

**CLIMATE VARIABILITY AND COCOA PRODUCTION: THE
IMPLICATIONS OF MICRO-ADAPTATION MEASURES ON COCOA
FARMERS' INCOME**

BY

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON,
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DECLARATION

I, Emmanuel Mireku Osei, do hereby declare that, with the exception of works cited which are duly acknowledged, the work presented in this thesis: **“CLIMATE VARIABILITY AND COCOA PRODUCTION: THE IMPLICATIONS OF MICRO-ADAPTATION MEASURES ON COCOA FARMERS’ INCOME”** was entirely done by me under the Climate Change and Sustainable Development Programme, College of Humanities, University of Ghana, Legon.

This thesis has never been presented either completely or in part for any other degree in this University or anywhere else.

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ABSTRACT

Climate change is having severe impacts on agricultural production and food security, with yields from rain-fed agriculture in developing countries projected to halve by 2020. One crop vulnerable to the effect of climate variability and change is cocoa (*Theobroma cacao*). Though there are extensive studies on how the cocoa sector can adapt to the adverse effects of climate variability and change, little empirical research has been carried out on the consequences of micro-adaptation measures on the net farm income of cocoa farmers. The study sought to analyse the effects of micro-adaptation measures to variability in two key climatic variables (temperature and rainfall), on cocoa farmers' net farm income. The study used multi-stage sampling techniques to purposely select 180 cocoa farmers and 6 key informants in six (6) communities in the Dormaa West District for primary data collection. The district has high reliance on agriculture, two major cocoa producing districts, increasing deforestation in the district that influences the local climate, and it is located in the transitional agro-ecological zone of Ghana. A 25-year period (1991 – 2015) climate and cocoa output data were obtained for trend analysis, determination of coefficient of variation (CV) and modelling with linear regression model. The study found out that there has been approximately 28% and 1% variability in average rainfall and temperature trends respectively for the period 1991 to 2015, which accounted for 56.7% variations in cocoa outputs. Results of a random effect model showed that application of micro-adaptation measures such as improved seed varieties, use of organic manure and increased farm size have significant positive impacts on cocoa farm net income. The study recommends the collaboration of the Forestry Commission with the Ghana Cocoa Board to promote these micro-adaptation measures and ensure programs that discourages forest depletion in the district to help boost the local average rainfall.

DEDICATION

I dedicate this thesis to my parents Mr. M. K. Oppong and Mrs. Alice Oppong, and my sister Rebecca Oppong.



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Emmanuel Mireku Osei

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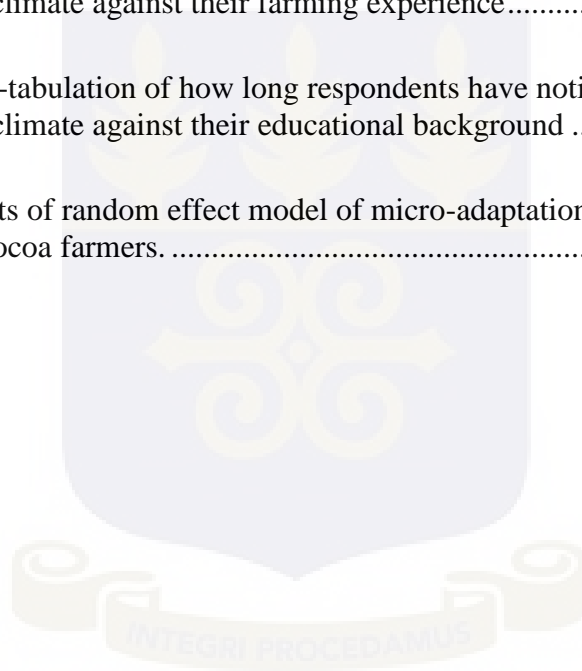
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LIST OF ABBREVIATIONS

COCOBOD	Ghana Cocoa Board
CODAPEC	Cocoa Division and Pest Control
CRIG	Cocoa Research Institute Ghana
CSA	Climate Smart Agriculture
CV	Coefficient of Variation
ENSO	El Nino Southern Oscillation
EPA	Environmental Protection Agency
ERP	Economic Recovery Programme
FAO	Food and Agriculture Organization
FAs	Farmers Associations
GCM	Global Circulation Model
GMet	Ghana Meteorological Agency
ICCO	International Cocoa Organization
IPCC	Intergovernmental Panel on Climate Change
LAI	Leaf Area Index
MoFA	Ministry of Food and Agriculture
PBC	Produce Buying Company
SPSS	Statistical Package for Service Solution
SST	Sea Surface Temperature
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Agriculture in Africa is one of the sectors most susceptible to climate variability and change, as it is highly rain-fed and dependent on other climatic variables such as temperature, relative humidity, and sunshine (Müller-Kuckelberg, 2012; IPCC, 2014). Climate variability directly affect crop development processes (Sarr, 2012) and indirectly affect soil properties, as well as thriving pests that attack crops (Sagoe, 2006). The temperature in Africa is rising faster than the global average and is likely to persist in the future (IPCC, 2014). These rising temperatures coupled with variable and highly unpredictable rainfall patterns have negative impacts on agricultural activities across Africa and the developing world (Sarr, 2012). In effect, empirical studies suggest that changes in the climate have led to a reduction in crop production (Ehiakpor *et al.*, 2016). Yield from rain-fed crops in some countries especially Sub-Saharan Africa is projected to halve by 2020 (UNFCCC, 2007; Di Falco *et al.*, 2011; Pilo *et al.*, 2016).

According to Agbongiarhuoyi *et al.*, (2013) and Lawal & Emaku (2007), one crop that is vulnerable to climate variability is Cocoa (*Theobroma cacao*). Cocoa on the average thrives well within the temperature range of 18°C to 21°C mean minimum and 30°C to 32°C mean maximum (Anim-Kwapong & Frimpong, 2004), and rainfall averages of 1500 millimetres (mm) to 2000mm annually (Nair, 2010). This means that any increase or decrease below the mean minimum or beyond the mean maximum would negatively affect cocoa output, as well as, the application of some other determinants of cocoa output such as fertilizer and pesticides. In addition, variations in rainfall pattern often

confuse farmers and affect the production process of the cocoa tree (Ehiakpor *et al.*, 2016).

In Ghana, historical climate data recorded by Ghana Meteorological Agency (GMet) across the country between 1960 and 2000 shows a progressive and clear rise in temperature and a decrease in rainfall in all agro-ecological zones of the country (Sagoe, 2006; Boon & Ahenkan, 2011), which poses threats to Ghana's cocoa industry and cocoa livelihoods as it is highly rain fed. Cocoa production contributes the highest to foreign exchange earnings of approximately 30% of the total export earnings (Codjoe *et al.*, 2013; Hutchins *et al.*, 2015). It also contributes significantly to the generation of employment for about 800,000 smallholder farm families (Anim-Kwapong & Frimpong, 2004).

A survey conducted among cocoa farmers in 1991, 1999 and 2005 indicated a reduction in poverty levels among cocoa-producing households from 60.1% in the 1990's to 23.9% in 2005; the reduction was attributed to favourable cocoa prices, higher yields and increased production (Tawiah, 2015). In 2010/2011, Ghana's exports of cocoa reached 1,004,000 metric tonnes (MT) and, has since been the second largest exporter of cocoa in the world, in terms of quantity (Asante-Poku & Angelucci, 2013). In addition, cocoa plays a significant role of providing a secondary habitat for some forest animals and species (Läderach *et al.*, 2013).

The socio-economic significance of cocoa to the country has led to an extensive study on how to adapt to the adverse effects of climate variability on cocoa production both at the national (macro) and individual (micro) levels by various researchers (Anim-Kwapong & Frimpong, 2004; Ehiakpor, 2016). At the macro level, the government through the Cocoa Research Institute of Ghana (CRIG) has introduced new cocoa

species such as the hybrid type to farmers as an adaptation to climate variability and change, in order to maintain adequate cocoa outputs (Kolavalli & Vigneri, 2011). The micro-adaptation measures by the farmers on the other hand, include the decisions of farmers to increase or decrease the fertilizer and pesticide usage on their farms. These measures are intended to increase yields and eventually increase farmers' farm income from cocoa produce. According to Anim-Kwapong & Frimpong (2004) and Oguntade & Fatunmbi (2012), farmers at the micro level resort to increasing their farm area especially into virgin forest areas with fertile soils and low crop disease levels as a way to increase cocoa production. This according to them happens only when the premium paid for higher quality cocoa is greater than the added cost of producing it, making pricing and profit an important factor to farmers' adoption of adaptation measures.

In spite of several studies on the effects of climate variability on cocoa production, and adaptation, little empirical research has been carried out on the effects of the use of micro-adaptation measures by farmers on their farm income (Mendelsohn, 2012), and how these effects influence their future adoption of adaptation measures (Huda, 2015). Farmers fail to meet transaction costs necessary to acquire adaptation measures due to income constraints, and at times cannot make beneficial use of the available information they might have (Nhemachena & Hassan, 2007). Improving the adaptive capacity of farmers require ensuring access to resources, income generation activities and increasing the capacity of the poor to participate in local actions (Nhemachena & Hassan, 2007). For this reason, it is necessary to understand how the adopted micro-adaptation measures by cocoa farmers affect their net farm income and eventually influence their response to future adaptation to climate variability.

1.2 Problem Statement

Cocoa is a tropical crop grown in six (6) regions out of the ten (10) regions in Ghana. Cocoa has been the backbone of the country's economy and source of livelihood for cocoa farmers in the growing regions for several decades, contributing about 70% to 100% of their annual household income (Anim-Kwapong & Frimpong, 2004). The bulk of the cocoa produced in Ghana is cultivated by smallholder farmers, who grow over 90% of the crop (Codjoe *et al.*, 2013). These farmers are largely aged, 50 years and above and most often do not earn enough income as individuals to easily adapt to yield improvement measures to respond to variability in climate (Anim-Kwapong & Frimpong, 2004).

At the beginning of the 2014/2015 growing season, targeted yields by Ghana Cocoa Board (COCOBOD) was 1 million metric tonnes (MT). Increases in producer prices of cocoa (by say 62.74% in 2014) were expected to be an enough economic incentive for farmers to increase production. However due to illegal mining activities (Boateng *et al.*, 2014), seasonal bushfires, deforestation, poor farm maintenance, and pest and disease infestations, (Tawiah, 2015) the actual cocoa yield of the country fell below the targeted 1,000,000 MT to about 740,000 MT (Ghana Cocoa Board, 2016). The situation was exacerbated by variability in climatic variables (temperature, humidity, sunshine and rainfall). These factors can be tackled through law enforcement and the provision of extension support. The climate factor remains a big challenge; the projected climatic variables in areas such as the forest-savannah transitional zone found in and around the Brong-Ahafo Region suggest the area will be unfavourable for cocoa production in the not too distant future (Kyere, 2016).

