red borer (Zeuzera coffeae), Cockchafer Beetle (Leucopholis spp.). Striped Squirrels (*Funambulus tristriatus*), which is a non-insect pest, is also a problem. Parry (2015) notes that the most devastating of the numerous illnesses that damage the developing or ripening cocoa pods around the world is the black pod disease. In Ghana, it has been noted that Phytophthora palmivora and P. megakarya are the two Phytophthora species that cause the illness (Parry, 2015). Moreover, Parry (2015) indicates that Capsid pests (miridae) which are sucking insects, also cause damage to the cocoa tree's soft, young tissues by piercing the young shoots with their mouthparts, injecting poisonous saliva, and then sucking liquid nourishment out of the wound. As a result of this, the affected shoot perishes. Oppong (2017) adds mistletoe, a parasitic that grows on cocoa trees. If not removed early, they harm the young branches of cocoa trees. Mistletoe is handled by completely removing the mistletoe-infested areas of the tree to prevent it from spreading to other sections of the tree.

Oppong (2017) noted that human and socio-cultural factors also affect cocoa productivity in Ghana. These factors he noted are labour, modern equipment, age of trees, the quantity of fertilizer used, pesticides, and farm sizes. Most major cocoa-producing countries employ more modern technology compared to Ghana. Fertilizers and insecticides are rarely used by most farmers. However, Vigneri, M. (2007) indicates that for each “1% increase in farm area dedicated to cocoa, there is a 0.5% increase in production, and for 1% increase in the usage of fertilizer and labour, there is a 0.09% and 0.07% increase in growth respectively”. Notwithstanding, government programs such as the Cocoa Diseases and Pests Control Programme (CODAPEC) and the Cocoa Hi-Technology Programme (CHTP) are helping to fill some of these loopholes.

Considering the above, Kwabena (2013) indicates that the causes of low cocoa productivity in Ghana can be categorised under biological factors and socio-economic. Biological factors are pests and diseases while the socio-economic are low producer price, inadequate and high cost of labour, and lack of amenities, including modern technology.

2.3 Climate Change and Cocoa Production

Globally, the increasing instability and unpredictability of rainfall patterns, along with rising temperatures, has posed a severe challenge to agricultural productivity. Climate change impacts various locations in different ways, with possible benefits for certain geographical areas, while making agriculture more difficult in many drought-prone locations like Sub-Saharan Africa (Kyere, 2018). According to Kyere (2018), cocoa production depends heavily on land, rainfall, and sunshine. He showed that cocoa is vulnerable to high temperatures and drought as these elements potentially reduce the vitality of the cocoa plant. Anim-Kwapong and Frimpong (2004) indicate that climate change also affects the stages and rates of development of cocoa pests and pathogens, as well as host resistance and the physiology of host-pathogen/pest interactions. According to Anim-Kwapong and Frimpong (2004), these may result in changes in the geographical distribution of hosts and pathogens/pests, altered crop yields, and crop losses, all of which will have an impact on socioeconomic variables such as farm income, livelihood, and farm-level decision making. Anim-Kwapong and Frimpong (2004) indicate that cocoa production in Ghana is affected greatly by climate change. As a result, more research is needed to understand the effects of climate change on cocoa production as well as the possibilities for adaptation to climate change.

2.3.1 Climate Trends and Projection in Ghana

Climate change has been a major global concern in the last two decades. This is due to recent changes in climatic conditions already affecting physical and biological systems on all continents. Most Sub-Saharan African countries, including Ghana, are vulnerable to climate change and variability. According to Armah et al. (2019), studies on climate change indicate that precipitation has been reduced since the 1960s and rainfall patterns have been noted to be uneven. Temperatures have increased over the years. McSweeney et al. (2010) note that since 1961, the average annual temperature has risen by 1.0^0C or 0.21^0C for each decade. The mean annual temperature is estimated to rise by 1.0°C to 3.0°C by the 2060s, and 1.5°C to 5.2°C by the 2090s and this will raise both day and night temperatures, making cocoa more susceptible in such conditions. According to the IPCC report (2021), since 1850, each of the last four decades has been successively warmer than the decades before it. Asante and Amuakwa-Mensah (2015) also show that according to World Bank projections, the temperature trend from 2010 to 2050 predicts warming in all regions of Ghana, with the greatest temperatures in the

Northern, Upper East, and Upper West regions. The Brong Ahafo area, on the other hand, will have the lowest temperature. Moreover, it was revealed that depending on the scenario, temperatures in the three northern areas will rise by 2.1-2.4 °C by 2050. The anticipated rise in the Ashanti, Western, Eastern, Central, and Volta areas is 1.7-2.0 °C, whereas the Brong Ahafo region is 1.3-1.6 °C. Regarding rainfall, Wongnaa and Babu (2020) indicate that annual rainfall in Ghana is uneven, as such making long-term forecasting somehow difficult. Rainfall is expected to decrease across the entire country in 2020, 2050, and 2080, according to eco-climatic projections (Minia, 2008). For 2020, 2050, and 2080, the decrease in rainfall tends to increase from north to south, -1.1%, -6.7%, -12.8% in the Sudan Savanna Zone to -3.1%, -12.3%, -20.5% in the Coastal Savanna Zone respectively. The Deciduous Forest and Rain Forest Zones are expected to have the greatest absolute change in rainfall. These changes are going to have a negative impact on agriculture and cocoa production, for that matter, if efficient adaptability measures are not ensured. However, the sixth assessment report of the IPCC (2021) does not support the findings of Minia (2008). The IPCC report predicts that the frequency and severity of heavy rains are expected to rise almost everywhere in Africa with further increases in global warming.

2.3.2 Climate Trends in Bibiani-Anhwiaso-Bekwai Municipality

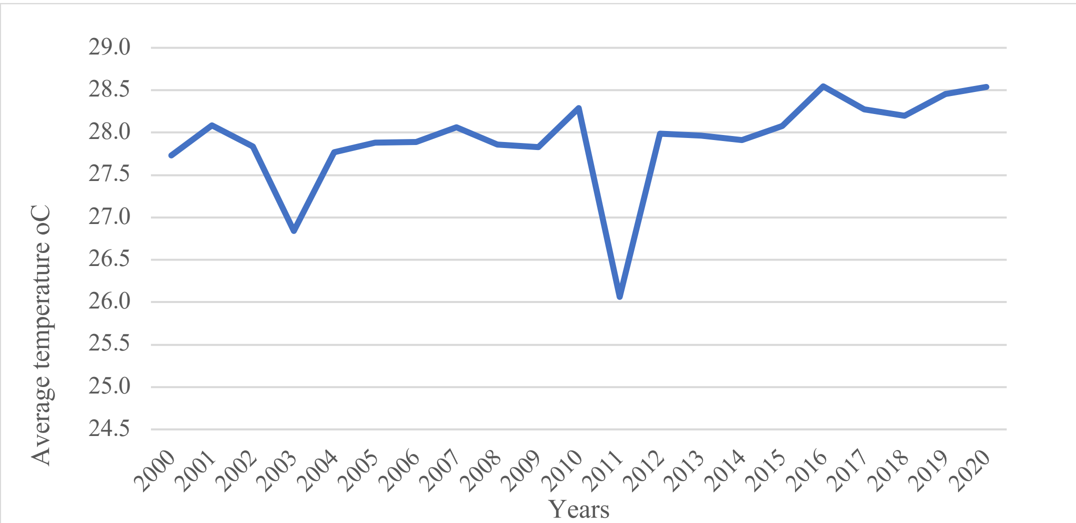

Figure 3 Trend of average annual temperature in the Western North Region from 2000-2020

Source: Ghana Meteorological Service, 2021

Figure 3 shows the average annual temperature for the past 20 years of the Bibiani-Anhwiaso-Bekwai municipality. From the figure, temperature increased from 27.7°C-28.3°C from 2000 to 2009 respectively, except in 2003 where temperature decreased to 26.3°C. Again, there was a decrease in temperature to 26.1°C in 2011 and since then, the temperature has increased from 28.0°C in 2012 to 28.5°C in 2020. According to the IPCC report (2021), the rate of surface temperature increase has generally been faster across Africa than the global average, with human-induced climate change being the primary driver. The report further states that with additional global warming, increase in hot extremes and decreases in cold extremes are estimated to continue throughout the 21st century. A study conducted by Daze (2007) also predicted a steady rise in temperature across the different ecological zones in Ghana. Extremely high temperature intensifies the spread of capsid pests in cocoa production. It also reduces soil water reserves through evapotranspiration, lowering yield by reducing pod set and, eventually, bean sizes.

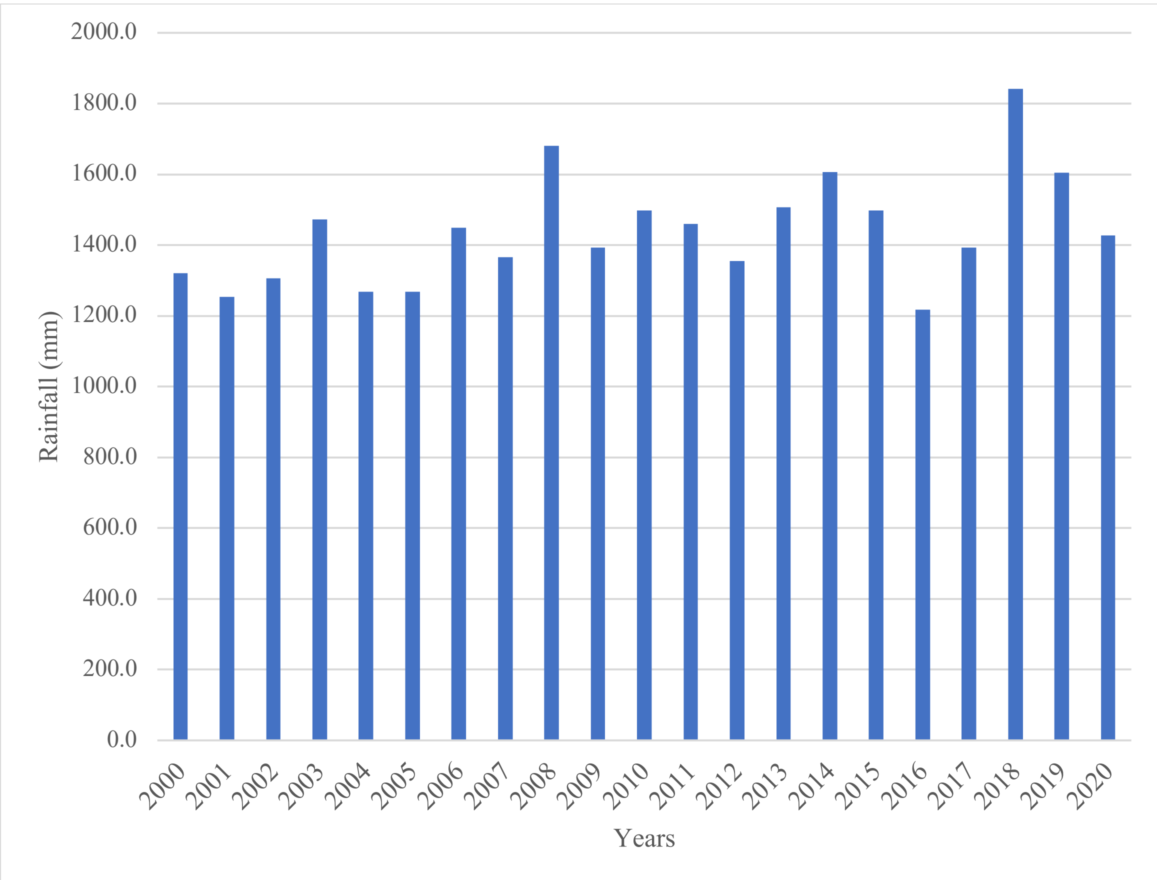

Figure 4:Trend of total annual rainfall in the Western North Region from 2000-2020

Source: Ghana Meteorological Service, 2021

Figure 4 also shows the total annual rainfall pattern for the past 20 years of the Bibiani-Anhwiaso-Bekwai municipality. The figure shows that the annual rainfall for the study area has increased from 2000 to 2020, with the highest rainfall (1842.1mm) recorded in 2018. According to the IPCC report (2021), at 1.5°C global warming, extreme rainfall is expected to increase in most regions in Africa. In addition, there is an expected increase in mean wind speed and pluvial flooding across the West and Central African sub-region.

2.3.3 Impact of Climate Change on Cocoa Production in Ghana

Natural factors such as land, rainfall, and sunshine have all a significant role in cocoa production. Cocoa is vulnerable to high temperatures and drought since these factors might reduce the vitality of the cocoa plant. Cocoa seedlings cannot thrive in high heat or extended drought. Under high temperatures, most cocoa flowers wither and tear down. In rare circumstances, mature cocoa plants may perish as a result of prolonged drought and high temperatures. Worthy of note is that the impact of climate change on agricultural output varies by location. Few studies on the effect of climate change on cocoa production are done in Ghana. For example, Wiah and Twumasi-Ankrah (2017) note that high temperatures and the number of rainy days adversely affect cocoa yield while low temperatures and high precipitation affect yield positively.