The government of Ghana in anticipation of low cocoa yields had adopted several macro-level policies and measures such as Cocoa Diseases and Pest Control

(CODAPEC) to strengthen the factors of cocoa production and to boost farmers' resistance to climate variability effects (Afrane & Ntiamoah, 2011; Kumi & Daymond, 2015). Other policies included the provision of fertilizers and improved seedlings to some farmers to improve production, and encourage expansion of areas under cultivation (Anim-Kwapong & Frimpong, 2004). This has seen in recent times some farmers in the Brong-Ahafo Region (who had abandoned the production of cocoa to growing crops such as maize) converting back to cocoa production (Adjei-Nsiah & Kermah, 2012). Other farmers who had gone to the Western Region after the 1983 bushfires have returned to establish new cocoa farms in their original place of residence outside the Western Region (Kyere, 2016).

The macro-level policies and measures by the government alone do not solve these problems of low cocoa outputs, as they are concerned with production at national and regional scales and therefore do not fully cover individual farmers localized and distinct problems affecting their outputs and incomes. In this regard, most farmers tend to finance and take decisions on the use of some adaptive measures on their own at the micro-level, which are mostly short-term in a way to help boost their income. Farmers' ability and willingness to adopt these micro-adaptation strategies depend on their level of income, of which income from the previous year is a major factor. It is therefore critical to identify the micro-adaptations and examine returns the micro-adaptation measures bring to the farmers. Understanding the effect of micro-adaptation measures on farmers' income is important because it is a great determinant of choices of future adaptation measures by the farmers. The study sought to address the following questions:

1. How does climate variability affect outputs of cocoa farms in the Dormaa West District?

2. What are the micro-adaptation strategies used to improve output on cocoa fields in the Dormaa West District?
3. How do micro-adaptation strategies affect the net income of cocoa farmers in the Dormaa West District?

1.3 Study Objective

The major objective of this study is to examine the implications of micro-adaptation measures to climate variability on the incomes of cocoa farmers.

The specific objectives of the study are to:

1. Determine how climate variability affect outputs of cocoa farms in Dormaa West District
2. Identify specific micro-adaptation measures used to improve output on cocoa fields in Dormaa West District
3. Determine the effect of these micro-adaptation measures on the net income of cocoa farmers.

1.4 Justification of Study

Understanding the micro-adaptation measures to climate variability and change used by farmers and its effect on their incomes would achieve the following: (i) Help the various stakeholders especially the farmers identify the effects that variability in climatic variables (temperature and rainfall) has on their cocoa yields. According to Kurukulasuriya & Rosenthal (2003) the efficiency of an adaptation must include the level to which the farmers believe that there has been a change in the climate, and their awareness of the type and form of change. (ii) Help reveal what measures farmers are

implementing on their own to increase their production. According to Ehiakpor *et al.*, (2016), vulnerability of smallholder farmers is projected to increase without adaptation. Therefore, farmers adopt several adaptation strategies to minimize their susceptibility to crop failure due to climate variability. (iii) Show the extent to which the micro-adaptation measures by the farmers affect their income from cocoa produce and their choice of future adaptation measures.

This research is important, especially at a time when the global cocoa industry is investing in productivity gains through sustainable agriculture, as one of the main pipelines for higher income and cocoa sustainability (Witjaksono, 2016).

The research findings will provide the basis for appropriate interventions as well as for creating avenues for the COCOBOD and other stakeholder institutions to promote the micro-adaptation measures identified as significant, and to provide extra support to farmers in order to reduce the burden on them and increase their income.

Climate-Smart Agriculture (CSA) which aims at “Sustainable increasing agricultural productivity, to support equitable increases in farm incomes, food security, and development” (FAO, 2013), is linked to micro-adaptation measures. Finding that cocoa farming in the Dormaa West District is climate smart will provide relevant information for niche markets and support policy formation.

1.5 Organization of Study

The study is organized into five main chapters. The first chapter introduces the study. The second chapter provides a review of relevant literature on climate variability on cocoa production, adaptation to variability and effect on farm net income.

Chapter Three provide the theoretical and conceptual frameworks and an in-depth description of the methodology of the study. Specifically, the methods of data analysis, data collection, the study area and, the scope and limitation of the study are described.

Chapter four presents the results of the study as well as the discussion of the results presented in relation to the research objectives. Finally, Chapter Five outlines the summary, conclusions, and recommendations for policymaking and future research.



CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter presents a review of reports and articles on definitions, concepts and previous studies that have examined cocoa production and climate variability. The review opens with literature on key concepts, climate variability and cocoa production, cocoa production in Ghana and climate adaptation strategies commonly used by cocoa farmers. The empirical studies on effect of adaptation measures on farm income.

2.1 Definition of Key Concepts

Climate change and variability

This refers to a change in the state of the climate which may be due to natural internal processes or external forcing and anthropogenic activities that can be identified by using statistical tests to observe changes in mean and variability of its properties that persist for an extended period of time, typically for decades or longer (IPCC, 2014).

Climate change adaptation

Adaptation refers to the process of adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. (IPCC, 2014).

Micro-adaptation measures to climate change

Micro-adaptation measures are behavioural response by an individual or firm to an environmental change for one's own benefit, by reducing damages that would otherwise occur or taking advantage of the opportunity that comes with climate change. (Mendelsohn, 2000)

Climate change impacts

Impacts of climate change refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system to the hazard. (IPCC, 2014).

Net income

Net income is the income available to an individual or firm after all expenses of production activities have been taken care of.

2.2 Climate Variability and Cocoa Production

Cocoa is a tropical crop grown in most tropical areas in the world such as Brazil and Indonesia, with roughly about 70% of the world's total outputs produced by West African countries such as Ghana, Ivory Coast, Nigeria and Cameroon (Schroth *et al.*, 2016). This is due to the availability of favourable cocoa production conditions in these areas such as the soil types and the climate found among countries along the West African coastline.

2.2.1 Evidence of climate variability and change

Climate variability is the way climate of an area fluctuates yearly above or below a long-term average value. That is a yearly shift from the long-term mean climate of an area attributed to events such as EL-Nino, La Nina and volcanic eruption, known as climate teleconnections (Sarr, 2012). The persistence of this variability eventually leads to a change in the climate of the area.

Rainfall over West Africa is influenced by both the global climate teleconnections such as those associated with El-Nino Southern Oscillation (ENSO) and regional climate systems which include inter-tropical discontinuity, monsoons and sea surface temperature (SST) anomalies, as well as human impacts from land use changes (deforestation) (Sarr, 2012). These climate teleconnections are influenced by solar radiation and temperature deficit at the tropics. The increasing global temperatures, frequency, and uncertainties in the factors that affect rainfall in West Africa are likely to increase rainfall anomalies within the West African sub-region.

In Ghana, an analysis of a 40-year data from 1960 to 2000 displayed a clear rise in temperature and a simultaneous decline in rainfall across all agro-ecological zones (EPA, 2007 cited in Adjei-Nsiah & Kemah, 2012). In addition, according to Anim-Kwapong & Frimpong (2004), climate change scenarios for some agro-ecological zones in Ghana shows a decline in annual rainfall by 2.8%, 10.9% and 18.6% in 2020, 2050 and 2080 respectively and a rise in temperature by 0.6°C, 2.0°C and 3.9°C in 2020, 2050 and 2080 respectively. These changes projected are to decrease soil moisture conditions during the dry seasons and intensify the risk of cocoa production to the adverse impacts of climate change. According to Kyere (2016) within the past 50 years, sea surface temperature (SST) changes in the Western Pacific (El Nino), led to below average rainfall in most West African countries in 1983, leading to a national plea for aid.

2.2.2 Cocoa production in Ghana

The Ghana Cocoa Board (COCOBOD) is mandated by the Government of Ghana to manage activities in the cocoa industry, due to its economic importance to the country. Their mandate includes agricultural research into cocoa, export and internal marketing

of cocoa beans, hybridization of seeds, sale of seeds, extension services to farmers and quality control services (Hutchins *et al.*, 2015). The existence of this institution over the years has ensured sustained growth in the cocoa industry in spite of low productivity when compared to other leading cocoa producers in the world.

According to Kolavalli & Vigneri (2011), the country's cocoa production since its establishment in the 1800's has seen four (4) major phases. The introduction and exponential growth period (1888 – 1937), stagnation followed by a brief but rapid growth, after the country's independence (1938 – 1964), a near collapse (1965 – 1982) and finally, the recovery and expansion following the implementation of the Economic Recovery Program (ERP) (1983 – 2008). The last phase became successful with the implementation of the ERP, which involved increases in the price paid to Ghanaian farmers as compared to those paid to neighbouring countries. In addition, farmers were compensated for removing trees infested with swollen shoot virus and planting new ones. This led to a large number of farmers planting higher yielding cocoa tree varieties developed by the Cocoa Research Institute of Ghana (CRIG), with 1995/1996 growing season having an increase in productivity from 210 to 404 kilograms per hectare (kg/h). From 2001/2002 growing season saw some other interventions by the Government of Ghana through the mass spraying program and HI-TECH subsidy packages to promote the adoption of a higher and more frequent application of fertilizer. In addition, the Cocoa Diseases and Pests Control (CODAPEC) program coupled with a massive increase in world cocoa prices motivated more farmers to increase their production. These interventions from its start saw a massive increase in national cocoa output from 380,000 MT to 500,000 MT in the 2002/2003 growing season (Baah *et al.*, 2011).

Upon these interventions by the government that sought to motivate farmers and increases production, cocoa productivity rate in Ghana recently is estimated at around

400kg per hectare (kg/h) (Aneani & Ofori Frimpong, 2013). Compared to annual yield rates of countries such as Cote d'Ivoire (600kg/h) and Indonesia (1000kg/h), Ghana's annual yield rate is very low, though most of our agricultural lands are committed to growing cocoa (Appiah *et al.*, 1992; Anim-Kwapong & Frimpong, 2004; Frenzen & Mulder, 2007). In addition, Oguntade & Fatunmbi (2012) analysed the technical efficiency among cocoa producing communities in West Africa using the stochastic frontier model and the Meta-stochastic frontier analysis and, Ghana had the least efficiency of 44% with Nigeria having the highest of 74% efficiency.

The low productivity has been attributed to several factors such as variable climatic conditions, poor farm practices, seasonal bushfires, illegal mining activities, and pest infestations. Most of which are intensified by climate variability, especially in rainfall and temperature (Tawiah, 2015). According to Anim-Kwapong & Frimpong (2004), the highly contagious black pod disease is the most damaging disease that affects the development and riping of the cocoa pod. Lawal & Emaku (2007) attributes these high incidences of black pod disease to high relative humidity obtained in the morning across the growing belt in West Africa and also a continuous rainfall for several weeks (Oyekale, 2015).

The effects of climate variability on cocoa production render the government interventions insufficient. The kind of cocoa variety Ghanaian cocoa farmers are encouraged to grow (the hybrid type), only ensures a continuous higher yield with lots of fertilizer and pesticide application. In most cases the farmers are unable to afford, therefore result in some recurring low yields (Frenzen & Mulder, 2007), which require some supporting strategies at the individual farmers' level to boost their yield.

2.2.3 Impacts of climate variability on cocoa production

A number of climatic factors (temperature, rainfall, humidity and sunshine) are noted to have interrelated impacts on the growth of the cocoa crop (Owoeye & Sekumade, 2016), but the major determinants of cocoa growth are temperature and rainfall (Ngoong & Forgha, 2013). Research conducted in Ghana by Hutchins *et al.*, (2015), indicated that all key informant interviews and farmers revealed that variability in temperature and rainfall are the major challenges being faced. These impacts of climate variability, especially prolonged drought on cocoa makes it difficult to establish new cocoa farms (Anim-Kwapong & Frimpong, 2004; Hutchins *et al.*, 2015). Marked dry periods result in a reduction in Leaf Area Index (LAI) leading to a reduction in cocoa yields (Adjei-Nsiah & Kermah, 2012).

Temperature affect crops growth and development in a number of ways. These include, alteration of the crop flowering period, leading to a reduction in seed numbers and high evapotranspiration (Challinor & Wheeler, 2007). The moisture loss leads to an increase in Plant Water Demand (PWD), causing drought stress on the crop during the dry season (Schroth *et al.*, 2016). According to Oyekale (2015), changing climate can also alter the development of pests and diseases, that affect cocoa by modifying the host's resistance to pesticides. A case study conducted at the Cocoa Research Institute Nigeria (CRIN), Ibadan by Lawal & Emaku (2007) on the effect of some climatic variables on black pod disease revealed a positive correlation (0.370 and 0.003) for temperature and humidity respectively. That is, as these climatic variables increase the incidence of black pod disease also increases. In addition, the changes in length and intensity of sunshine, that is, exceeding 60% tends to decrease the rate of photosynthesis, with prolonged exposure to higher sunshine damaging the photosynthetic mechanism of the leaf (Anim-Kwapong & Frimpong, 2004).

Rainfall affect cocoa yields more than any other environmental factor (Adjei-Nsiah & Kermah, 2012). Cocoa is highly sensitive to drought and the pattern of its cultivation is related to rainfall distribution (Owoeye & Sekumade, 2016), and therefore produces well under minimal but sustained water availability all year (Oyekale, 2015). This implies that the year to year variations in cocoa yields are affected more by rainfall regime than any other climate variable, and therefore, the ideal annual rainfall regime suitable for maximum growth and yield is between 1500 and 2500mm (Nair, 2010). Even though global projection for future rainfall indicates a decline, Läderach *et al.*, (2013), suggests an insignificant decline of 12mm in rainfall over Ghana and Cote d'Ivoire by 2030. In as much as an increased rainfall is needed for high productivity, Oyekale *et al.*, (2009) cited in Hutchins *et al.*, (2015), argued that increased rains and prolonged wet seasons slows cocoa drying and processing, thereby reducing the value of the bean and increasing the cost of processing. Therefore, an effective cocoa production through harvesting and processing require timely and moderate rainfall distribution, as cocoa is highly sensitive to extreme weather events. In addition, due to the unpredictable rainfall patterns, cocoa farmers tend to confuse regular times of spraying cocoa pods to ensure maximum protection (Oyekale, 2015).

2.3 Adaptation Strategies Used in Agriculture

Adaptation to climate change is the adjustment to actual or expected climate and its effects, which seeks to moderate or avoid harm and exploit beneficial opportunities (IPCC, 2014). Berhe (2016) refers to any reactionary responses to a new set of conditions either intentionally or autonomously to adjust to certain pressures posed by climate change which distress human wellbeing and that it only serves its purpose when its application reduces the intensity of a person's vulnerability and increases their

adaptive capacity. Kurukulasuriya & Rosenthal (2003) emphasized that, adaptation is not a new phenomenon and that the intensity of a potential adverse or beneficial impacts on agricultural productivity, potentially could be significantly reduced or enhance through the right mix of adaptation measures. According to Codjoe *et al.*, (2013), they include policies and measures to reduce exposure to climate variability and extremes and the strengthening of adaptive capacity.

According to Berhe (2016), adaptation is heavily dependent on a variety of factors such as traditional and modern institutions, resource availability and availability of other livelihood options as farmers' resource allocation decisions are determined by their resource endowment, social and institutional environment and thereby their response to climate change (Pilo, 2016). However, for the effectiveness of an adaptation, it must be site specific. That is to say, it must include the extent to which the people believe that there have been some changes in the climate, their awareness of the type and form of change and knowledge on available and future technology (Kurukulasuriya & Rosenthal, 2003), as different sites may require different levels of these factors in their application and adoption processes.

2.3.1 Categories of adaptation measures used in agriculture

Several scholars have categorized agricultural adaptation options in diverse ways based on several factors, Pilo (2016) categorized them into two forms, that is, on-farm and off-farm adaptation measures, which are strictly based on the availability of other livelihood options. Off-farm adaptation measures are mainly the creation of income alternatives from other activities such as selling firewood, charcoal, and growing other crops that have quick maturity to be able to sell in a shortest possible time, such as growing maize rather than cocoa to generate more income to meet the short-term needs

(Berhe, 2016). This, Kurukulasuriya & Rosenthal (2003) says there is greater benefit from adaptation options in sectors and systems where the turnover of capital investment and operating cost is shorter, rather than where long-term investment is required. On the other hand, on-farm measures involve investing further on the existing farm that is being affected by climate change (Berhe, 2016) such as applying chemicals and fertilizers to the farm to help increase production.

In addition, adaptation can be reactive or anticipatory (Kurukulasuriya & Rosenthal, 2003). Anticipatory in the sense of being able to predict what is ahead of you or an incoming change to which you adapt. These kinds of adaptation measures are commonly aimed at capital-intensive sectors such forestry and coastal sectors, as these sectors take time to respond to effects. Reactive adaptation, on the other hand, is mostly coping mechanisms likely made by an individual or an institution in response to climate impact. These coping mechanisms are the immediate response of a society, used quickly to respond to the adverse effects posed by climate variability with its available resources and abilities. Kurukulasuriya & Rosenthal (2003) argue that the effectiveness of both reactive and anticipatory adaptation measures, is purely based on resource availability of which, Berhe (2016) suggest resource availability to be one of the factors on which adaptation is heavily dependent.

Adaptation in agriculture as well can be categorized based on the decision and implementation body, such as farm-level (micro-adaptation) measures based solely on the farmers' decision making and at the national level (macro-adaptation) measures concern about national and regional agricultural production, and its relationship with domestic and international policies (Nhemachena & Hassan, 2007). Micro-adaptation options are undertaken solely for the exclusive benefit of the individual decision maker

(Mendelsohn, 2000), and are known as private adaptation options, as they are purely driven by self-interest and underlying farm income, and yield maximization motive.

2.3.2 Micro-adaptation measures used to improve output on cocoa fields

A research conducted by Kyere (2016) in the forest-savanna transitional zone of Ghana revealed that planting more plantain suckers as a protective shield over cocoa seedlings against excessive sunshine is one of the major adaptation strategies practiced by the farmers due to deforestation that has left large parts of the land bare.

In addition, Below *et al.*, (2010), concludes that improved variety has a considerable potential to strengthen the adaptive capacity of farmers. An example is the hybridization of cocoa seeds by the Cocoa Research Institute of Ghana in 1984 (Kolavalli & Vigneri, 2011) to produce the hybrid type grown by most cocoa farmers recently, as it is sunshine tolerant, matures early and give higher yields compared to the Amazon and Amelonado types previously cultivated. Aneani & Ofori-Frimpong (2013) analysed the yield gap and some factors of cocoa yield in Ghana and found that planting poor cocoa varieties have negative impacts on cocoa yield. This they indicated, can reduce cocoa yield by 28.1 (kg/h) due to the highly genetic variations among the cocoa varieties. According to Burke & Lobell (2010), decisions to switch crop variety cannot be made on the basis of climate alone. Different varieties have different input requirements and cost associated with their production. Therefore, the farmers must be willing to bare those costs that comes with the use of new crop varieties.

One other important adaptation measure used in agriculture is both income and crop diversification (Nhemachena & Hassan, 2007). Income diversification involves the sale of non-timber forest products and activities that farm families undertake beyond the farm such as petty trading (Below *et al.*, 2010). These kinds of adaptation strategies are

common phenomenon internationally and directed toward earning much-needed income. Crop diversification involves engaging in production activities of crops that are drought tolerant or resistant to temperature stresses and take maximum advantage of prevailing rainfall and temperature conditions among other factors (Nhemachena & Hassan, 2007; Adjei-Nsiah & Kermah, 2012).

Crop diversification is expensive in terms of income opportunities that farmers forgo, making it less profitable than to specialize in one crop (Kurukulasuriya & Rosenthal, 2003). Codjoe *et al.*, (2013) argues that it can rather reduce vulnerability by serving as an insurance to rainfall and temperature variability as different crops are affected differently by climatic events. Mertz *et al.*, (2010) as cited in Akinngbe & Irohibe (2014), indicated that in Southern Burkina Faso, farmers adapt to the effects of low yield by engaging in the dry season market gardening and off-farm income sources, and in such instances they turn their attention to activities that are less dependent on the climate.

Fertilizer use in Ghana has increased significantly since the 1990s, and surveys of cocoa farms from the major cocoa producing areas in the country suggest an increased rate of 9% in 1991 to 47% in 2003 fertilizer application (Kolavalli & Vigneri, 2011). This is partly due to the cultivation of the hybrid type of cocoa, which require a lot of fertilizer and other chemicals to ensure maximum productivity. Even though chemical fertilizer use shows a drastic increase and still increasing, Codjoe *et al.*, (2013) argue that most farmers are interested in the use of without fertilizer strategy such as mulching to improving soil fertility as it is less costly.

Increasing farm size strategy involves expanding farms and establishing new farms in addition to old and low yielding farms (Codjoe *et al.*, 2013). Mostly, many farmers find

it economical to expand their farms rather than to replace old and diseased trees, as it takes as twice as the cost to clear an old cocoa farm as it does to clear a forest (Kolavalli & Vigneri, 2011).

One major constraint to cocoa farmers' inability to adapt to certain micro-adaptation measures such as increased fertilizer application and pesticide use is the lack of capital, which would become problematic to them if yields continue to decrease (Codjoe *et al.*, 2013). Some suggest that this can be improved by the intensification of yields on existing cocoa lands and not necessarily increase of farm lands as argued by Schroth *et al.*, (2016). As this would help prevent additional deforestation that is associated with clearing new lands for cocoa production, which happens to be a major, local cause of rainfall variability in cocoa growing areas.

2.4 Impacts of Micro-Adaptation Measures on Farmers' Income

Many factors affect the income of rural farmers such as rural policies, household adaptive behaviours and natural pressure such as drought and temperature changes. In situations where a rural community faces multiple effects from climate variability over a period, farm income of the farmers tends to fluctuate. It is important to understand how the various climate adaptation measures being implemented by the farmers affect their income (Berhe, 2016). According to Mendelsohn (2012), adaptation is efficient only if their benefits exceed their cost of implementing them, and farmers, therefore, would adopt efficient adaptation measures to help improve their yields and income. In addition, the mode of implementing adaptation measures must address not only vulnerability but also the specificity of both vulnerability and poverty by looking at how they affect the incomes of the farmers (Eriksen & O'Brien, 2007). Therefore, the need

to explore on how cocoa farm households' decision to adopt a set of micro-adaptation measures such as increased used of fertilizer, crop diversification, increased farm size, etc. in response to variability in climate (temperature and rainfall) and how it affect farm income of farmers and their households in general (Pilo, 2016).