Moreover, Anim-Kwapong and Frimpong (2004), in their assessment of the impact of climate on dry cocoa beans, show that "over 60% of the variation in dry cocoa beans could be explained by combining the climate trends in the two driest months together with the amount of total sunshine in that season". Codjoe et al. (2013) show that climate change has a substantial impact on the occurrence of cocoa pests and diseases, and therefore alters their interactions. As such, they assert that cocoa production in Ghana is substantially affected by climate change. Wongnaa and Babu (2020) show that Ghana's cocoa farmers are fully aware of climate change, its causes, and the risks it presents to their operations. However, research shows that only a small percentage of farmers use some sort of adaptation technology, although adaptation technologies are an important part of creating resilience to climate change. Considering the unfavorable climate forecasts, with Ghana also aiming to reclaim its position as the world's leading cocoa producer, stakeholders in the cocoa sector should be concerned about the issue of climate change and as such, act proactively.

2.4 Climate Adaptation

According to the International Panel on Climate Change (IPCC, 2001), "adaptation is an intervention, which is embarked upon so as to manage the losses or take advantage of the opportunities presented by a changing climate". It may be regarded from two perspectives: anticipatory, where initial readiness mechanisms are in place to stop and reduce any potential impact, and reactive, where a response mechanism is only implemented at the beginning or at the point where impact is felt. Anim-Kwapong and Frimpong (2004) show that climate change adaptation, therefore, entails taking steps to mitigate the adverse effects of climate change. Okyere (2016) argues that adaptation has the ability to reduce the bad effects of climate change while enhancing the positive effects, but it will come at a cost and will not avoid all losses. He notes that adaptive steps are taken to avoid any immediate or impending effects that may occur as a result of climate change. However, certain adaptive activities may be performed to deal with circumstances where genuine climate change consequences do occur. The ultimate objective of adaptation measures should be to improve the system's ability to deal with negative shocks. Oyekele et al. (2009) indicate that agricultural adaptations consist of two (2) types of production system modifications. The first option is to increase diversification, which entails engaging in temperature-stress and drought-tolerant production activities. This includes actions that take full advantage of the current temperature and rainfall conditions and make efficient use of them. The second option is to focus on crop management strategies that are aimed at avoiding crucial crop growth stages colliding with severe weather circumstances. However, most agricultural methods used in Ghana and most other Sub-Saharan African nations are climate change adaptation technologies that can help farmers build resilience to the negative effects of climate change provided they are well-planned and maintained with the larger landscape in mind (Wongnaa and Babu, 2020).

The employment of shade trees in cocoa fields, for example, will be a feasible adaptation strategy to minimize the sensitivity of cocoa to high dry season temperatures. Hassan and Nhemachen (2008) also note that the use of fertilizers and insecticides, as well as providing insurance to agricultural crops, are significant climate change adaptation methods. According to Deressa (2008) and Nwachukwu and Shisanya (2017), "lack of information about the weather, shortage of labour, lack of access to appropriate seed, the poor potential for irrigation, and inadequate financial resource are the major barriers to climate adaptation faced by farmers in Ghana". Adaptation is difficult as most measures are costly. Most farmers are unable to adjust due to a lack of financial means. Due to their inability to modify and cope with climate change because of several reasons, some farmers may be unable to use any adaptation strategies to minimize the effects of climate change. Lastly, having access to weather information coupled with experience in farming can also determine or influence farmers' ability to adapt to climate change (Okyere, 2016).

2.5 Conceptual Approach: Climate Change and Variability, and Adaptation

The aim of this study is to assess the effect of climate change and variability on cocoa production in the Bibiani-Anhwiaso-Bekwai municipality. So far, very little or no study of this kind has been conducted in the study area; therefore, the study aims to fill this gap. This section, therefore, highlights the conceptual framework that underpins this work.

Climate change and variability: According to Rahman (2013), climate change literally refers to long-term changes in the distribution of weather patterns (e.g., temperature, precipitation, and so on) across decades to millions of years. He notes that Earth's climate has been altered on all time scales long before human activity could have played a part in its alteration. Also, according to Gale.com (2018), climate change denotes the gradual alteration of the Earth's temperature, humidity, air pressure, wind, clouds, and precipitation patterns. However, Climate Change, as defined by the United Nations Framework Convention on Climate Change (UNFCCC), refers to a change in climate that is attributed directly or indirectly to the activities of humans that alter the structure of the atmosphere in addition to natural climate variability observed across comparable time periods (Greene, 2000). On the other hand, climate variability refers to the climatic parameter of a region varying from its long-term mean. It means changes in climate that occur within smaller timeframes, such as a month, a season, or a year. Climate variation is any unusual change from a state's normal or mean annual climate record or season over several weeks or months from the usual pattern as experienced by the state. Climate change and variability denote a shift in the average temperature and rainfall conditions of a region.

Adaptation: According to UNFCCC (2020), adaptation refers to adjustment in ecological, social, or economic systems in response to current or anticipated climatic stimuli, as well as the repercussions or impacts of such changes. It refers to adjustments in procedures, methods, and structures used to mitigate possible losses or capitalize on possibilities brought about by climate change. Successful adaptation is dependent not only on governments but also on the active and sustained engagement of stakeholders such as national, regional, multilateral, and international organizations, the public and private sectors, civil society, and other stakeholders, as well as effective knowledge management (UNFCCC, 2020). Climate conditions and its impacts demand that Governments and communities must create adaptation solutions and execute plans to respond to current climate change consequences as well as plan for future repercussions. For this study, Adaptation is conceptualized as environmental and social measures and strategies adopted and implemented to offset the shocks of climate change and variability.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter presents the research methodology with a description of the study location, followed by the research design, data collection and analysis, validity and reliability, ethical consideration as well as limitations of the study.

3.1 Overview of Study Area

The area of study for this research is the Western North Region of Ghana. The region was carved out from the former Western Region and was created in 2019. The region is bordered by the Ivory Coast on the West, the Central region in the southeast and the Ashanti and Bono in the north. The region has an area of 10,074km^2 and a population of 1,168,235 (Ghana Statistical Service, 2019). Before being established as a region on its own, the Western North Region as part of the Western Region was Ghana's largest cocoa producing area until 2015/2016, when it became second to the Western South Cocoa region (Mawutor, 2018).

As noted by Mawutor (2018), the region comprises the following cocoa districts, namely, Bibiani-Anhwiaso-Bekwai district, Sefwi Akontombra district, Bodi district, Juabeso district, Suaman district, Sefwi Wiawso district, Bia East district, and Bia West district. The area has been the nation's largest producer of cocoa in the last decade, producing about 202,261 metric tons in the production year of 2015/2016 (Mawutor, 2018).

Most of the indigenous people of the area are either formally or informally engaged in cocoa production in the region. For this study, the district chosen to be focused on is Bibiani-Anhwiaso-Bekwai district. The Ghana Cocoa Board, which is the management body of cocoa production and trade classify cocoa regions and districts based on the scope of operations of the region. The aim is to ensure effective targeting for policy implementation and input distribution by the management body (Mawutor, 2018). The map of the region and the cocoa districts therein are represented in Figure 4 below.

Bibiani-Anhwiaso-Bekwai Municipality is one of the cocoa areas in the Western North Region of Ghana. The municipality is situated between latitude 6º 3" N and longitude 2º 3" W (Fig.5). It is one of the most important cocoa-producing areas in Ghana, covering an estimated 873 km^2 of land. An approximate 62% representing 39,829 hectares out of 54,240 hectares of the total arable land available for both cash and food crops, such as cocoa, wheat, plantain, and cassava, is cultivated (MoFA, 2013). The land topographically rises from approximately 350 metres to 660 metres above sea level (Quarshie E. et al., 2011).

Bibiani-Anhwiaso-Bekwai is climatically in the wet semi-equatorial rainforest zone. The municipality has bimodal patterns of rainfall between March-August and September-October. The average annual rainfall is from 1200mm to 1500mm with the peak periods between June and October (Annan B.T. et al., 2011). The dry season lasts between November and January. The municipality has a consistent average temperature of around 26^0C all year round with a relatively high humidity averaging 75% to 95% daily (MoFA, 2013). The favourable climate, combined with the high fertility of forest Ochrosols and forest Oxysols soil, encourages the production of cocoa and makes it the most important cash crop grown by farmers (BABDA, 2006).

In addition, food crops such as rice, cassava, black pepper, and plantain are grown on an average farm size of 1.5 hectares (Ghana Statistical Service, 2012). Predominantly, Bibiani-Anhwiaso-Bekwai municipality is agrarian with an estimate of 61% of labour force, engage in agricultural activities such as crop and mixed farming as well as animal husbandry. The industrial sector is dominated by mining activities such as gold in Bibiani and Chirano and bauxite in Awaso. According to the MoFA during the 2010 Population and Housing Census of Ghana, Bibiani-Anhwiaso-Bekwai municipality's population stood at 123,272, with 49.4% males and 50.6% females (MoFA, 2013). The map of the region and municipality are shown in Figures 5 and 6 respectively below.

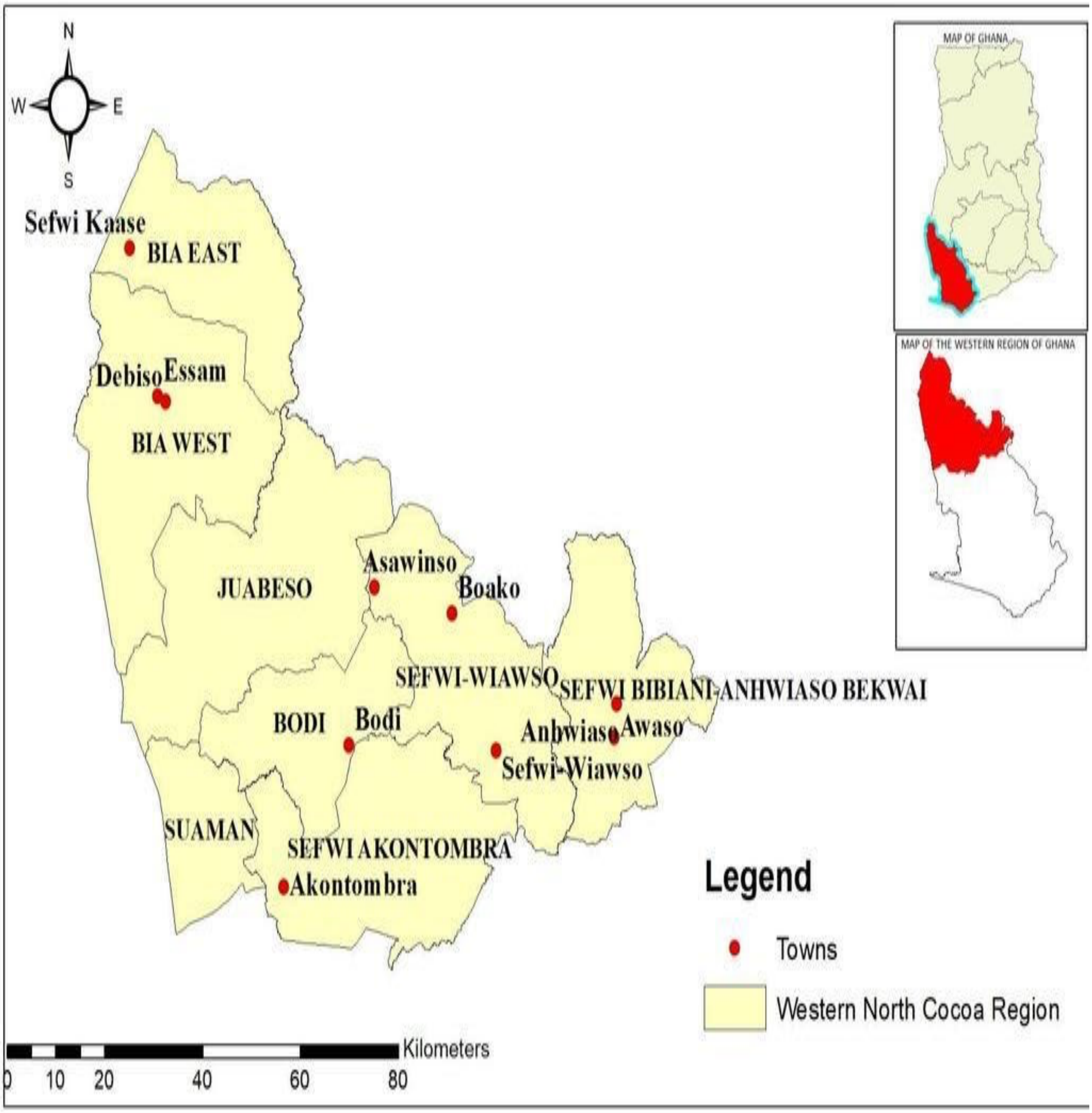

Figure 5:Map of the cocoa districts in the Western North Region.