2.4.1 Models for estimating climate impacts assessment on farmers' net income

Impacts of climate variability and change assessment on agriculture are widely estimated using one of these two general categories (Process-oriented approach and the statistical approach) (Nwachukwu *et al.*, 2012; Huda, 2015). The process-oriented (agronomic) approach simulates crop growth as a function of climatic parameters such as temperature and precipitation. In this approach plant leaf, and stem growth rates are estimated in the context of a study of six stages of bio-climate interaction and some other marginal inputs (Di Falco *et al.*, 2011; Huda, 2015). In addition, it could be used to estimate the impacts of climate change on agricultural productivity, as well as to investigate the potential effects of different modes of adaptation (Di Falco *et al.*, 2011). The process-oriented approach has its strength with its ability to stimulate growth in stages so that every event could be assessed, even daily (Antle & Capalbo, 2010). However, economic considerations and human capital limitations that affect farm decision-making processes are not taken into account, as well as extensive data, on the other hand, is required for estimation of this model, therefore, making it a great limitation for study in developing countries where data on agricultural production are less often recorded (Di Falco *et al.*, 2011).

A statistical approach, on the other hand, is useful in predicting future responses based on past relationships. Within the statistical analysis approach, there is cross-sectional and time series data, which focuses on long-run adaptation measures to climate

variability and change. Therefore, it has problems with omitted variables such as unobserved heterogeneity among individuals or communities. To correct such problem of omitted variables as suggested by some researchers (Deschenes & Greenstone, 2007; Massetti & Mendelsohn, 2011), is the use of panel data where cross-sectional data is followed over time and by the use of a fixed-effect analysis, help account for regional determinants of yield. The advantage with the use of a panel data statistical approach for analysing the impacts of climate change on farming depends on its methodological approach. The data required for the assessment is relatively small, has a spatial resolution and higher goodness of fit compared to cross-sectional statistical approach.

Some researchers in their various studies have used several approaches and models such as the Ricardian model, bio-economic model, standard instrumental variables approach and the fixed effect model (Panel data analysis) in assessing the intensity and significance of climate change effects (Mendelsohn, 2000; Deschenes & Greenstone, 2007; Massetti and Mendelsohn, 2011; De Falco *et al.*, 2011; Pilo, 2016; Berhe, 2016). In estimating the impacts of climate change on agricultural net income, a widely used approach is the Ricardian (hedonic) Approach, which is based on the notion that long-term productivity of a land is realized in its asset value (Di Falco *et al.*, 2011). The model, therefore, assumes that farmers are changing their mix of activities in favour of crops that yield the highest returns from a unit of land, which eventually boost its asset value. The approach focuses on the impacts of climate change on the values of land and not crop yields (Huda, 2015) and has a basic concept as the statistical approach as it uses cross-sectional data for its impact assessment. The model uses historical data to determine the statistical relationship between economic values of land or farm earnings and changes in climatic variables. Antle (1996) as cited in Antle & Capalbo (2010),

argue that the use of historical data requires the assumption that future climate has the same statistical properties as past climate.

The Ricardian model also assumes that there are no adjustment costs such as land rent, inputs cost that fully reflect the value of the climate at any given location. Therefore, farmers maximize profit subject to exogenous conditions such as temperature and precipitation of the farm. The farmer, therefore, chooses the list of inputs (adaptation measures) that would help increase his profit. This model just as the cross-sectional statistical approach is limited by its inability to take into account unobserved determinants of the individuals or firms profit that influence decision-making processes such as the wealth and experience level of the individual. Secondly, due to its cross-sectional behaviour, limited data across space or sections may affect the estimation of impact assessment. In most cases, these are likely issues in developing countries where meteorological stations are widely set apart but are greatly affected by climate variability and change. Lastly, farmers cannot implement their full range of adaptation measures in a year to be able to estimate their effects on the net income of the farmers. Therefore, assessing impacts across time gives room to include fully, all measures that are likely to be implemented by the farmer (Deschenes & Greenstone, 2007).

It is based on these limitations of the traditional Ricardian Model, which rely on cross-sectional data that some researchers suggest an Advanced Ricardian Model (ARM), which is based on a panel data statistical approach. The Advanced Ricardian Model, unlike the traditional Ricardian Model, focus on the short-term weather fluctuations rather than on climate change, therefore making it easy to estimate the impact of climate change with less available data over time (Huda, 2015). In addition, the model caters for unobserved variables that may affect the individual choice of inputs (adaptation measures) to climate variabilities such as farmers' information and understanding on

climate variability and adaptation. Some researchers have criticized that farmers adopt alternative practices not only for a short-term weather variability but rather to cope with the long-term climate change.

Therefore, with the available data from the field survey, the advanced Ricardian Model (ARM) deemed the best model for estimating the effects climate variability and the adaptation measures used by farmers in the Dormaa West District is having on their farm net income.

2.4.2 Empirical literature on impacts of micro-adaptation measures on farmers income using a panel data approach

Deschenes & Greenstone (2007) used county-level panel data to measure the economic impacts of climate change on US agricultural land by estimating the effect of random year-to-year variation in temperature and precipitation on agricultural profit. The study found that estimation by repeated cross-sectional data model is robust in numerous specification checks and relatively precise, so large negative and positive effects are unlikely. In addition, the study found that the traditional Ricardian Model, widely used for climate change impact assessment is unreliable as it produces estimates that are extremely sensitive to seemingly minor choices of control variables, sample, and weighting.

Masseti and Mendelsohn (2011) as well used the county-level panel data to measure the economic impacts of climate change on US agricultural land by estimating the effect of random year-to-year variation in temperature and precipitation on agricultural profit. Their study argued that if a panel data is available for the Ricardian method, estimating consequences using repeated cross-sectional method is inaccurate. Instead, one should use the panel data methods that properly specify which coefficients should vary over time and the ones that remain stable. The study, therefore, developed a panel data

method for estimating panel data with Ricardian Model (Advanced Ricardian Model). The study found that climate coefficients from the advanced Ricardian Model are far more accurate than coefficients from repeated cross sections. This suggests that many cross-sectional valuation methods may benefit from panel data provided the models are estimated correctly.

Huda (2015) used the advanced Ricardian Model on a farm-level panel data of rice farming in the coastal area of Bangladesh to study the economic implications of alternative farming activities relating to climate change. The study found out that there would be an adverse effect on farm net income as climate change is a continuous process that relates to global economic development using its estimated climate variability model.

Berhe (2016) used a fixed effect model on a panel data for pastoral farming from the Aba'ala district in the Afar Regional State of north-eastern Ethiopia to establish the effects of climate adaptation strategies on the income of cattle owners. In his study, he grouped adaptation into two parts. These are creating alternate income options and adaptation through cattle management and their effects on farmers' income across the panel years under review. In his findings, he realized that most adaptation through cattle management practices has statistical significance and positive effects on incomes of households, unlike creating alternative income options.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter presents a description of the theoretical and conceptual frameworks and the methods of data analysis for each of the specific objectives. First, the description of the theoretical and conceptual frameworks, methods of data analysis, data sources, data collection methods, instruments used for data collection, description of the study area, and the scope and limitation of the study.

3.1 Theoretical framework: Climate Change, Micro-Adaptation Measures, and Farmers' Income.

The theories underpinning climate variability, micro-adaptation measure and farmers' income are the Efficient Adaptation Theory (EAT) and the Advanced Ricardian Model (ARM). The Efficient Adaptation Theory is based on the notion that adaptations are essential or desirable only if their profit exceeds their cost. Therefore, in order to understand how households, adapt to climate change, one must first understand how climate directly affect household decisions (micro-adaptation choices).

The theory assumes that before climate variability and change, households or individuals maximize profit with their available outputs sold at a given unit price minus their available inputs at a given unit price.

$$Max \pi = P_Q(Z, C) - \Sigma P_Z Z \dots \dots \dots (3.1)$$

Where; Max π = maximum profit,

P = Price

Q = Outputs

Z = Farm inputs

C = Climatic factors.

Climate factor enters the production function and modifies the relationship between inputs and outputs. This change in relationship is argued to be nonlinear. For instance, rainfall and temperature tend to have a hill-shaped relationship in agriculture (Passel *et al.*, 2012), where productivity of a crop at the initial stage increases due to increase in photosynthesis and then begins to decrease with warmer temperatures as the crop reaches its thermal tolerance.

Therefore, as climate changes, households may experience an increase or a decrease in output. This change in output cause households to change their inputs (micro-adaptation measures) because marginal productivity of the inputs often would be changing. The theory concludes that if the marginal profit from the production increase or decreases with climate change it will affect how much inputs households will use.

From the basis of this theory, Mendelsohn (2012) argue that private (micro) adaptations are likely to be efficient because benefits and cost incur to the decision maker. As the decision maker is interested in maximizing profit, adaptation measures that are efficient to them will be selected.

At the micro-level one widely used approach for estimating effects or an impact assessment of climate change on farm income is the Ricardian Model (RM), which regress changes in climatic variables such as temperature and precipitation on farm yields (Kyere, 2016). The Ricardian Model uses cross-sectional approach and had been criticized widely by some researchers to be biased, as it omits variables such as unobserved individual heterogeneity that may affect decision-making (Deschenes &

Greenstone, 2007). Another limitation to the Ricardian Model approach is that in developing countries, where there is an inadequate spatial variation of key climatic parameters such as temperature and precipitation, it becomes difficult in estimating true effect with the limited data (Di Falco *et al.*, 2011). Based on these criticisms of the traditional Ricardian Model, came the introduction and use of the Advanced Ricardian Model (Deschenes & Greenstone, 2007; Massetti and Mendelsohn, 2011; Huda, 2015).

The Advanced Ricardian Model (ARM) is a panel data technique that measures the determinants of farm net income on the notion that the value of any natural resource (land) service can be determined by its internal characteristics (productivity) across time. This approach helps in dealing with the bias of omitted variable, gives the flexibility to estimate effects based on inter-annual variations in climatic variables, and the estimated value of net income resulting from each regression varies greatly across time (Deschenes & Greenstone, 2007; Huda, 2015).

A limitation to this approach is that the data used for estimation focuses on short-term weather variations rather than climate change, as farmers adopt alternative measures not only for the short-term weather variability but rather to cope with long-term climate change. (Massetti and Mendelsohn, 2011).

3.2 Conceptual Framework: Climate Adaptation Measures, Cocoa Production, and Farm Income.

Climate variability remains an important but an uncontrollable factor to cocoa production. It alters the development of cocoa pods, insect pest and pathogens, which leads to lower crop outputs and eventually influences farm income (Agbongiarhuoyi *et al.*, 2013).

Variability in the climatic variables such as rainfall and temperature directly affect the cocoa tree and fruit development. Temperature extremes during flowering causes lowering of seed number (Challinor & Wheeler, 2007). Indirectly, climate variability affects cocoa production by affecting the other factors of production such as soil nutrient and moisture, pesticide and fertilizer application, farming methods, seed varieties and even the health of the farmers, which tend to affect the overall outputs of cocoa.