Source: University of Ghana, 2018

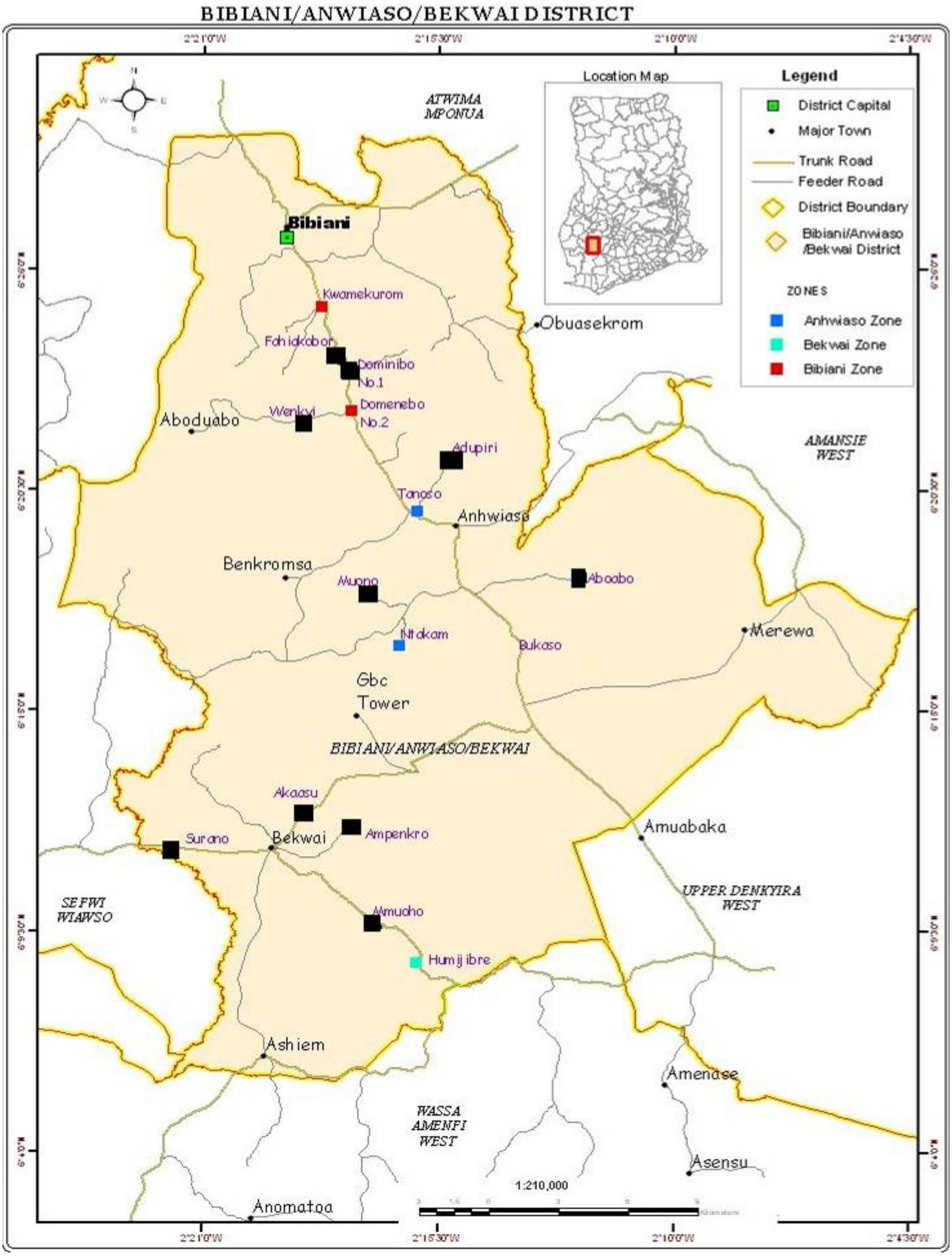

Figure 6:Map of the Bibiani-Anhwiaso-Bekwai Municipality

Source: Danso-Abbeam, 2010

3.2 Research Design

According to Bryman (2016), a research design provides a framework for the collection and analysis of data. It is case study research that aims at assessing the effect of climate change and variability on cocoa production and measures to mitigate these impacts. A case study approach is appropriate in this regard because it entails the detailed and intensive analysis of a single case or multiple cases (Bryman, 2016). This research can be classified as both qualitative and quantitative. It is considered qualitative in the sense that interviews were conducted with personnel from the Ghana Cocoa Board to ascertain government policies undertaken to address the effects of climate change and variability on cocoa production. The work is also considered quantitative because of the use of questionnaires and the Statistical Package for Social Sciences (SPSS) employed in the analysis of the primary data to draw conclusion. Bibiani-Anhwiaso-Bekwai municipality of the Western North region was selected as the area of analysis. The selection of this municipality was due to its dominance in cocoa production among the cocoa-producing areas of the region. The work drew insight from both primary and secondary data. The primary data was analyzed with the use of the Statistical Package for Social Sciences (SPSS). On the other hand, the secondary data was analysed and interpreted by the usage of desk analysis approach.

3.3 Data Collection and Sampling

This study used both primary and secondary data. Primary data is data collected by the researcher through strategies such as surveys, interviews, and experiments to help explain and solve the research problem at hand (Wagh, 2020). Secondary data, on the other hand, involves using existing data generated by government agencies, healthcare services, and other institutions to keep track of their records. The information is then retrieved from a variety of data files.

The primary data for this study was sourced using questionnaires and one-to-one interviews.
A structured questionnaire comprising both close-ended and open-ended questions summing up to 29 questions was administered. Closed-ended questionnaires made it easier to compare responses from respondents, while open-ended questionnaires allowed respondents the flexibility to answer questions in a more expressive way, providing the researcher with detailed information on the study. The interviews were semi-structured, and it was conducted among ten personnel from the Ghana Cocoa Board both at the national and the regional offices. At the

national level, the director of Research, Monitoring and Evaluation, as well as that of Monitoring and Evaluation of CODAPEC/HI-TEC were interviewed. At the regional level, the director of Cocoa Health and Extension Division, as well as that of Quality Control in the study area expressed the views on the subject under study. The purpose of the interviews was to ascertain government interventions as a way of addressing climate change and variability effects on cocoa production.

The secondary data on the other hand was sourced from Ghana Statistical Service, Ghana Meteorological Agency, and scientific journals. It comprised data on climate trends and cocoa production. The use of questionnaires and interviews therefore meant that the work benefitted from the use of both qualitative and quantitative data collection methods. Again, considering that both primary and secondary data were used means that this work made use of triangulation. Triangulation is basically the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of a phenomena while ensuring validity (Carter et al., 2014).

The study used a multi-stage sampling technique involving different sampling methods in the stages. In the first stage, Bibiani-Anhwiaso-Bekwai was purposively selected due to its dominance in cocoa production in the Western-North region. In the second stage, cluster sampling, which is a non-probability sampling, was used in dividing Bibiani-Anhwiaso-Bekwai municipality into three zones, namely, Bibiani zone, Anhwiaso zone, and Bekwai zone. This was important looking at how large and dispersed the municipality was. Based on the clusters, a simple random sampling was employed in selecting communities from each zone. As noted by Teddlie and Yu (2007) and Bryman (2016), with simple random sampling, all the communities have equal chance of being selected. In each zone, communities were assigned numbers and a set of random numbers were produced using Microsoft Excel until six communities; Kwamekrom, Dominibo No2, Tanoso, Ntakam, Surano and Humjibre were selected randomly. In the third stage, 20 cocoa farmers were selected randomly from each of the six communities chosen. This gave a total sample of 120 cocoa farmers. The obtained data was analysed using SPSS. Purposive sampling was used in selecting personnel from the Ghana Cocoa Board based on their supervisory roles.

3.4 Data Analysis

Data analysis is fundamentally about data reduction; thus, it is concerned with reducing a body of information that the researcher has gathered so that he or she can make sense of it (Bryman 2016). This means that unless the amount of data collected is reduced, for example, in the case of quantitative data by producing tables or averages, and in the case of qualitative data by grouping textual material into categories like themes, it is more or less impossible to interpret the material. This work used both primary and secondary data. The primary data was analyzed using the Statistical Package for Social Sciences (SPSS). The data was interpreted using descriptive statistics such as frequencies, percentages, simple bar charts, pie charts and histogram. Regarding the secondary data, a desk analysis approach was used. A desk analysis was chosen because it is concerned with identifying and summarizing previous research and publications in the public domains to establish existing knowledge about a current phenomenon. (Juneja, 2015). The use of Secondary data was meant to augment the primary data.

3.5 Validity and Reliability

The term validity refers to how effectively a study measures what it means to measure (Bryman, 2016. P.158). Thus, it is an assessment of accuracy. To ensure validity, this work made use of triangulation by using both secondary and primary data, as well as survey and interviews. Triangulations confirms and validates the quality of results of a study (Mohammad, 2007). By employing different sources, inadequacies in the generations of data were decreased, while also the different data collection strategies yielded valuable data to provide more insights to the study. Again, to ensure validity, my findings were presented to some of the respondents to assess if I had correctly evaluated their responses.

Reliability on the hand concerns with whether you obtain the same result when you use an instrument to measure something several times. In simple terms, research reliability is the degree to which a research process provides consistent and reliable outcomes. Reliability is way of evaluating the measuring procedures used to acquire data (Lærd, 2012). This study used a structured questionnaire and a semi-structured interview to acquire data. Flexibility is key in research as it gives room for diverse responses and opinion on a subject matter. Hence, making a semi-structured interview viable for this study to achieving an in-depth response on the topic of study. Because a structured questionnaire was used, each respondent was asked the same question in the same way resulting in a high level of data credibility. This also implies that the coding of the data and its interpretations are reflective of the views of the respondents.

3.6 Ethical Considerations

Ethics is essential in every research. Since the study used primary data, the Norwegian Centre for Research Data was notified to avoid causing harm to the respondents. Before the entire exercise started, the consent of each of the respondents was sought. The respondents were informed about the intent and objective of the research. The implications of their participation in the research project were explained to them. They were notified that their information would be used in aggregate to ensure anonymity and confidentiality. Again, regarding the secondary data, the management of the Ghana Meteorological Agency and Ghana Statistical Services were informed of the purpose and intention of the data before having access to them.

3.7 Limitations of the Study

It is necessary to recognise that the study had some limitations and that the findings of the study were confined to the Bibiani-Anhwiaso Bekwai Municipality of Ghana to avoid generalisation. However, the research was conducted in an area made up of several farming communities, but due to time constraints, only six of these farming communities were selected.

Additionally, the fact that only two climatic variables (temperature and rainfall) were used suggested that other variables such as sunlight and humidity, which equally affect cocoa yield, were omitted. According to the Ghana Meteorological Agency, data for such variables for the area were unavailable. It must also be indicated that relatively small sample size was used in the analysis. Cocoa farmers in the municipality are many. However, for the purpose of the study and considering the duration for completion of the work, only a small sample size of 120 was chosen.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results and discussion of the study. A total of 120 sampled questionnaires were administered in six (6) communities of the Bibiani-Anhwiaso-Bekwai municipality. The data obtained was analysed using SPSS. The results have been presented using frequencies, percentages, simple bar charts, pie charts and histogram.

4.1 General Demographic Information of the Respondents.

Table 1: Demographic Characteristics of the Respondents

Variable	Frequency	Percentage (%)
Age		
Below 20	2	1.7
20 - 29	4	3.3
30 - 39	6	5.0
40 - 49	37	30.8
50 - 59	60	50.0
60 and above	11	9.2
Total	**120**	**100**
Sex		
Male	85	70.8
Female	35	29.2
Total	**120**	**100**
Education		
Basic	60	50.0
Secondary	30	25.0
Tertiary	4	3.3
Non-formal	4	3.3
No education	22	18.3
Total	**120**	**100**

Marital status		
Single	8	6.7
Married	86	71.7
Divorced	12	10.0
Widowed	14	11.7
Total	**120**	**100**

Source: Field survey, 2021.

Age of Respondents

From Table 1 above, a majority (89.1%) of the cocoa farmers sampled in the research area were within the ages of 20 – 59 (Table 1). The data is close to Kumi and Daymond (2015), who indicated that 92.7% of the smallholder cocoa farmers in Bibiani-Anhwiaso-Bekwai District in the Western North Region of Ghana were within the age of 18 – 64 years. Another research study by Danso Abeam et al. (2014) in the Sefwi-Wiawso Municipality also showed a high percentage (88.46%) of youths in cocoa production. Age may have an influence on the size of cocoa farm and the overall output of cocoa because as the age increases, the physical strength of farmers tends to reduce, and this will affect their ability to grow cocoa on a large scale as well as the implementation of most of the farming practices such as weeding, pruning, and removing mistletoes. However, since most of the farmers are rather young, this shows a bright future for the cocoa industry in Ghana because of their versatility and physical strength which will help them in implementing most of the farming practices and enhance the output of cocoa.

Gender of Respondents

Both males and females were given the opportunity to express their opinions. Out of the 120 respondents, 85 were males, equivalent to 70.8% of the sampled population. There were 35 women constituting 29.2% of the respondent's population. This confirms Osei's (2017) assumption that there is male dominance in terms of land titles in the cocoa-growing areas. The male dominance in cocoa-growing can be traced to Ghana's traditional land tenure systems, which favour male land ownership over female land ownership. This viewpoint is held by Onumah et al. (2014). The male dominance could also be attributed to the fact that in many Ghanaian family settings, women play subordinate roles to their husbands as men are considered owners of factors of production. This may have contributed to a lower number of female responses.

Educational Levels of Respondents

Generally, it is believed that the level of education of farmers will have an influence on their ability to understand and interpret information on methods of adaptation strategies and their willingness to adopt. It was revealed from the research that 50% attained basic education, 25% attained secondary education, 3.3% had tertiary and non-formal education, respectively, and no education constituted 18.3%. It also showed that over two-thirds of the responses, constituting 71.6%, had attained education up to the basic level indicating a low level of education. This supports the findings of Aneani et al. (2012), which showed a high level of low education among cocoa farmers. The high rate of illiteracy will affect their ability to adapt to new methods of farming and adaptation measures to increase yield.

Marital Status of Respondents

Cocoa cultivation is labour-intensive as cocoa production is non-mechanised. From table 1, 6.7% of the responses were single, 71.7% were married, 10% were divorced, and 11.7% were widowed. Mostly, the women serve as support to their husbands during the planting and harvesting of the cocoa beans. They also assist in the weeding and spraying during the prime age of cocoa trees. Farmers who are married and have children are more likely to be able to implement various adaptation technologies because they will have access to cheap family labour. This is also in the findings of Denkyirah et al. (2017).

4.2 Cocoa Cultivation and Productivity

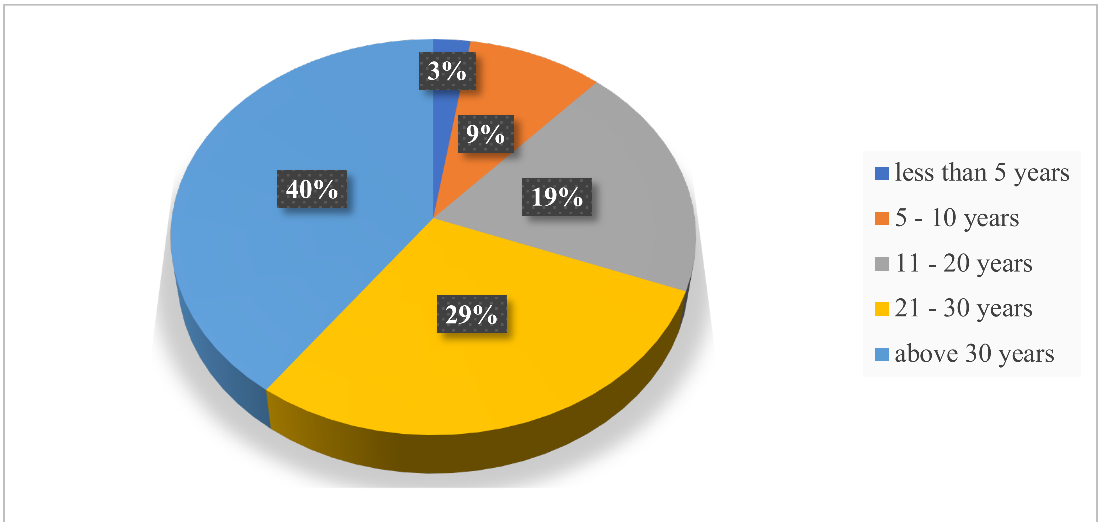

Figure 7: Farming experience of respondents

Source: Field survey, 2021.

Figure 6 presents the number of years farmers have been cultivating cocoa in their various communities. The result indicates that 40% of the respondents have been cultivating cocoa for more than 30 years, 29% of the respondents have cultivated cocoa between 21 to 30 years, 19% between 11-20 years, 9% between 5-10 years, and 3% less than five years, depicting that majority of the respondents have a high number of years of experience in cocoa farming. According to Kumi and Daymond (2015), farmers with more years of experience in cocoa cultivation tend to have a higher yield per hectare compared to those with less experience. This modal age of more than 30 years gives farmers more practical knowledge in farm management practices and better adaptation measures.

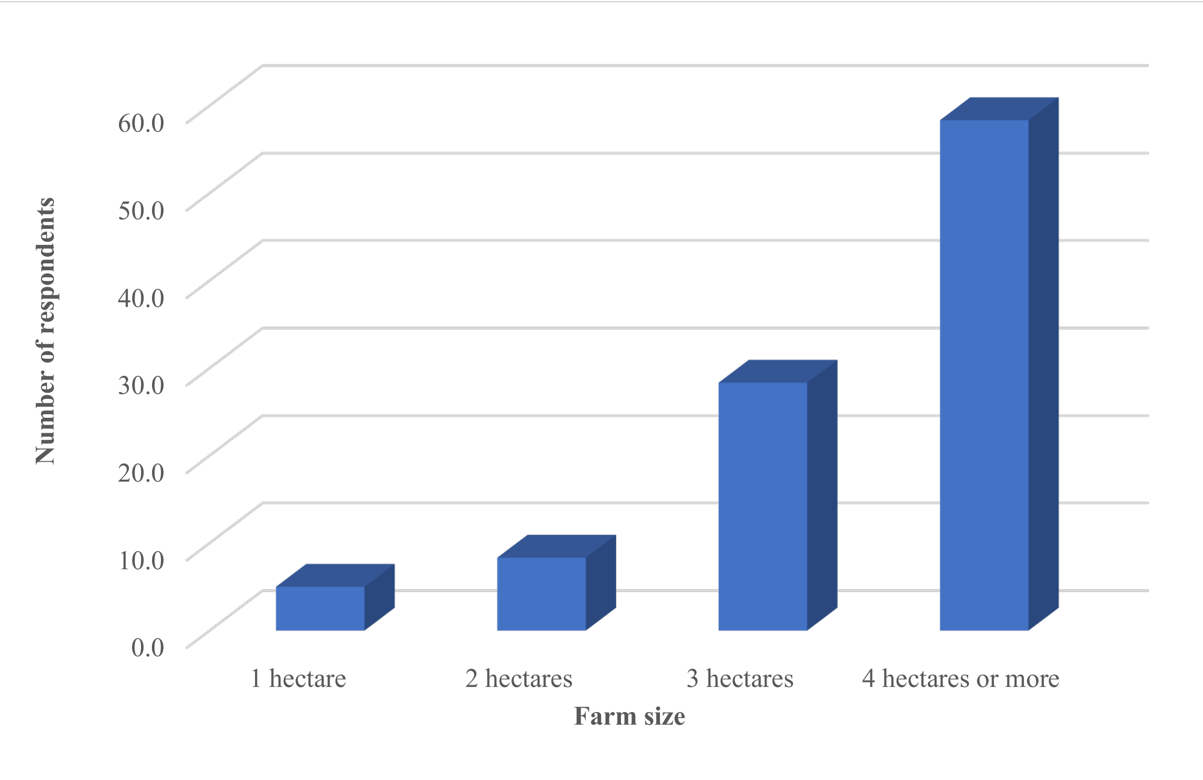

Figure 8: Size of cocoa farm

Source: Field survey, 2021.

Respondents were asked to give the total size of their cocoa farm(s). Because farmers are more familiar with acres, they first stated the overall size of their cocoa farms in acres, which were then converted to hectares for consistency. The results showed that about 58.3% of the farmers had total cocoa farm sizes of 4 hectares or more. The least percentage (5%) of respondents had total farm sizes of 1 hectare. Although a higher percentage of farmers were found within the category of 4 hectares or more, it was revealed through the study that majority of them had farm sizes between 4 to 5 hectares indicating small sizes of their farm. This confirms the research findings of Duguma et al. (2001) that smallholder farmers usually work on a farm size of 2 to 5 hectares. Some of the reasons given for the small sizes are that lands are mostly owned by the family and shared among family members, which are relatively small, and this makes it difficult for farmers to grow cocoa on a large scale. Land is also expensive to acquire in Ghana and this discourages farmers from venturing into commercial farming. As a result of the small sizes of their farms, the output is expected to be lower. Low productivity reduces the income levels of the farmers, which hinders them from acquiring expensive but essential farming tools for their operations. Moreover, low-income levels of the farmers as a result of low yield hinder them from adopting most of agronomic and adaptation measures to improve productivity and adaptation to climate change.

		Level of education					Total
		Basic	Secondary	Tertiary	Non-formal education	No education	
Age	20-26	0.8%	1.7%	0.0%	0.8%	0.8%	4.2%
	27-36	0.8%	2.5%	1.7%	0.0%	0.0%	5.0%
	37-50	13.3%	12.5%	0.8%	0.8%	3.3%	30.8%
	51-60	30.8%	8.3%	0.8%	0.0%	10.0%	50.0%
	Above 60 years	4.2%	0.0%	0.0%	1.7%	4.2%	10.0%
Total		50.0%	25.0%	3.3%	3.3%	18.3%	100.0%

Table 2:Relationship between farmer's age and level of education (%)

Source: Field survey, 2021

The cross-tabulation results of the ages and educational levels of respondents are presented in Table 2. The results indicate that few educated farmers were younger (20-26 years age range) while the majority (30.8%) of farmers between 51-60 years had basic education. From the table, it could be seen that few of the youth (20-26 years) are into cocoa production because they do not see it as a profitable venture. This could account for the low percentage of the relationship between their age and level of education as few of the educated youths were selected.

4.3 Climate Change and Cocoa farming

Farmers Awareness on Climate Change

The study shows that 87.5% of the respondents are aware of climate change and variability. This means that most of the respondents (cocoa farmers) in this cocoa-growing region are much aware of climate change and its effects on their farming activities. Climate change affects the time of planting cocoa, pest and diseases and the time of harvesting and drying cocoa beans. This agrees with the work of Wongnaa and Babu (2020), who suggested that climate change is occurring, and cocoa producers are aware of its causes as well as its effects on their farms. Only 12.5% of the respondents said they are not aware of climate change and variability, though they have witnessed some changes in the pattern of rain and temperature.

Farmers Access to Whether Information

Access to good information on weather and climate allows farmers to choose measures that will make them cope with changes in the climatic condition (Di Falco et al., 2012). From the study, 106 out of 120 respondents representing 88%, indicated that they have access to weather information, whereas 14 out of 120 of the respondents representing 12%, said they do not have access to weather information.

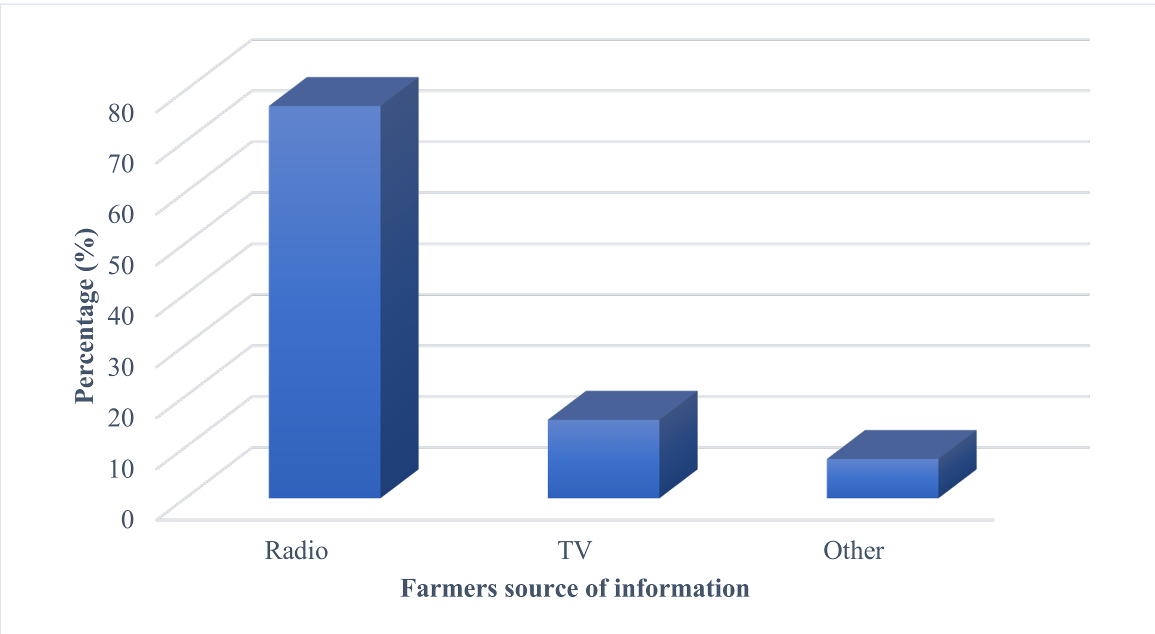

Figure 9: Farmers' source of information about climate variability and change

Figure 8 presents farmers' sources of information about climate change and variability. From the study, 76.9% said they heard about climate change on radio, followed by television (15.4%). This shows that the media plays a pivotal role in informing cocoa farmers in the municipality about climate change and variability, which eventually inform them on the kind of adaptation methods they may use. Fewer farmers received information (7.7%) through other sources such as extension officers, phones, and fellow farmers. According to the farmers, extension officers educate them on the impacts climate change and variability can have on their farms. They received training on farming methods and management practices they could adopt to increase their yield.