As cocoa output changes, (mostly decreasing) due to climate variability and change, cocoa farmers adopt new adaptation measures, decisions that will help them minimize the impacts climate variability, and change has on their cocoa outputs. These adaptation measures affect the quantity and use of the other factors of cocoa production. These include the use of improved varieties of cocoa, application of more fertilizer to enrich soil nutrients, pesticides to curb the incidence of black pod, capsid diseases and the emergence of unfamiliar diseases. Most of these adaptation measures are in line with improving the other factors of production. These adaptation measures are partly provided by the government (macro-adaption measures), and others (micro-adaptation measures) by the individual farmers. The micro-adaptation measures by the individual farmers are largely decision-based, taken with the aim of increasing their net farm income in the events of negative impacts of climate variability on their cocoa farms.

This implies that the farmer needs some level of income to purchase most of these fertilizers, pesticides and in making certain decisions. The farmer's net income from his cocoa farm then becomes a determinant of his level and type of climate adaptation measures he adapt to improve his cocoa outputs. Therefore, if these adaptation measures adopted by the farmers are efficient, it leads to higher cocoa output which the farmers can sell to get more income to cover their production cost and make profit. In

such instance, the farmers will be willing to continually use their choice of adaptation measures.

On the other hand, if the adaptation measures adopted by the farmers are not efficient, it will cause low cocoa output. In such an instance, farmers will not be able to cover their production cost leading to lower or even negative net income from the yield. Therefore, these farmers will stop using these adaptation measures.

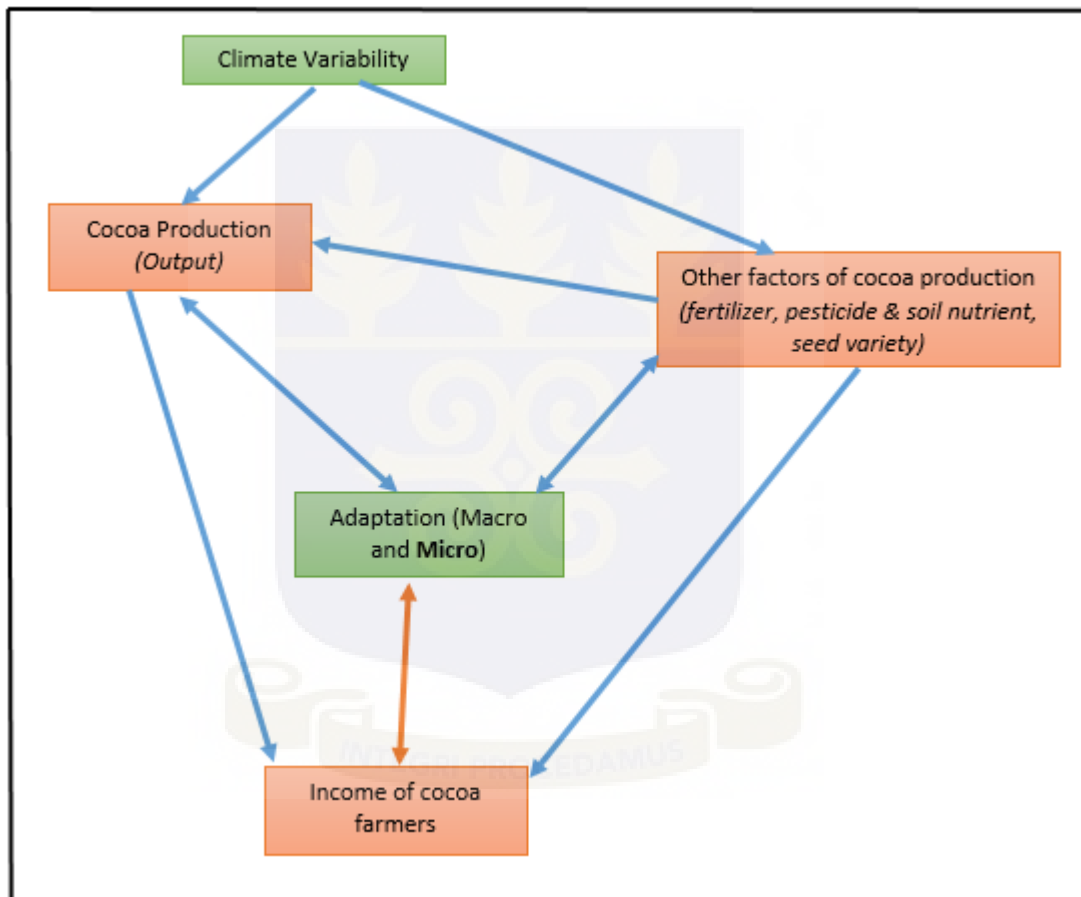


Figure 3.1: Conceptual framework

3.3 Methods of Data Analysis

Three statistical software packages were used to process the data collected for the study. These are the Statistical Package for Social Sciences (SPSS) version 21, which was used for data entry, analysis of relative frequencies, central tendencies, cross-tabulation

of variables and chi-square. The Microsoft Excel (MS Excel) version 2016 was used to generate all graphs. Finally, R statistical package version 3.3.2 was used to develop a balanced panel random effect model that best fit and explains how micro-adaptation options used by cocoa farmers affect their farm net income.

3.3.1 Determining the effects of climate variability on cocoa outputs

In determining how climate variability affects cocoa outputs, a 25-year period (1991 to 2015) temperature and rainfall data for the district were obtained from the Ghana Meteorological Agency. The rainfall and temperature data were put into Microsoft Excel version 2016 and the yearly averages for the various years in the two climate parameters (rainfall and temperature) were generated. These averages were used to develop a line graph that gave a pictorial view of the trend of increased variability in rainfall pattern but at a decreasing rate in rainfall amount, and an increasing trend in temperature in the Dormaa West District over the 25-year period under study.

A descriptive statistical table was later developed to generate the mean for the years, and other relevant figures, which aided in the calculation of the standard deviation for both rainfall and temperature. The formula used to calculate the standard deviation was

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} \dots\dots\dots (3.2)$$

Where SD = Standard Deviation, $\sum(x - \bar{x})^2$ is sum of rainfall or temperature measure (x) for each year minus the mean value (\bar{x}) for the years, all squared, and finally (n) is the number of years used in the calculation.

After calculating the standard deviation (SD) for both temperature and rainfall, the value obtained were used to determine the coefficient of variation (CV) (Kimengsi & Tosam, 2013) by substituting the mean and standard deviation into the formula

$$CV = \frac{SD}{\bar{x}} \times 100 \dots\dots\dots (3.3)$$

Where CV is coefficient of variation, SD is standard deviation and (\bar{x}) is the mean for the rainfall and temperature data used for the calculation.

Annual cocoa outputs from the Dormaa West District for the 25-year period was regressed against average rainfall and temperature for the same period using a multiple linear regression model in SPSS version 21.0. This, determined whether changes in the climatic variables have significant effects on the annual variations in cocoa outputs from the district. A multiple regression is defined by four (4) parameters; Y represents the dependent variable, α represents the model constant, β represents the slope and χ represents the different independent variables.

$$Y = \alpha + \beta_1x_1 + \beta_2x_2 + \varepsilon \dots\dots\dots (3.4)$$

In this application, Y represents the cocoa yields, α represents the constant (y-intercept), β represents the slope, x_1 represents average rainfall, x_2 represents temperature and ε represents the error term.

3.3.2 Assessing micro-adaptation measures used to improve outputs on cocoa fields in Dormaa West District.

In assessing the micro-adaptation measures used by farmers, a list of twelve (12) commonly used micro-adaptation measures in most cocoa growing areas was presented to the respondents to select from which they have been using to curb the impacts of temperature and rainfall variability on their cocoa farms. This was to determine which of these micro-adaptation measures is widely used among the farmers and the ones that are less employed by the cocoa farmers in the Dormaa West District. Descriptive statistics (means and frequencies) was employed to describe the various adaptation

measures in the order of preference by the farmers. Spearman correlation analysis was used to examine the relationship of socio-demographic variables on the choice of micro-adaptation measures used by the farmers. That is, the significance of the relationship between farmers' individual differences and the kind of micro-adaptation measures they adopt was tested. Finally, through descriptive analysis the barriers that undermine farmers' ability to use micro-adaptation measures and whether they are in the position to continually use them were identified.

3.3.3 Determining how micro-adaptation measures affect farmers' net income.

In identifying specific effects these micro-adaptation strategies, have on the net income of farmers, income of the farmers was estimated, by multiplying the number of bags of dried cocoa beans sold by the farmer against the price of a bag of dried cocoa beans. Therefore, in estimating the net income (profit) obtained from cocoa production, expenses made through implementation of the selected adaptation strategies for each year, especially the quantifiable ones, such as cost of added fertilizer, cost of added pesticide application and cost of labour were subtracted from the gross income (revenue) for each of the three (3) years under review (2013, 2014 and 2015).

$$Y = P_C(Q_C) - \sum [P_E(Q_E) + P_I(Q_I) + P_U(Q_U)] \dots\dots\dots (3.5)$$

Where *Y* represents net income, *P* represents price, *Q* represents quantity or output, *C* represents cocoa, *E* represents pesticides, *I* represents fertilizer, and *U* represents the number of hired labour used on the farm per day.

The assumption being that as the outputs of cocoa increases, the farmers are able to sell more to increase their gross income (revenue) to cover their cost of production *ceteris paribus*, which will translate into higher net income (profit). In such instance, there is

a higher probability a farmer will continue to use his micro-adaptation measure, as it may be regarded efficient and vice versa.

Approach for model estimation:

The traditional Ricardian Model is estimated using the cross sectional model as stated below:

$$Y_i = \beta_1 x_i + \beta_2 x_i + \dots + Q c_i + \varepsilon_i \dots \dots \dots (3.6)$$

Where Y_i represents the value of a farm land i , x_i represents the socio-economic and farm level characteristics, c_i represents the weather and climatic variables, β_1 , β_2 and Q represents the vector of the unknown estimates to be estimated, and ε_i represents the error terms.

Using the panel data, an advanced Ricardian Model can be estimated by repeated independent cross sections, which were the individual farmers across three (3) growing seasons. Applying a panel data technique to the traditional Ricardian Model (equation 3.6) allows the control for omitted variables, and an ideal estimating model would be (Huda, 2015):

$$Y_{it} = \beta_0 + \beta_1 x_{it_1} + \beta_2 x_{it_2} + \dots + Q c_{ti} + \varepsilon_{it} \dots \dots \dots (3.7)$$

Where Y_{it} represents the dependent variable (net income of the cocoa farmers i at time t), x_i represents the vector of explanatory variables (regressors of both time variant and time invariant variables), c_i represents the weather and climatic variables, t represents the time ($t=1, 2, 3$ years), ε_{it} represents error terms across years, and $\beta_0, \beta_1, \beta_2$, and Q represents the estimating coefficients.

Therefore, from the panel data obtained from the individual household survey, a pooled model (ordinary least square (OLS) model) for the data was estimated using a panel linear model technique, in the ‘R’ Statistical Software (Croissant & Millo, 2008) using equation (3.7)

Test for individual heterogeneity was conducted using the Breusch Pagan test. After the test, the P-value was equal to zero (p-value < 2.2e-16 = 0.00), therefore the null hypothesis was rejected, implying that there is heterogeneity among the individuals. Therefore, the pooled model was not fit for estimation due to the individual differences that exist among the farmers. This meant that either the random effect or fixed effect model was deemed appropriate for estimating the effect.

In this case, individual fixed dummy variables that measure whether a farm household uses an adaptation measure or not in response to the perceived climatic variability (Di Falco *et al.*, 2011) were introduced to the estimation model. This is to control the effect of unobserved heterogeneity that serves as determinants to the dependent variables (Deschenes & Greenstone, 2007) to obtain equation 3.8 below

$$Y_{it} = \beta_0 + \beta_1 x_{it_1} + \beta_2 x_{it_2} + \dots + Q c_{ti} + H a_i + \varepsilon_{it} \dots \dots \dots (3.8)$$

Where Y_{it} represents the dependent variable (net income of the cocoa farmers i at time t), x_i represents the vector of explanatory variables (regressors that consist of both time variant and time invariant variables), c_i represents the weather and climate variables. t represents the time ($t=1, 2, 3$ years), a_i represents fixed effect (vector of unobserved effects or individual heterogeneity dummies that is invariant across time t), ε_{it} represents error terms across years and, $\beta_0, \beta_1, \beta_2, Q$ and H represents the estimated coefficients.

In order to ensure that the individual heterogeneity or unobserved effects (a_i) had no correlation effect with the regressors or explanatory variables (x_i), equation (3.10) was estimated by using the within transformation method to remove the individual heterogeneity or unobserved effects (a_i) from the estimation (Verbeek, 2004).

First, the average for the individual variables was calculated by dividing equation (3.8) by time (t) to obtain equation (3.9) in the form:

$$\bar{y}_i = \beta_0 + \beta_1 \bar{x}_{i1} + \beta_2 \bar{x}_{i2} + \dots + Q \bar{c}_i + H a_i + \bar{\varepsilon}_i \dots \dots \dots (3.9)$$

Since the fixed variables (a_i) does not change over time, in equation (3.9) it does not have an average. Now, subtract (3.9) from (3.8) to eliminate a_i to obtain the equation (3.10) below;

$$(Y_{it} - \bar{Y}_i) = \beta_1(x_{it_1} - \bar{x}_{i1}) + \beta_2(x_{it_2} - \bar{x}_{i2}) + \dots + Q(c_{ti} - \bar{c}_i) + (\bar{\varepsilon}_i - \varepsilon_{it}) \dots (3.10)$$

Therefore, the individual heterogeneity was correlated with the regressors to test and see whether it required random effects or fixed effects model, and this needed the application of the Hausman test that requires equation 3.8 and 3.10 for its application in ‘R’ Statistical Package. (Wooldridge, 2003; Croissant & Millo, 2008). After the test, the P-value of the Hausman test was greater than 0.05 (p-value = 1 > 0.05). By this, the null hypothesis of the Hausman test was accepted, which states that there is no correlation effect between individual heterogeneity and the regressors, which implied that, I choose the random effect model over the fixed effect model. The effect of micro-adaptation measures used by cocoa farmers on their farm net income was then estimated using random effect model (Equation 3.8).

In the random effect model application, vector of unobserved effects or individual heterogeneity and the error terms across years ($a_i + \varepsilon_{it}$) are considered together as error

term which is assumed to be uncorrelated over time and therefore can identify the effects of any variables that vary only across units. On the other hand, fixed effect model cannot perform this function and therefore has difficulty identifying effects, especially if most of the meaningful variations are across units (Verbeek, 2004). In addition, the random effect model gives the opportunity to make inference about situations with respect to the socio-demographic characteristics of the population.

In this case, the random effect model estimation allowed for the observation of the true effect of applying various micro-adaptation measures on the net income of farmers at the individual level. Therefore, the results shown in Chapter 4 indicate whether the individual farmers will continue to implement or decline to the use of these adaptation measures in the future.

The reason is that an increase in the net farm income or revenue due to the use of the micro-adaptation strategies by a cocoa farmer suggest a positive influence of the adaptation measures on net income. The farmers' decision, therefore, will be to use these micro-adaptation measures in the future to increase cocoa production. On the contrary, a decrease or an increase in the income or revenue lesser than the cost of adopting the adaptation measures, suggest a negative influence of the micro-adaptation measures on net farm income of the farmers. The farmers' decision, therefore, would be to adapt to new and efficient adaptation measures.

Variables selected for model estimation variables:

The dependent variable for the study is the returns to land per hectare, which in other sense is the net income of cocoa farmers. Based on literature and field observations, adaptation measures identified as widely used by cocoa farmers include the use of improved cocoa varieties, mixed cropping, fertilizer application, pesticide application,

income diversification, fire belts, planting of shade plants and trees, and the use of organic manure etc. The net income of farmers is the dependent variable. Independent continuous variables that are both individual and time variant consisted of the quantity of fertilizer bought, the quantity of pesticide bought, the number of labour employed, and production cost. Only time variant independent variables included rainfall, minimum temperature, and maximum temperature for the three years (2013, 2014, and 2015). Independent dummy variables that are constant within time but varying across individuals were the list of adaptation measures used by the cocoa farmers in the Dormaa West District. Lastly, independent categorical variables consisted of socio-demographic variables (Age of farmers, level of education, number of dependents, farming experience, age of cocoa farms, land ownership).

Table 3.1: Definition of the model estimation variables for the study

Variable	Description	Measurement	Expected outcome
Socio-demographic factors			
Age of respondents	Categorical variable: Range of years	1=30-39yrs, 2=40-49yrs, 3=50-59yrs, 4=60yrs+	-/+
Level of education	Categorical variable: Stage completed	1=Primary, 2=JHS, 3=SHS, 4=O-Level, 5=Tertiary	+
Number of dependents	Categorical variable: Range of number	1=1-3, 2=4-6, 3=7-9, 4=10-12, 5=13+	-
Farming experience	Categorical variable: Range of years	1=1-5, 2=6-10, 3=11-15, 4=16-20, 5=21-25, 6=26+	+
Land ownership	Categorical variable:	1=Myself, 2=Ext. family, 3=Friend, 4=Renting	+
Land Size (acres)	Continuous variable	Number	+

Age of cocoa farm	Categorical variable:	1=1-10, 2=11-20, 3=21-	
	Range of age of trees	30, 4=31-40, 5=41-50, 6=51+	
Socio-economic Factors			
Net income (GHC)	Continuous variable	Amount	
Production cost (GHC)	Continuous variable	Amount	-/+
Quantity of fertilizer bought	Continuous variable	Litre/kg	-/+
Quantity of pesticide bought	Continuous variable	Litre	-/+
Hired labour use	Continuous variable	Number	-
Weather/Climate Factors			
Rainfall (mm)	Continuous variable	Rainfall amount	+
Maximum temperature (⁰ C)	Continuous variable	Degrees of measure	-
Minimum temperature (⁰ C)	Continuous variable	Degrees of measure	-
Adaptation Measures			
Improved variety	Dummy variable	1 if Yes, 0 if No	+
Increased spraying of cocoa farms	Dummy variable	1 if Yes, 0 if No	+
Increased use fertilizer	Dummy variable	1 if Yes, 0 if No	+
Change in fertilizer type	Dummy variable	1 if Yes, 0 if No	+
Increased farm size	Dummy variable	1 if Yes, 0 if No	+
Non-farm activity	Dummy variable	1 if Yes, 0 if No	-
Mixed cropping	Dummy variable	1 if Yes, 0 if No	-
Growing shaded trees	Dummy variable	1 if Yes, 0 if No	+
Creating fire belt	Dummy variable	1 if Yes, 0 if No	+
Use of manure & compost	Dummy variable	1 if Yes, 0 if No	+
Migrating to new sites	Dummy variable	1 if Yes, 0 if No	-/+
Change in farm practices	Dummy variable	1 if Yes, 0 if No	+

3.4 Method of Data Collection

3.4.1 Research methods

The collection of primary data was based on two forms of research methods: survey and observation. The survey were two kinds, individual farmer survey through questionnaire administration and interview sessions with some key stakeholder institutions. The observations were made by the Researcher; time was spent making transect walks in the communities.

i. Individual Survey

A survey guided by a structured questionnaire of both closed-ended and open-ended questionnaires of approximately forty (40) questions divided into five (5) sections were administered. The questions were based on the demographic characteristics of respondents, and the three (3) main research questions, in order to get the views of the farmers in the district (See Appendix 3.1). To make it easy for the researcher to answer the last research question, the last section of the questionnaire was gathered in a panel series for three years (2013, 2014 and 2015). Closed-ended questionnaire enhanced easy comparability of answers from respondents, while open-ended questionnaire gave freedom to respondents to answer questions in their own terms and thus, gave the researcher detailed information on the research. The survey was conducted in the first week of January 2017 by the researcher and two other colleagues.

ii. Institutional Interviews

Six (6) key informant interviews were conducted among three (3) stakeholder institutions namely, Ghana Cocoa Board, Produce Buying Company (PBC), and the Ministry of Food and Agricultural (MoFA). This was done to get expert insight into

climate change, cocoa, and climate-smart agriculture. Information on how the institutions are helping smallholder farmers to engage in practices that will help minimize the negative impacts of climate variability and change and take advantage of the positive impacts was obtained.

iii. Personal Observations

There were some personal observations on the farmers’ life, assets, resources, and activities required for living to confirm some of the information given by the farmers. This helped the researcher to have the firsthand information on processes and behaviours on issues being study.

3.4.2 Study population and sample size determination

The targeted population for this research was the smallholder cocoa farmers in the Dormaa West District and some key stakeholder institutions. The district has a total number of 10,327 households; 81.2% (8,386 households) engaged in agricultural activities, 98.4% (8,252 households) of the 8,386 households do crop farming. To estimate the sample size of the study, the formula for proportions was used.

$$n = \frac{N}{1+N(e)^2} \dots\dots\dots (3.11)$$

Where: n = sample size,

N = population

e = level of precision (0.05).

When this formula was applied, the sample size obtained n = 382 households. The sample size obtained was then divided by two (2) to obtain 191 households due to financial and time constraint. For a fair representation of the six (6) towns, 180 cocoa

farmers (30 from each town) were selected randomly, as all the households in the selected towns engaged in cocoa farming. A farmer represented each household and therefore not more than one cocoa farmer was selected from the same household.

3.4.3 Sampling techniques

The study employed a multi-stage sampling technique. At the first stage, Dormaa West District was purposively selected based on its high reliance (81.2%) on agriculture. The existence of two major cocoa producing districts (Nkrankwanta and Kasapin cocoa districts) of the Brong-Ahafo Region within the Dormaa West administrative district. In addition, there is increasing deforestation in the district that affect the local climate of the area, and it is located in the transitional agro-ecological zone of Ghana. These characteristics made the district a preferred area for the study, compared to other districts in the Brong-Ahafo Region.