4.4 Climate Change and its Effect on Cocoa Production

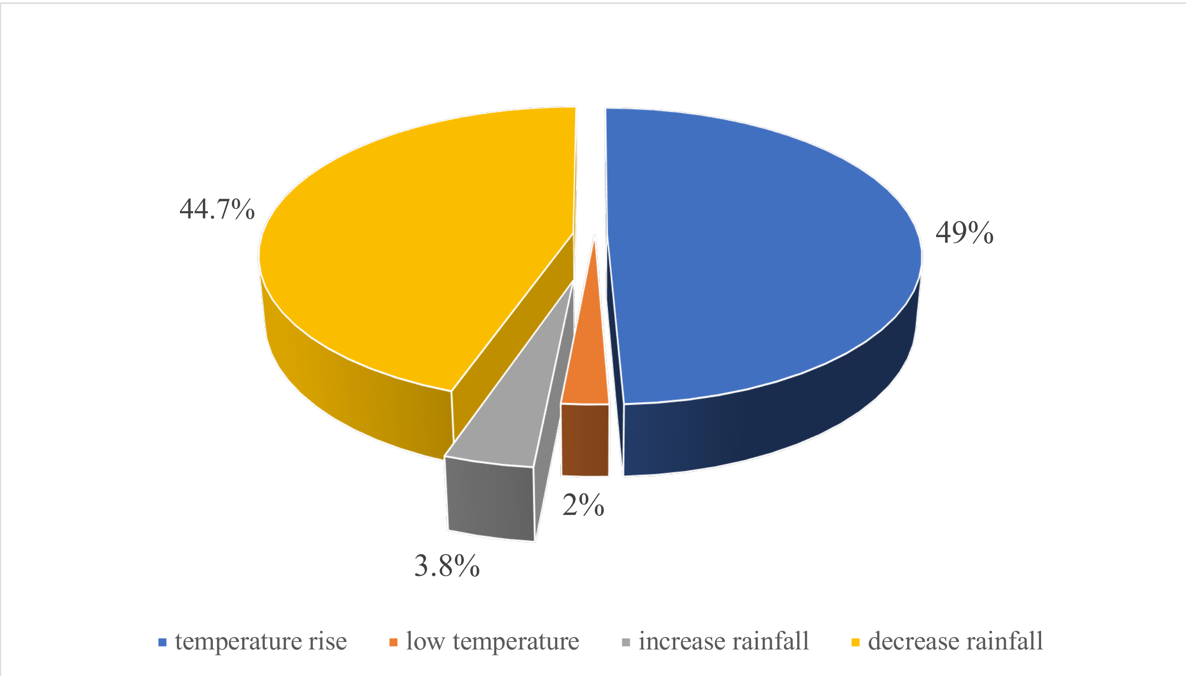

Figure 10: Perception of farmers on climate change indicators

Source: Field survey, 2021.

Farmer's perceptions on climatic conditions are often based on past observations and recent climatic events, which influence their decisions on adaptive behaviour (Ndamani and Watanabe, 2015; Ehiakpor et al., 2016). Temperature and rainfall were used as indicators to assess farmers' perceptions on climate variability. From figure 9, 49% of the respondents agreed to an increase in temperature for the municipality, with 2% indicating that the temperature has been low. In addition, 44.7% of the respondents said rainfall in the municipality has decreased, and only 3.8% of the respondents claim rainfall for the municipality has rather increased. The perceptions of the farmers were verified using historical mean annual temperature and rainfall data of Bibiani-Anhwiaso-Bekwai municipality from Ghana Meteorological Agency from 2000 to 2020. The data showed an increase in temperature from 27.7°C in 2000 to 28.5°C in 2020 in the municipality (Fig. 2). This confirms the IPCC report (2021) that the rate of surface temperature increase has generally been faster in Africa than the global average. Deressa et al. (2008) also concluded that farmers were aware that the temperature was increasing.

According to the statistics, the mean annual rainfall of the study area has increased significantly since 2000. This also supports the projection by the IPCC report (2021) that the frequency and intensity of heavy precipitation are expected to increase in most parts of Africa.

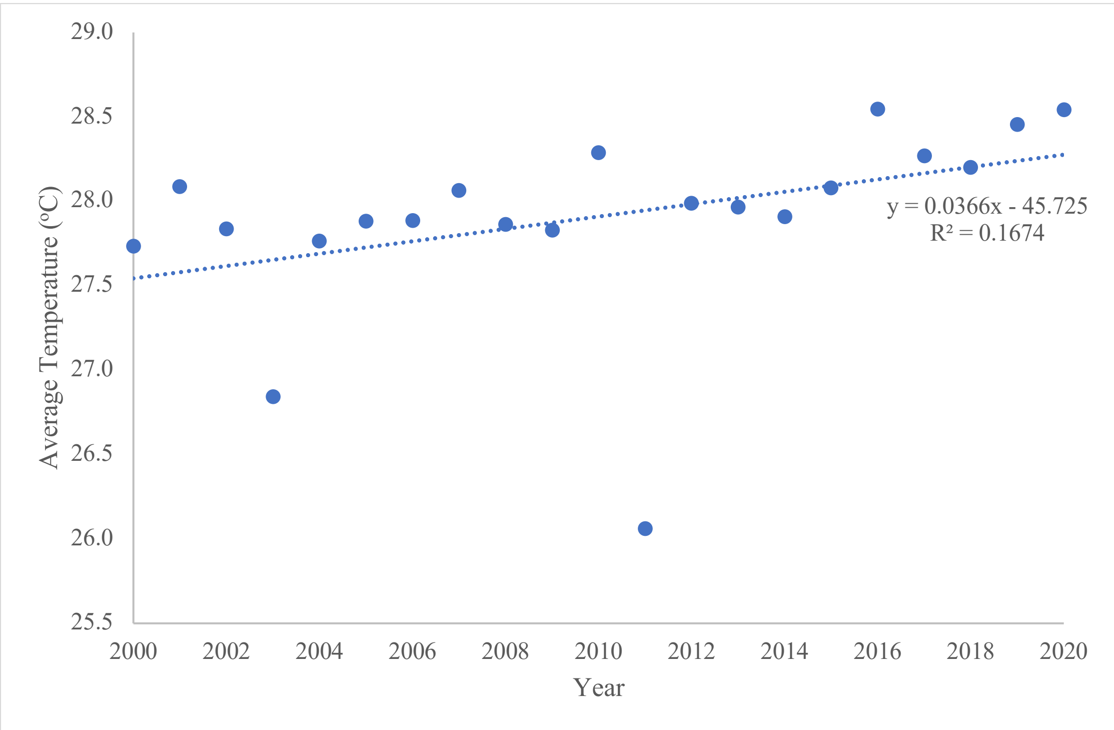

Figure 11:Regression analysis of temperature for Bibiani-Anhwiaso-Bekwai municipality

Figure 10 shows the regression analysis of temperature for the Bibiani-Anhwiaso-Bekwai municipality. The line shows a positive association between average temperature and the years under review. This means that for each year, temperature increase by 0.04^{0}C (y = 0.0366x - 45.725) on average in the municipality. The regression test has a significant factor of 0.054233232(α=0.05), indicating that the test is statistically significant. It means that as the year increases, there is also an increase in temperature in the municipality. This corresponds to the farmers' response that temperature in the study area has increased.

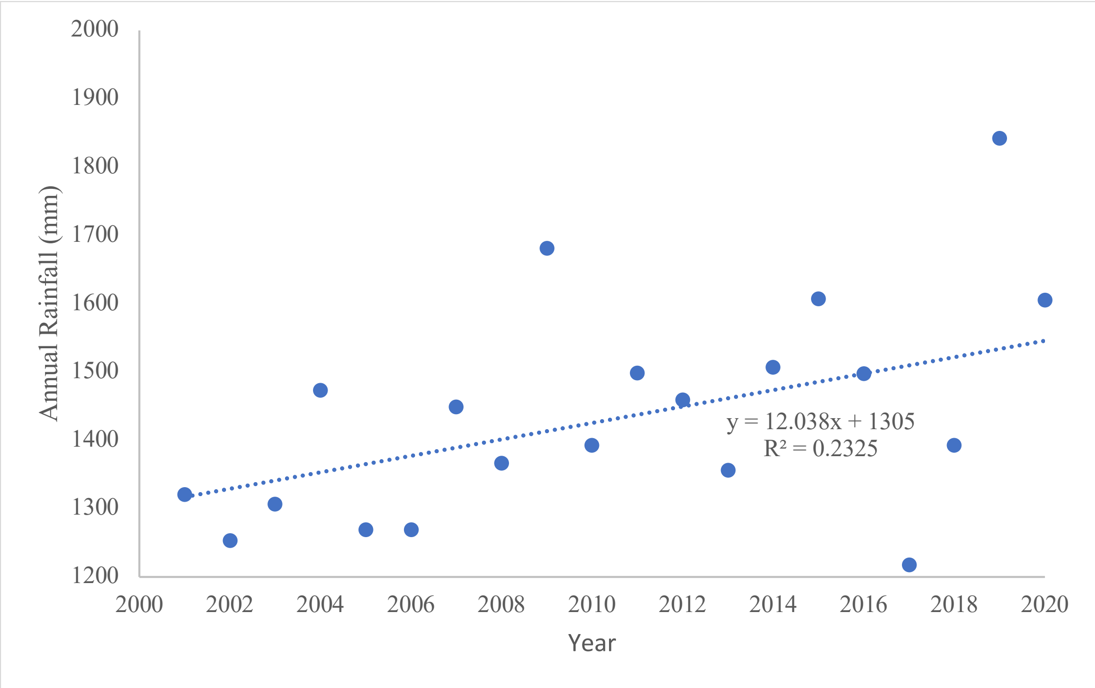

Figure 12:Regression analysis of rainfall for Bibiani-Anhwiaso-Bekwai municipality

Figure 11 also shows the regression analysis of rainfall for the Bibiani-Anhwiaso-Bekwai municipality. The analysis shows a positive association between average rainfall and years, indicating that for each year, there is an increase in rainfall of 12.04mm (y = 12.038x + 1305). The regression test has a significant factor of 0.02684082(α=0.05), indicating that the test is statistically significant. It means that as the year increases in Bibiani-Anhwiaso-Bekwai municipality, there is an increase in rainfall. This contradicts the farmers' observations that rainfall in the study area has decreased.

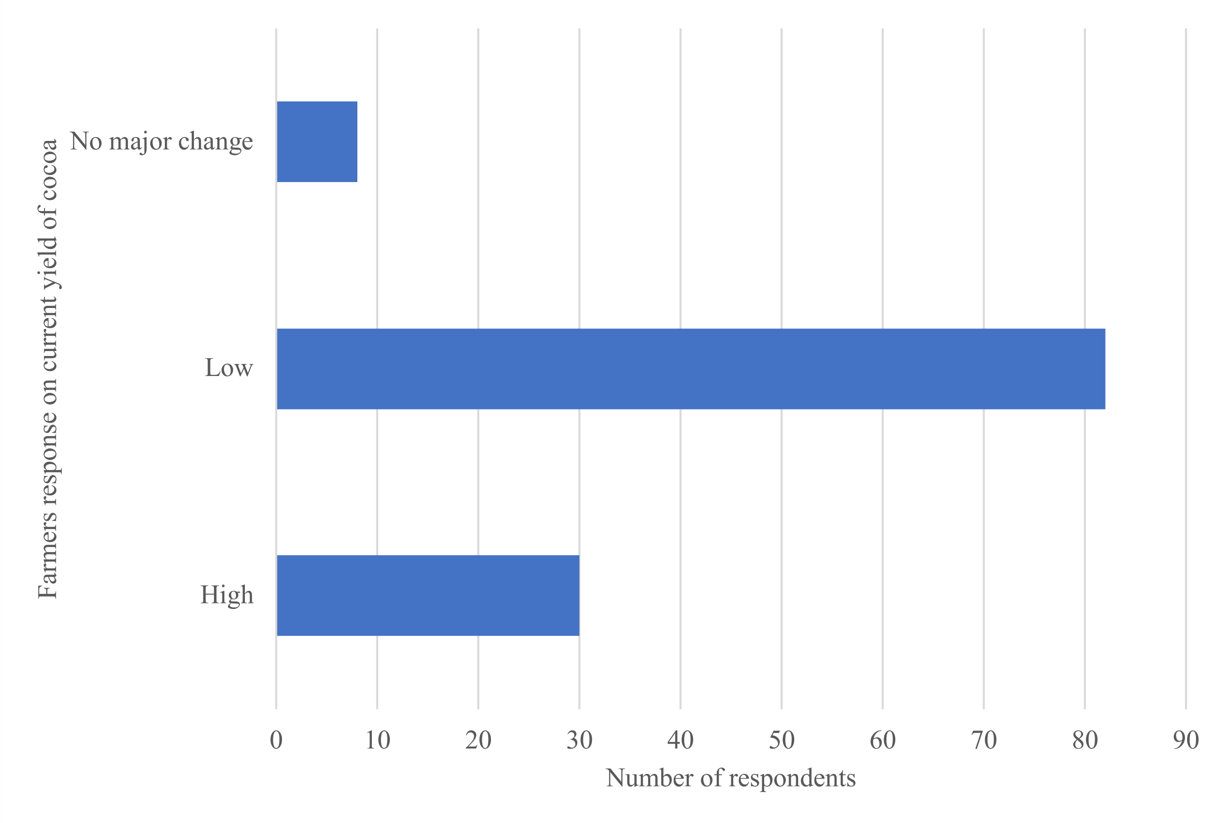

Figure 13: Farmers' response on the effects of climate change and variability on cocoa yield

From the survey, 82 out of the 120 respondents representing 68.3%, said that their cocoa yield currently is lower as compared to the previous years. Most of the farmers indicated that increased temperature has resulted in heating up of the land. This has led to high mortality of both the young seedlings and mature trees. Some also said the heating has resulted in the ripening of immature seeds on the cocoa trees. The respondents further indicated that low rainfall has made it difficult for the cocoa trees to bear fruits which has eventually affected cocoa yield. However, according to the regression analysis (figure 11), there has been an increase in volume in rainfall which contradicts the views of the farmers. Thus, it can be inferred that the fall in yield could be due to other factors. According to Wiah and Twumasi-Ankrah (2017), increased temperature and the number of rainy days have negative effects on cocoa yield.

Personnel from the Ghana COCOBOD also highlighted that "*Extreme temperature affects the physiological functioning of cocoa trees thereby reducing yield. Torrential rainfall, flooding, wildfires and prolonged rainfall all influence cocoa production. Wildfire has been a major threat to cocoa cultivation in Ghana, especially during the harmattan season*". Oppong (2017) shows that the prevalence of bush fires is due to the actions of smokers, rat hunters, and farmers who adopt slash and burn farming methods during the harmattan season. On the other hand, 30 respondents representing 25% said that their yield is higher. The farmers attributed this to the different adaptation strategies such as the application of fertilizer to enrich the soil nutrient and artificial pollination (where volunteers pluck the male flowers and cross them with that of the females to make them fertile to produce fruits) adopted by the government. In addition, 8 of the respondents representing 6.7%, were not able to observe changes in yield. According to Anim-Kwapong and Frimpong (2004), cocoa is extremely susceptible to changes in climate, particularly temperature, due to its effect on evapotranspiration. The International Cocoa Organization (2005) also stated that changes in weather affect the stages and development of cocoa, as well as the incidence of cocoa pests and pathogens, and this ultimately leads to a reduction in cocoa yield and negatively affects socio-economic variables such as farm income and decisions on farm level (Ajewole and Iyanda, 2010). According to Lawal and Emaku (2007), this is worrisome since cocoa plays an important role in the economic growth of many African countries and the income level of cocoa farmers.

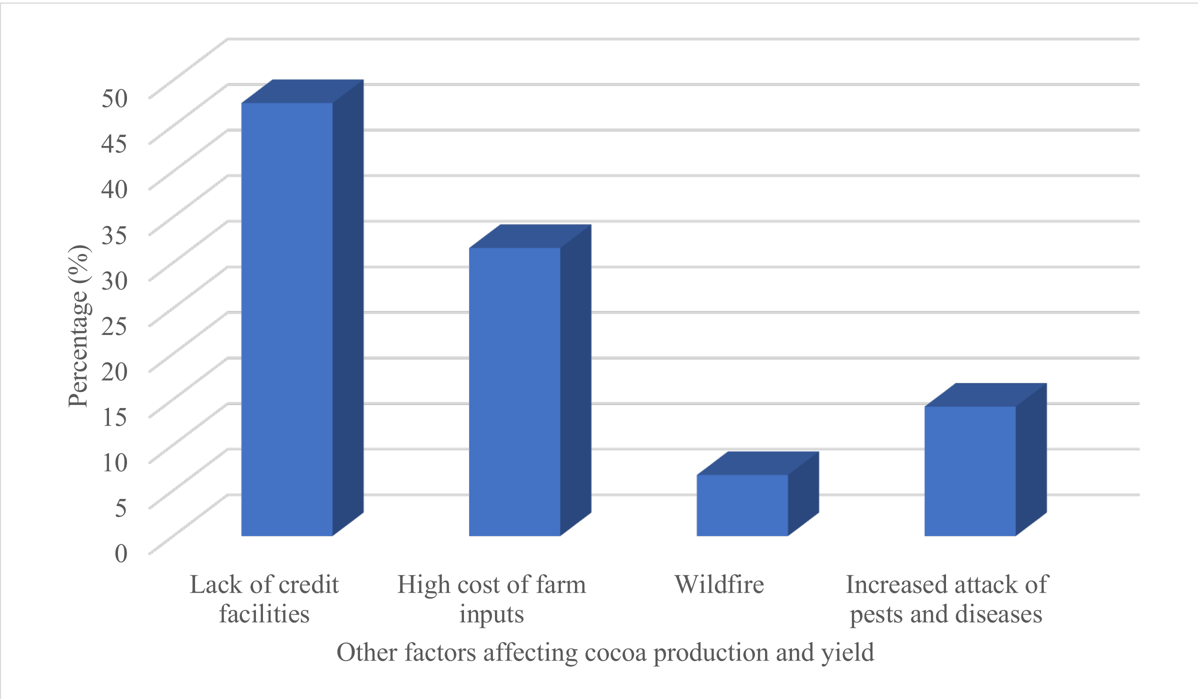

Figure 14:Other factors perceived by farmers to affect cocoa production and yield in the Bibiani-Anhwiaso-Bekwai Municipality

In order to know if the farmers were not blaming every decrease in yield on climate change, farmers were asked what other factors affect cocoa production and yield. From the survey, lack of credit facilities was ranked highest with 47.5%, followed by the high cost of farm inputs (31.6%). Increased attacks of pests and diseases and wildfire, particularly during the harmattan season, were also considered as an inhibiting factors to cocoa production.

According to Oyekale et al. (2009), climate change is changing the stages and rates of growth of cocoa pests and pathogens and increasing cocoa vulnerability to such threats. Changes in temperature and amount of rainfall have the potential to increase the incidence of pests and diseases as well as change in the types of pests and diseases that find the cocoa farm environment conducive haven. The high cost of farm inputs has always been a constraint to cocoa production in Ghana. With their little income, cocoa farmers find it difficult to purchase inputs like fertilizer, chemicals, and improved seeds to increase production and adapt to climate change.

4.5 Adaptation Strategies to Climate Change

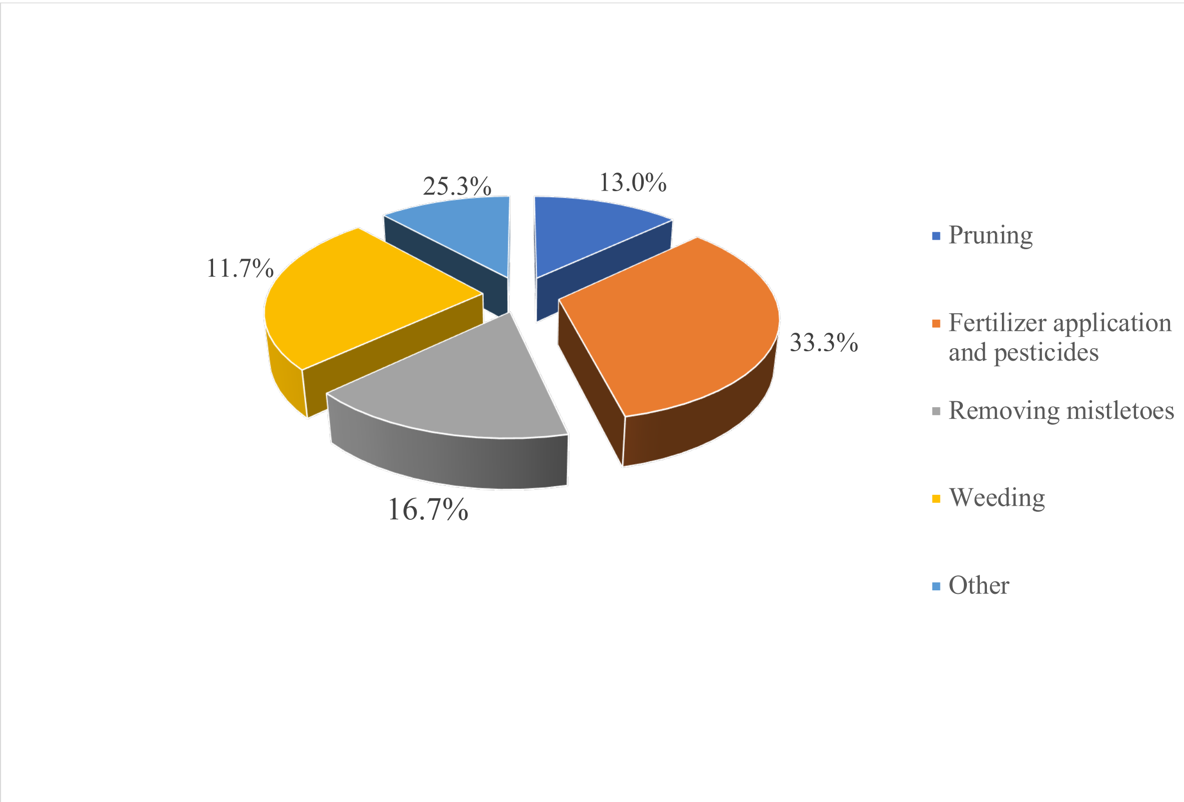

Figure 15: Farmers' adaptation strategies to ensure higher yield

According to Anim-Kwapong and Frimpong (2004), climate change adaptation entails taking steps to reduce the adverse effects or to exploit the positive effects of climate change. IPCC

(2001) asserts that adaptation can potentially reduce the negative impacts of climate change and enhance the beneficial impacts but will incur the cost and will not avert all damages. Adaptive actions are instituted to avoid any immediate or impending effects that may occur as a result of climate change. Some adaptive measures may be implemented to deal with instances where actual climate change impacts occur. The goal of adaptation measures should be to improve a system's ability to deal with negative shocks.

To overcome the vulnerabilities of cocoa production to climate variability, the farmers have adopted adaptation measures to overcome these challenges (figure 14). A study conducted by Agbongiarhuoyi et al. (2013) indicated that climate change significantly changed cocoa pest and pathogens incidence. Therefore, it was not surprising that 33.3% of the cocoa farmers adopted the use of fertilizer and pesticides as a measure to mitigate climate change impacts. The farmers admitted that poor harvesting and a high rate of post-harvest losses are associated with low use of fertilizer and pesticides. A significant number of people also adopted the removal of mistletoes (16.7%) and pruning (13.0%) to improve the health of cocoa trees and competition for soil nutrients, respectively. However, 25.3% of the farmers adopted other methods such as the use of improved seed varieties and seedlings and planting of shade trees to resist the impact of climate change on their farms.

The employment of shade trees reduces the sensitivity of cocoa to high temperatures in the dry season. These responses given by the farmers are supported by literature. According to Hassan and Nhemachen (2008), the use of fertilizers and insecticides, as well as providing insurance to agricultural crops, are significant climate change adaptation methods. Fertilizer helps to replace the soil nutrient after years of mining these nutrients through annual harvest. Ogunsola and Oyekale (2013) stated that farmers, to cope with the changing climate, uses regular cocoa spraying. Oppong (2017) also said that mistletoe is a parasitic plant that grows on cocoa trees. They harm the young branches of cocoa trees if not removed, and they are controlled by completely removing the mistletoe-infested areas of the tree to prevent it from spreading to other parts of the tree. Across Africa, coping strategies used by farmers to protect their crops against climate change impacts include tree planting, income diversification, early planting and digging drainage channels, among others (Deressa et al., 2008; Okonya et al., 2013).

4.6 Barriers to Adaptation Strategies

Barriers to adaptation methods	Frequency	Percentage
Inadequate finance	58	48.3
Inadequate weather information	32	26.7
Inadequate land resource	18	15.0
Low level of technology	12	10.0
Total	**120**	**100.0**

Table 3: Farmers' response on factors that hinder their use of adaptation strategies

Barriers to adaptation are the constraints faced by farmers as they try to adjust to the effect of climate change on their cocoa production. Although farmers in the municipality are using some adaptation strategies to help improve their yield, they appear to be facing some challenges that are preventing them from fully adapting to these measures.