In the second stage, a simple random sampling method was used to select six (6) communities namely; Krakrom, Nkrankwanta, Yaw Owusu Krom, Brofoyeddu, Diabaa, and Kwankuanya, from the nineteen (19) communities in the district. This was carried out using the lottery method, since the sampling frame (19 major communities) was known and highly homogenous (they all engaged in cocoa production). In the third stage, thirty (30) cocoa farmers from different households were then randomly selected from each of these six (6) communities for the survey, such that each household had the chance of being selected.

3.5 Description of Study Area

Location and size

The Dormaa West District is one of the twenty-two (22) political and administrative districts in the Brong-Ahafo Region of Ghana. It is located in the western part of the Region, between Longitude 6° 51'45N and 7° 2'0N and Latitude 2° 50'45W and 3° 1'0W. It is bounded to its southwest by Bia East Districts, the west by La Cote d'Ivoire, the east by Asunafo North Municipality and to the north by Dormaa Central municipality. The district has a total land area of 381 square kilometres and nineteen (19) major towns with Nkrankwanta as its capital (Ghana Statistical Service, 2014).

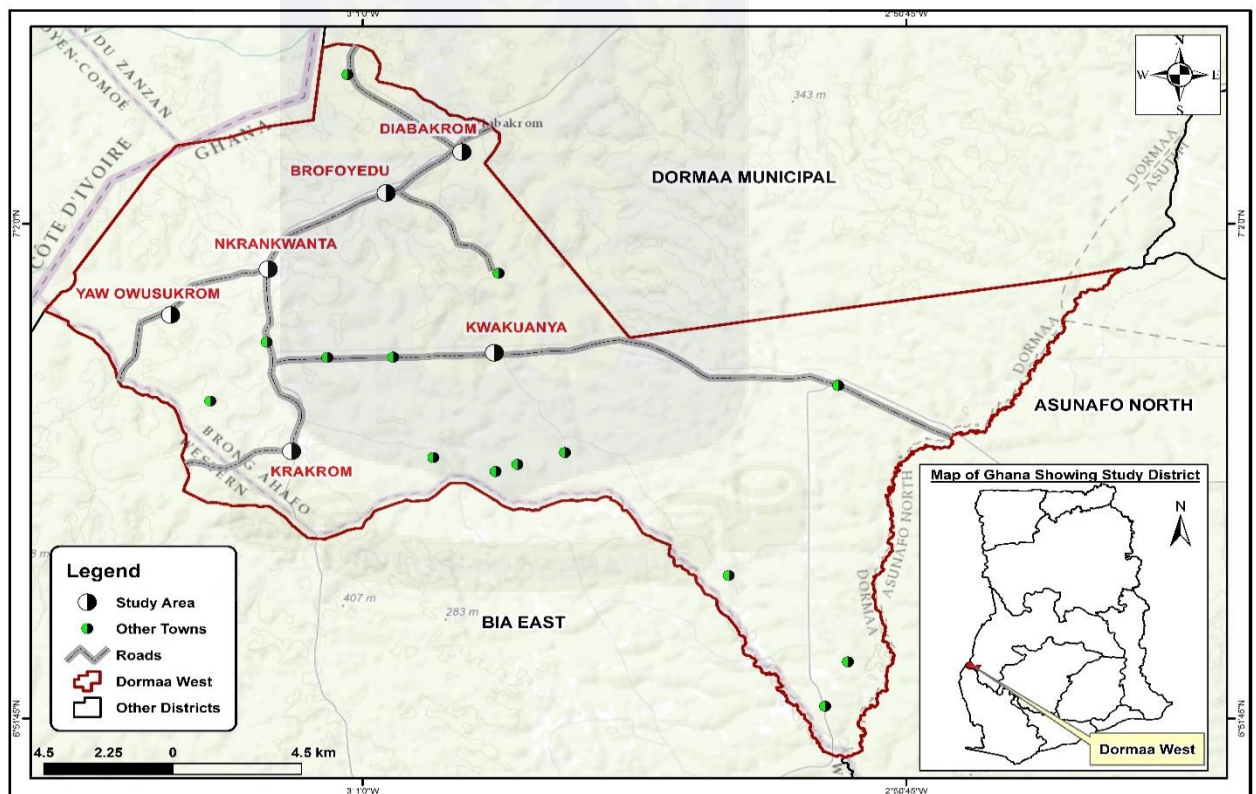


Figure 3.2: Map of Dormaa West District showing sampled communities.

Source: Author's construct, December 2016

Population and economy

The population of the district according to the 2010 population census is 47,678, with 51.8% being males and 48.2% being females. Moreover, this represents 2.1% of the Brong-Ahafo Region's total population. Majority of the population (77.3%) live in the urban areas. The population of the district is youthful with a total age dependency ratio of 79.4 (Ghana Statistical Service, 2014). The most important economic activity of the district is agriculture as the sector employs 81.2% of the households in the district, with most (98.4%) engaged in crop farming. In the rural areas, 86.9% are agricultural households while in the urban areas 63.4% of the households are into agriculture. Cash crops grown are mostly cocoa, coffee, and oil palm, with plantain, cassava, maize, tomatoes, etc. being the major food crops grown in the district (Ghana Statistical Service, 2014).

Climate and vegetation

The district falls within the wet semi-equatorial climatic region of the country with an average annual rainfall between 125cm and 175cm. The district experiences a double maxima rainfall regime that is from May to June and September to October. The area has a pronounced dry season that is from the latter part of November to February. Temperatures are generally high, ranging from 26.1°C to 30°C with minimum temperatures recorded in August and maximum between March and April. In addition, there is high humidity of 75 to 80% during the rainy seasons and 70 to 72% humidity in the rest of the year. These climatic conditions, therefore, makes it favourable for the cultivation of cash crops such as cocoa, coffee and food crops such as plantain, cocoyam (Ghana Statistical Service, 2014). The major vegetation types in the district are the unused forest, partly broken forest and extensively cultivable forestland and forest reserve that are the Pamu-Mpameso Forest Reserve covering 197.67 square kilometres.

The predominant timber species found in the area are Wawa, Odum, Sapele, and Mahogany. Availability of these timber species has led to the growth of carpentry industry, which is a huge contributing factor to the depletion of the forest cover with its adverse effect on the local climate (Ghana Statistical Service, 2014).

Relief, drainage and soil

The district is generally undulating and rises between an average of 180 meters and 375 meters above sea level. The area well drains with network of rivers spread out within the district. These rivers are mostly perennial due to the double maxima rainfall regime experienced in the area. Notable among these rivers are the Bia, Nkasapim and Pamu rivers. These rivers are used as a source of water for the cultivation of vegetables such as okro and tomatoes in the dry seasons (Ghana Statistical Service, 2014). The soils in the district belong to the Bekwai-Nzema compound association, but the Nkrankwanta Association dominates the south-western section of the district. The Nzema series is made up of quartz gravels and ironstone and are moderately well drain. The soil types in the area support the cultivation of cash crops such as cocoa, coffee, oil palm and food crops such as plantain, maize, and cassava (Ghana Statistical Service, 2014).

3.6 Scope and Limitation of Study

The study focused on Dormaa East District of the Brong-Ahafo Region due to its high reliance on agriculture. Majority of its households engage in cocoa farming, and it covers two of the major cocoa producing districts (Nkrankwanta and Kasapin districts) of the Brong-Ahafo Region. Deforestation has affected the local climate of the area.

One hundred and eighty (180) respondents from six (6) towns in the district were engaged in the survey to study and inquire about their knowledge on climate variability and its effects on cocoa production. The kinds of micro-adaptation measures commonly

used among the cocoa farmers in the district to reduce the impacts of climate variability on their output and for that matter the income they generate from its sales. Finally, whether the micro-adaptations employed by the farmers have positive or negative effects on the farmers' income were studied.

The study was limited to only two (2) climatic variables. Other variables such as sunlight and humidity, which equally affect cocoa development and the spread of pest and diseases were omitted. This is because, according to the Ghana Meteorological Agency, data for such variables for the area were unavailable.

In calculating net income of the farmers, only on-farm income was considered. Income from other sources which may come as a result of farmers engaging in off-farm activities such as the sale of firewood or from remittances were not included. New source of income is important strategy farmers use to cope climate change (a micro-adaptation measure). Therefore, returns from only cocoa yield farms were considered.

Lastly, in the survey, each household respondent was represented by one cocoa farmer (male or female). This created gender bias as in each household where husbands were available women gave preference to their husbands. Women (11%) were only in a position to answer the questions in the absence of their husbands, giving a false representation of women and their views on the issues at hand.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results and discussion of the study. All 180 sampled questionnaires, administered in the six (6) communities of the Dormaa West District were returned. Data obtained was analyzed with SPSS version 21.0, Microsoft Excel 2016 and R Statistical Package version 3.3.2. The socio-demographic and farm characteristics of the sampled respondents were presented first. This was followed by the farmers' perception of climate variability and change, its impact on cocoa production and micro-adaptation measures used by cocoa farmers. Finally, the results of the effect of the use of micro-adaptation measures on the net farm income were presented and discussed.

4.1 Socio-Economic Characteristics of Respondents

4.1.1 Socio-demographic characteristics of respondents

Responses were required on a household level, and the fact that cocoa production serves as the livelihood and employment for an entire family in the communities both males and females had opportunity to give their views on the study. From Table 4.1, it is shown that majority of the respondents (89.4%) were males while only 10.6% were females. In most of the households, females gave priority to the males to administer the questionnaires on behalf of the household as a sign of respect to their husbands. Females were only willing to answer the questionnaire when their husbands were not at home or

when given the mandate by their husbands after they had sought for their concern. This accounted for the lower number of responses from females.

Table 4.1: Socio-demographic characteristics of the respondents

VARIABLE		FREQUENCY (F)	PERCENTAGE (%)
Sex of Respondents	Male	161	89.4
	Female	19	10.6
Age of Respondents	30 - 39 years	12	6.7
	40 - 49 years	78	43.3
	50 - 59 years	57	31.7
Educational Level	60 years and above	33	18.3
	Primary	29	16.1
	JHS	105	58.3
Number of Dependents	O-Level	27	15.0
	Non-formal	19	10.6
	1 to 3	8	4.4
	4 to 6	47	26.1
	7 to 9	60	33.3
	10 to 12	39	21.7
	13yrs & above	26	14.4

Source: Field data, 2017

The age distribution showed that majority (43.3%) of the respondents were between the ages of 40 years to 49 years, followed by 50 years to 59 years representing 31.7% and the least (6.7%) were between 30 to 39 years.

In addition, the majority (58.3%) of the respondents had attained education to the JHS level, followed by primary level education (16.1%), with 10.6% of the respondents having non-formal education. The level of education of farmers influence their ability to interpret and understand information on adaptation measures and their willingness to adopt. It is observed that people with some form of formal education are likely to read,

analyse and understand information of some types of adaptation measures being provided, and are always willing to adapt faster than people with the non-formal educational background.