From the survey, 48.3% of the respondents revealed that inadequate capital is making it difficult for them to adopt the appropriate adaptation strategies that can reduce some of the challenges posed by climate change on their cocoa production. Also, 26.7% of the respondents said that inadequate information on weather affects their use of the adaptation measures. According to the respondents, they do not have full knowledge of the need to implement certain strategies on their farms. As a result, they are afraid of losing more than they can predict. This makes it difficult for them to make decisions about changing or adopting new strategies. According to Akinnagbe and Irohibe (2014), limited knowledge, expertise and data on specific climate change is a major challenge to implementing agricultural adaptation measures in Africa. In addition, some respondents (15.0%) said they find it difficult to secure new lands for cultivation, thereby making it difficult to increase their farmlands. The study revealed that most of the farmlands are owned and divided among family members, therefore, making the farm size smaller and eventually affecting yield. Lastly, low level of technology (10.0) on the use of improved seed, fertilizers and pesticides was another barrier affecting the cocoa farmers' adaptation. The farmers revealed that they lacked knowledge and expertise on the appropriate technology that could help them improve their adaptation strategies in order to offset some of the climate change challenges.

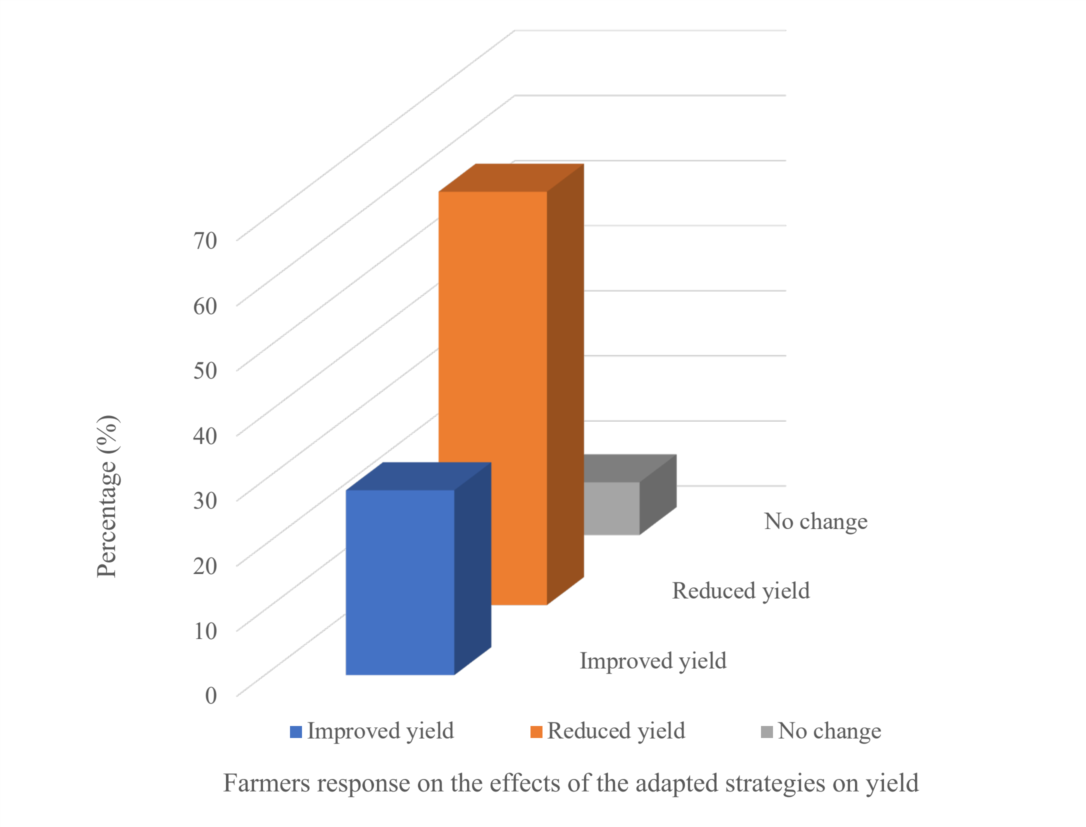

Figure 16: Farmers' perception on the effect of the adapted strategies on yield

Climate change effects are most evident in crop productivity because it represents the main concern to producers and consumers compared to the growth cycle (Hatfield and Prueger, 2015). Adaptation is undoubtedly a key strategy for reducing the impacts of climate variability on cocoa farmers whose susceptibility is projected to increase without adaptation (Niggol Seo and Mendelsohn, 2008; Ehiakpor et al., 2016).

From the survey, 63.5% of the respondents admitted that their yield has reduced despite the adopted measures. About 8.1% of the respondents were indifferent because they claimed there had not been any significant variations in their yield. However, 28.4% of the respondents claimed that their cocoa yield has improved.

With regards to the effect of the adaptation measures on economic return, the farmers suggested that their income is contingent on the yield and the weather conditions within the crop season. They perceived that they only get higher income when the adopted measures coupled with the weather condition are favourable. They also pointed out that economic trees such as mangoes and avocados are intercropped with cocoa trees so that while they provide shade to minimize the sensitivity of cocoa to high dry season temperatures, their fruits are harvested and sold to serve as additional income to farmers. According to Agbongiarhouyi et al. (2013), climate change influences the development of cocoa pods, as well as pests and diseases that affect cocoa trees, resulting in low crop yield and a reduction in farm income.

It was noted from some of the respondents that sometimes the chemicals and fertilizers are washed away by heavy downpour after application which makes them ineffective. Some also indicated that inadequate capital makes it difficult for them to purchase the required quantity of fertilizer and chemicals as per their farm size to improve their yield and hence their income.

4.7 Farmers Response on Government Policies to Address the Effect of Climate Change on Cocoa Yield

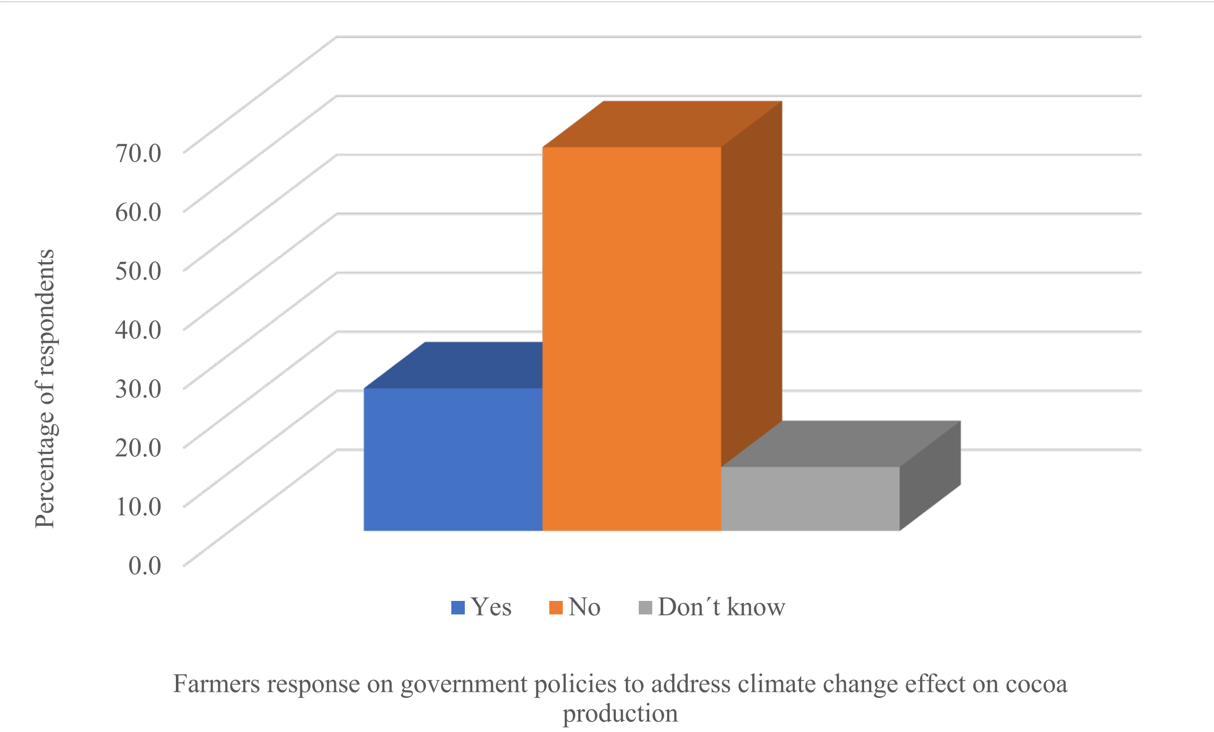

Figure 17: Farmers' response on government policies in place to address the effect of climate change on cocoa production

Figure 16 shows farmers' responses on policies adopted by the government to address the effect of climate change on cocoa yield. Out of the 120 respondents, 78 representing 65.0%, said they are unaware of any policy undertaken by the government to address the climate change effect. It was revealed from the study that majority of the farmers do not have adequate information on most of these government policies and this could explain why most of them are unaware of such policies. However, 29 respondents representing 24.2%, mentioned policies such as artificial pollination, cocoa mass spraying exercise, planting of economic trees by the Ministry of Food and Agriculture, giving of free seedlings such as mahogany and acacia by the Ghana Forestry Commission, sensitisation farmers on climate change effect on cocoa among others as some measures adopted by the government to address climate change effect on yield. During the interview with personnel of the Ghana COCOBOD, they also mentioned that the government, through the Board, has rolled out a programme known as Production Enhancement Programme (PEP's), which is geared towards addressing the menace of climate change on cocoa production. These programmes include pruning, artificial pollination, rehabilitation of disease and moribund cocoa farms, and Cocoa Disease and Pest Control Programme (CODAPEC), among others.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter six presents the conclusion and policy recommendations of the study. The chapter is subdivided into two main sections.

5.2 Conclusion

Climate change is increasing the vulnerability of agricultural systems at a rapid and uncertain rate, with higher impacts being seen by rain-fed agriculture operations like cocoa cultivation. This study, therefore, sought to first assess the effect of climate change and variability on cocoa yield in the Bibiani-Anhwiaso-Bekwai Municipality; second, to identify adaptation strategies used to improve the output of cocoa in the Bibiani-Anhwiaso-Bekwai Municipality, third, to examine the effect of the adopted strategies on cocoa yield and economic return, and finally to identify government policies adopted to address the effect of climate change and variability on cocoa production.

In assessing the effect of climate change and variability on cocoa yield in the Bibiani-Anhwiaso-Bekwai Municipality, the study has revealed that the area has been experiencing high temperatures and high rainfall. These results are supported by the data from the Ghana Meteorological Agency. The increase in rainfall, however, contradicts the farmer's view that rainfall in the study area has reduced, hence making it difficult for cocoa trees to bear fruits. However, the high temperatures have conditioned heating up of the land, causing high mortality of young seedlings and mature trees. It has also led to the ripening of immature cocoa seeds. The implication of these circumstances is that the cocoa yield of most farmers has been reduced.

Moreover, the study indicates that farmers in the study area have been using fertilizer and pesticides, pruning, mistletoe removal, as well as weeding as the adaptation strategies to reduce the impact of climate change on cocoa yield. In addition, improved varieties and seedlings, as well as the planting of shade trees, were new adaptation practices adopted by a few farmers in the study area to resist prolonged dry periods, drought and changing pest and disease dynamics. This has increased their yield despite the challenges posed by climate change.

The study also identified that the adopted strategies had had no impact on yield and economic return. This is because most of the adopted strategies are traditional management farm practices and these measures are not sufficient to offset the shocks of climate change and variability hence, affecting their yield. The study further indicates that the economic return of farmers was dependent on the weather condition of the crop season. As such, their income only increased when the adaptation measures coincided with favourable weather conditions. On the other hand, if the weather condition becomes severe since most of the adopted strategies are not sufficiently effective to address climate change, income becomes low.

Again, the study finds that most of the farmers are faced with some challenges, thus making it difficult for them to fully adopt these measures. Inadequate capital made it difficult for the farmers to adopt the appropriate measures to increase their yield. In addition, inadequate information on weather affected their use of appropriate adaptation strategies. Other factors such as inadequate land resources and low level of technology all hindered their use of the adopted strategies to increase their yield.

Lastly, the study finds that most of the farmers were unaware of most of the government policies adopted to address the menace of climate change on cocoa production. The study further finds that majority of the farmers lacked adequate information on such policies. However, it was revealed through the Ghana COCOBOD that the government had adopted a policy known as Production Enhancement Programme (PEP's), which includes pruning, artificial pollination, rehabilitation of diseased and moribund cocoa farms, and Cocoa Disease and Pest Control Programme (CODAPEC), aimed at addressing the effects of climate change on cocoa production.

5.3 Recommendations

From the findings of this research, the following policy intervention and recommendations may be considered to bring about increased yield and improve the adaptation of cocoa to climate change.

- Farm inputs such as agrochemicals and fertilizers should be made readily available and affordable to farmers. Prices of such inputs should be highly subsidized to encourage cocoa farmers to purchase them to ensure a higher yield.

- Government should encourage and support research institutes, such as the Cocoa Research Institute of Ghana (CRIG), to develop new varieties of cocoa that are adapted to climate change and harsh climatic conditions.

- The government, in collaboration with the various stakeholders, should provide frequent education and information about climate variability and adaptation techniques to ensure that farmers have a comprehensive knowledge of weather patterns and the necessary adaptation measures. This will help them to implement the various adaptation measures to ensure a higher yield.

- The government must fast-track the implementation of its climate adaptation strategies across the country to ensure wider access to majority of farmers, most of whom are unaware of such policies.

- Other environmental variables (sunshine and humidity) should be examined in a wider geographical spread. This will help in identifying regions where cocoa production will be beneficial, as well as areas where farmers are switching from cocoa to other crops due to adverse weather conditions. This will help the COCOBOD to identify the areas they can channel more resources to ensure a sustained output of cocoa for the country.

- Lastly, since inadequate finance was a major barrier affecting cocoa farmers to adopt the appropriate methods to offset the challenges posed by climate change, the government, in collaboration with NGO's should support the farmers financially in order to adequately adapt the appropriate methods to the changing climate.

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APPENDICES

Appendix 1: Questionnaire

NORWEGIAN UNIVERSITY OF LIFE SCIENCES
FACULTY OF LANDSCAPE AND SOCIETY
DEPARTMENT OF INTERNATIONAL ENVIRONMENT AND DEVELOPMENT STUDIES

Dear Participant,
I am a master student undertaking a research on the effects of climate change and variability on cocoa production in Ghana. The study is under the supervision of Professor Jens Bernt Aune. 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 the purposes of academic research as part of the requirements for the award of MSc. Global Development Studies degree. The information provided will be treated with extreme confidentiality and used for the intended purpose only. The responses will be analysed in aggregates and no one will be directly identified. 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 on the subject matter. We appreciate you for taking the time to complete this set of questionnaires.
Thank You.

A. Farmer's Personal Information

Please provide the information that reflects your circumstance.
Tick [√] where appropriate response.
Name of Community:………………………………… …………………………………….

1. Gender: (a) [ ] Male (b) [ ] Female (c) [ ] Other

2. Age: (a) 20-26 [ ] (b) 27-36 [ ] (c) 37-50 [ ] (d) 51-60 years [ ]
(e) Above 60 years [ ]

3. Level of Education

(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 [ ]

(e) Informal union [ ]

5. How long have you been cultivating cocoa in this community?

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

(e) 30 years and above [ ]

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 tonnes [ ] (d) 3-4 tonnes [ ]

(e) 5 and above tonnes [ ]

B. Effects of climate change and variability on cocoa production

8. Do you know Climate Change

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

9. Do you have access to weather information

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

10. If yes, from which medium do you receive the weather information?

(a) Radio [ ] (b) TV [ ] (d) Other [ ]

11. What is your experience with the weather condition (Tick more option)

(a) Temperature rise [   ]

(b) Low temperature [   ]

(c) Increase rainfall [   ]

(d) Decrease rainfall [   ]

12. What is the current yield of your cocoa

(a) High [   ]   (b) Low [   ]   (c) No major change [   ]

13. If high or low (reason)…………………………………………………………………...

……………………………………………………………………………………………..

…………………………………………………………………………………………….

…………………………………………………………………………………………….

14. Do you think the current weather condition is affecting your cocoa yield?

(a) Yes [   ]   (b) NO [   ]   (c) Neither Yes nor No [   ]

Reason…………………………………………………………………………………….

…………………………………………………………………………………………….

………………..……………………………………………………………………………

……………………………………………………………………………………………..

15. Is any of the following climate conditions affecting your cocoa yield?

(a) Temperature [   ]

(b) Rainfall [   ]

(c) Humidity [   ]

(d) Sunshine [   ]

(e) Other, specify ………………………………………………………………………..

16. How has climate change affected your cocoa farm?

(a) Yield has reduced [   ]

(b) Tress are dying [   ]

(c) Pest and diseases have increased [   ]

(d) Other, specify………………………………………………………………………

17. How does low or high rainfall affect the yield of your cocoa?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

18. How does the low or high temperature affect the yield of your cocoa?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

C. Adaptation Measures

19. What measures do you use to ensure higher yield?

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………….

……………………………………………………………………………………………..

20. In case of high/low rainfall, what do you do to mitigate its effects on the farm?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

21. When there is a temperature rise, what measures do you use to mitigate its effect?

…………………………………………………………………………………………………

…………………………………………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………….

22 Apart from climate change, what other factors affect the production of your cocoa farm?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

C. Effect of Adaptation Measures

23. (Build-up from 19 and 20) Are the adaptation measures helping you?

Yes [ ] No [ ] Neither Yes nor No [ ]

If No, why ……………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

If Yes, how is it contributing to the yield of your farm?

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

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

……………………………………………………………………………………………….

24. How are the adaptation measures impacting your income generation?

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

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

…………………………………………………………………………………………………

25. Is the adaptation measures having a positive result on the climate impact on your farm?

(a) Yes [ ] No [ ]

If Yes or No reason,………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………….

26. What barriers do you face in adapting to climate change and variability?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

27. Do you know any government policy in place to address the impact of climate change on cocoa yield

(a) Yes [ ] (b) No [ ] (c) Don't know [ ]

28. If yes, which policy do you know?

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

29. What do you think the government must or can do to help reduce the impact of climate change and variability on cocoa productivity?

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

Appendix 2: Interview Guide

The interview will be conducted with cocoa board authorities and other extension Officers.
|Introduce yourself and ask respondents to introduce themselves.
Introduce the purpose of the interview and seek permission to do so.

1. Generally, what is your view on the effects of climate change on cocoa production.

2. Do you think the government of Ghana is tackling climate change head-on?

3. Is there any sensitization workshop or other mechanisms put in place by the government to get cocoa farmers informed about climate change and its effects on cocoa production?

4. Are there any government measures in place to ensure high cocoa yield despite the possibility of climate effects? Can you share them with me?

5. Does the cocoa board as a regulatory body for cocoa production have measures in place to address the effects of climate change on cocoa yield (yes/no)
Can you share with me some of the measures?

6. How will the measures from the government and that of the body contribute to addressing the effects of climate change in general, and specifically cocoa yield, economic returns both to the state and to the farmers?

7. What recommendation will you give concerning actions by the government, the cocoa board and its related agencies, as well as the farmers as a way to reduce the effects of climate impact on cocoa productivity or if possible, create resilience against climate change and its effects.

Appendix 3: Data on Temperature and Rainfall for Bibiani-Anhwiaso-Bekwai Municipality

ELEMENTS	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
TT	2000	27.9	27.8	29.6	29.2	28.7	27.5	26.4	26.1	26.4	27.8	28.2	27.4	27.7
TT	2001	28.2	29.8	28.8	28.5	29.0	27.7	26.6	25.7	26.0	29.4	28.8	28.9	28.1
TT	2002	27.9	30.4	29.6	28.8	28.6	27.2	26.8	25.8	26.9	27.5	28.1	26.8	27.8
TT	2003	21.6	23.5	29.9	28.6	28.6	26.8	26.4	26.2	27.4	28.2	28.2	27.0	26.8
TT	2004	28.0	28.7	29.1	29.1	28.2	27.1	26.0	25.8	27.0	27.7	28.4	28.4	27.8
TT	2005	26.9	30.6	29.4	29.5	28.6	27.1	26.2	25.5	27.2	27.8	28.1	28.0	27.9
TT	2006	28.2	29.0	28.7	29.0	28.1	27.2	26.8	26.7	27.2	28.0	28.5	27.6	27.9
TT	2007	27.3	30.4	30.3	29.4	28.6	27.6	26.8	26.5	27.1	27.3	27.9	27.8	28.1
TT	2008	26.2	29.3	29.0	28.6	28.2	27.6	27.0	26.7	27.2	28.1	28.7	28.0	27.9
TT	2009	27.5	28.9	29.0	28.8	28.3	27.5	26.5	26.1	26.9	28.0	28.2	28.5	27.8
TT	2010	28.8	30.1	29.3	29.6	29.1	27.8	27.0	26.7	27.2	27.8	27.9	28.2	28.3
TT	2011	27.3	28.7	28.8	29.2	28.7	27.9	26.9	3.85	26.9	27.7	28.8	28.3	26.1
TT	2012	28.0	28.9	29.7	29.3	28.6	27.7	26.6	26.3	26.7	27.6	28.5	28.2	28.0
TT	2013	28.5	30.6	29.7	29.7	28.4	27.4	26.2	25.7	26.8	27.2	28.3	27.3	28.0
TT	2014	28.7	28.9	29.3	29.4	28.4	28.0	26.5	26.0	26.7	27.1	28.3	27.8	27.9
TT	2015	27.8	29.6	29.7	29.3	29.0	27.8	27.1	26.3	27.2	28.2	28.3	27.0	28.1
TT	2016	28.9	30.5	30.2	30.2	29.0	27.7	27.2	26.3	27.3	28.1	29.0	28.4	28.5
TT	2017	28.8	30.3	30.0	29.7	29.1	27.6	26.5	26.2	27.2	28.0	28.2	27.9	28.3
TT	2018	28.3	30.5	29.4	29.1	28.2	27.2	27.4	26.4	27.3	27.8	28.5	28.5	28.2
TT	2019	29.4	30.1	29.8	29.4	29.2	27.8	26.9	26.5	27.4	27.7	28.6	28.8	28.5
TT	2020	28.8	31.0	30.1	29.5	29.2	27.9	26.8	27.1	27.3	27.4	28.7	28.9	28.5

ELEMENTS	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL RAINFALL
RR	2000	19.2	28.5	141.8	200.5	222.6	265.7	83.7	112.3	141.5	24.4	78.1	1.7	1320.0
RR	2001	0.0	22.5	138.2	234.6	102.0	293.1	101.0	120.8	97.7	83.1	29.2	30.7	1252.9
RR	2002	15.3	0.9	99.1	138.8	241.3	190.0	223.9	92.1	103.1	103.7	56.4	42.0	1306.6
RR	2003	57.6	50.8	72.0	132.9	197.8	257.9	41.4	71.2	74.7	296.3	164.8	55.6	1473.0
RR	2004	46.4	69.1	83.3	42.7	107.0	102.0	194.4	95.6	212.0	223.7	77.8	14.6	1268.6
RR	2005	8.9	21.5	190.7	116.0	195.7	268.3	5.3	120.0	73.8	158.5	110.2	0.0	1268.9
RR	2006	43.5	111.5	87.0	169.9	296.4	146.7	131.5	104.0	136.6	159.5	15.3	46.7	1448.6
RR	2007	0.6	21.6	59.4	172.3	157.6	181.4	210.8	92.6	137.7	259.1	71.3	1.8	1366.2
RR	2008	0.0	84.3	143.6	146.8	244.7	224.7	132.2	96.1	193.1	251.1	36.5	128.0	1681.1
RR	2009	3.4	101.2	143.4	129.3	162.1	366.2	88.6	57.3	28.5	94.8	152.3	65.0	1392.1
RR	2010	40.3	74.4	199.7	189.9	196.7	130.0	150.9	75.6	153.8	182.5	51.0	53.2	1498.0
RR	2011	13.4	89.5	162.6	165.5	166.3	236.6	117.7	39.2	225.6	164.8	77.9	0.0	1459.1
RR	2012	55.1	90.0	44.5	93.3	187.3	227.5	141.1	17.9	197.7	178.2	108.9	14.0	1355.5
RR	2013	0.0	41.0	94.4	215.7	146.8	248.7	140.1	23.3	230.5	200.1	151.9	13.8	1506.3
RR	2014	58.4	52.2	159.3	180.2	194.9	244.1	171.9	43.7	67.4	225.3	153.5	55.7	1606.6
RR	2015	28.6	92.6	76.9	200.7	180.7	232.0	79.8	21.1	68.0	330.9	136.5	49.6	1497.4
RR	2016	0.0	19.5	172.0	56.5	213.5	143.0	67.1	35.4	164.1	223.1	71.3	52.1	1217.6
RR	2017	15.4	36.9	77.4	119.0	140.9	236.2	159.1	67.8	141.6	201.0	145.6	52.0	1392.9
RR	2018	2.7	117.3	176.4	202.9	202.0	233.5	160.3	125.2	292.0	197.3	128.2	4.3	1842.1
RR	2019	30.3	24.6	142.4	193.5	164.6	152.6	155.0	37.3	266.6	279.6	128.3	30.4	1605.2
RR	2020	0.0	0.0	171.2	78.4	265.8	236.5	139.4	0.2	138.6	250.4	127.9	18.7	1427.1

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