It was also realized from the survey that majority (33.3%) of the respondents had 7 to 9 people as their dependents. This was followed by 26.1% having a total of 4 to 6 people as their dependents, 21.7% were found to cater for 10 to 12 dependents, 14.4% having as high as 13 and above dependents, with just 4.4% having between 1 to 3 dependents. Dependents here meant both nuclear and extended family members who lived with the farmer and it is the farmer's responsibility to provide them with basic human needs such as food, clothing, shelter and health care.

4.1.2 Farm characteristics of respondents

It was also realized that majority (49.4%) of the respondents owned their cocoa farms, thus, are able to save money for different uses (Table 4.2). Forty percent (40.0%) farm on their family lands, a small fraction of the respondents (6.7%) pay rent for hired lands, which tend to increase their overall cost of production.

It was realized as well that most of the cocoa farms in the district are between the ages of 11 to 20 years (26.1%) and 21 to 30 years (20%), with a few between the ages 31 to 40 years (13.9%), 41 to 50 years (16.7%) and 51 and above (8.9%). This shows that cocoa farms in the area on the average are below 30 years. It was observed that older farms are gradually being replaced with new ones to help deal with low productivity resulting from old-aged cocoa farms. About 14.1% of the farms are from the ages 1 to 10 years.

Table 4.2: Farm characteristics of the respondents

Variable		Frequency (F)	Percentage (%)
Farming Experience	1 - 5 years	13	7.2
	6 - 10years	24	13.3
	11 - 15years	10	5.6
	16 - 20years	55	30.6
	21 - 25years	37	20.6
	26years & above	41	22.8
Ownership of Land	Myself	89	49.4
	Extended Family	72	40.0
	A friend	7	3.9
	Am renting	12	6.7
Farm age	1 to 10 years	26	14.4
	11 to 20 years	47	26.1
	21 to 30 years	36	20.0
	31 to 40 years	25	13.9
	41 to 50 years	30	16.7
	51 years & above	16	8.9
Cocoa variety Grown	Amazonia	13	7.8
	Hybrid	114	63.3
	Both (Amazonia and Hybrid)	52	28.9

Source: Field data 2017

Most (63.3%) of these farms were found out to be the hybrid varieties of cocoa, which require high intensive care against pest and diseases and the use of fertilizer to ensure maximum productivity. Farmers using such cocoa varieties will depend on high chemical inputs, but are not always able to afford and apply them to their maximum and therefore undermine their productivity rate (Franzen & Mulder, 2007). On the other hand, 28.9% of the respondents said they have begun growing the hybrid alongside the Amazonia to help increase their overall cocoa yield. Finally, 7.8% of the farms were

realized to be of only the Amazonia cocoa type, which is highly sensitive to rising temperatures.

4.2 How Climate Variability Affect Yield of Cocoa Farms in Dormaa West District

Seasonal variation in the climate in any area is undisputable, as indicated by the existence of several kinds of literature on how climate variability and change affects agricultural production and for that matter cocoa production. The effects are felt largely in areas that depend on natural conditions for its agricultural activities. For the purpose of this study, secondary data on cocoa outputs for the period 1991 to 2015 and for two climatic variables (rainfall and temperature) for the same year period was obtained from the COCOBOD and GMet respectively. This when analysed, established the trends and rate of variability in the climate for the district. How much the variations in the temperature and rainfall affect cocoa yields is the key result presented and discussed.

4.2.1 Trend Analysis of Temperature and Rainfall for Dormaa West District (1991 – 2015)

The trends in annual rainfall and temperature for Dormaa West District from 1991 to 2015 are presented in the following graphs (Figure 4.1, 4.2, 4.3, and 4.4). Rainfall distribution for the area indicates an upward trend even though historical climatic data by the Ghana Meteorological Agency (GMet) across the country between 1960 and 2000 projects a clear decrease in rainfall in all agro-ecological zones (Boon & Ahenkan, 2011). According to Schroth *et al.*, (2016), the 19 Global Circulation Models (GCMs) project a little increase in annual rainfall for drier areas of forest-savannah transition and the northern parts of the West Africa cocoa belt, which the Dormaa West District forms a part. This upward trend was explained to be an increase in rainfall intensity for

some particular months (Figure 4.4) and not necessarily a uniform distribution of rainfall throughout the year for those years under review.

In a change detection for the area between the years 1996 – 2000 and 2011 – 2015 (Figure 4.4), it was obvious that rainfall has positively changed across almost all the months, with significant upward shift in rainfall observed from the month of October to December. According to Schroth *et al.*, (2016), this is due to the general increasing trends in rainfall for the northern parts of the West African cocoa belt, which is projected to decrease the number of dry months from four (4) to three (3) by 2050, especially toward the north-western parts of the Western Region of Ghana. In addition, it can be observed that the area has a double maxima rainfall regime with the major seasons that starts in March and ends in July and the minor season from September to October. In addition, the more temperature increases, the more crop water use per unit biomass. This water is either directly evaporated from the soil or perspired by plants according to greater demand for water from the atmosphere (Fofana, 2011). Therefore, the increasing rainfall trends in the district indicates that Vapour Pressure Deficit (VPD) which is the main effect of temperature on cocoa production could be reduced. This will make up for soil moisture losses due to evaporation, and make temperature have an insignificant effect on cocoa production.

On the other hand, temperature trends for the same period for the district (Figure 4.1) shows an upward trend confirming historical data of an increase in all agro-ecological zones of the country between 1960 and 2000. This increase in average temperature is due to the effects of the increasing trend in the minimum temperatures for the district (Figure 4.2). According to Knowles *et al.*, (2006), the minimum temperature is more probable to increase under climate change, and this causes a decline in the average temperature ranges as the maximum temperatures rather show a decreasing trend

(Figure 4.2). The effects of this increase in minimum temperatures will be much significant in affecting all phases of the perennial crop (cocoa) growth and development (Hatfield & Prueger, 2015).

From a change detection record, it is shown that maximum temperature over the years 1996 – 2000 and 2011 – 2015 have not significantly changed for most months (Figure 4.3). Slightly increases were recorded in January, September, and October and slight decreases in March. Minimum temperatures, on the other hand, have increased throughout the year with the exception of December and January. In areas where the changing climate is expected to cause an increase in rainfall (Figure 4.1), large increases in maximum temperatures are less likely to occur than regions prone to drought (Hatfield & Prueger, 2015).

From Figure 4.2 and Figure 4.3, it is observed that even though the average yearly temperature ranges are gradually decreasing, monthly temperature ranges for January and December (dry season) are seeing an increase. According to He *et al.*, (2015), this is due to precipitation deficits that affect cloud cover and soil moisture anomalies, which eventually impact the energy balance. That is, dry conditions that correspond to the higher ratio of sensible heat flux to latent heat flux are responsible for the increased temperatures during the daytime and very low temperatures during night-time in the dry seasons. On the other hand, during the wet season, a large amount of energy for evaporation is used, which is a cooling effect, and supported by increased soil moisture, causing monthly temperature ranges for most land surfaces in the wet seasons (April – July, and September – October) to be a little stable compared to the dry season.

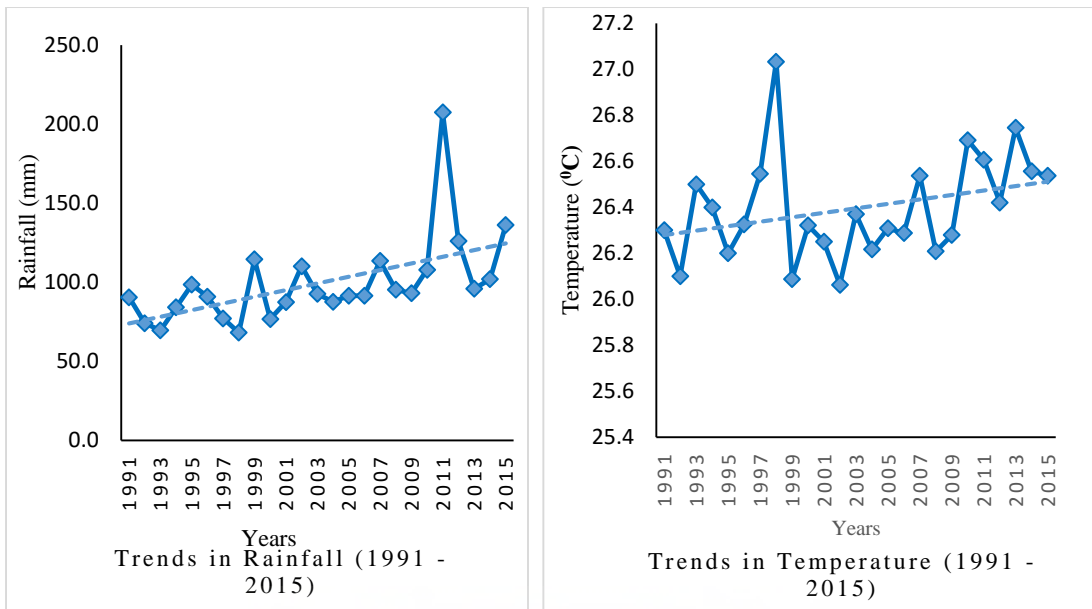


Figure 4.1: Trends in yearly average annual rainfall (mm) and temperature (°C) for Dormaa West District (1991–2015)

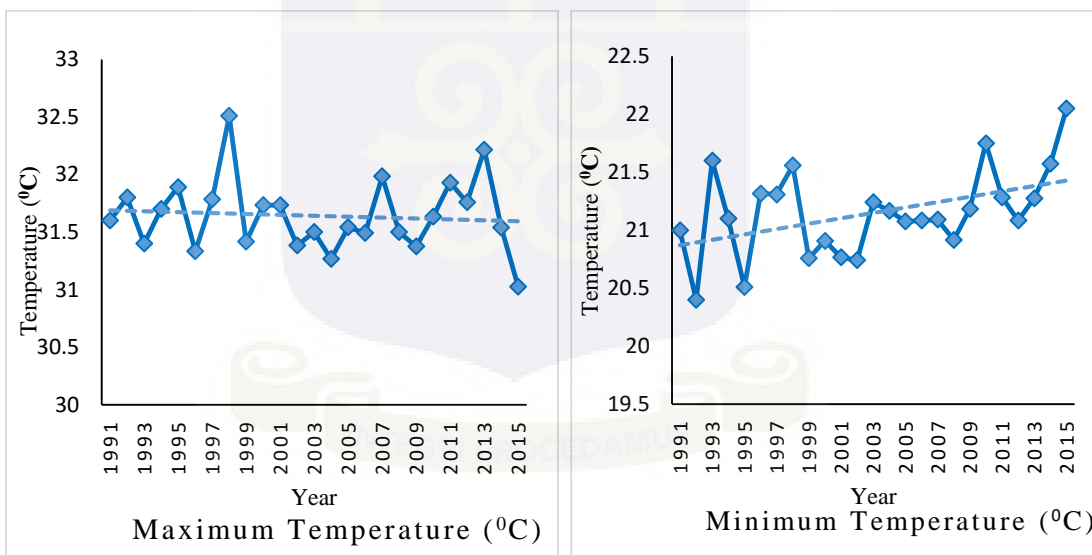


Figure 4.2: Trends in yearly average maximum and minimum temperatures (°C) for Dormaa West District (1991–2015).

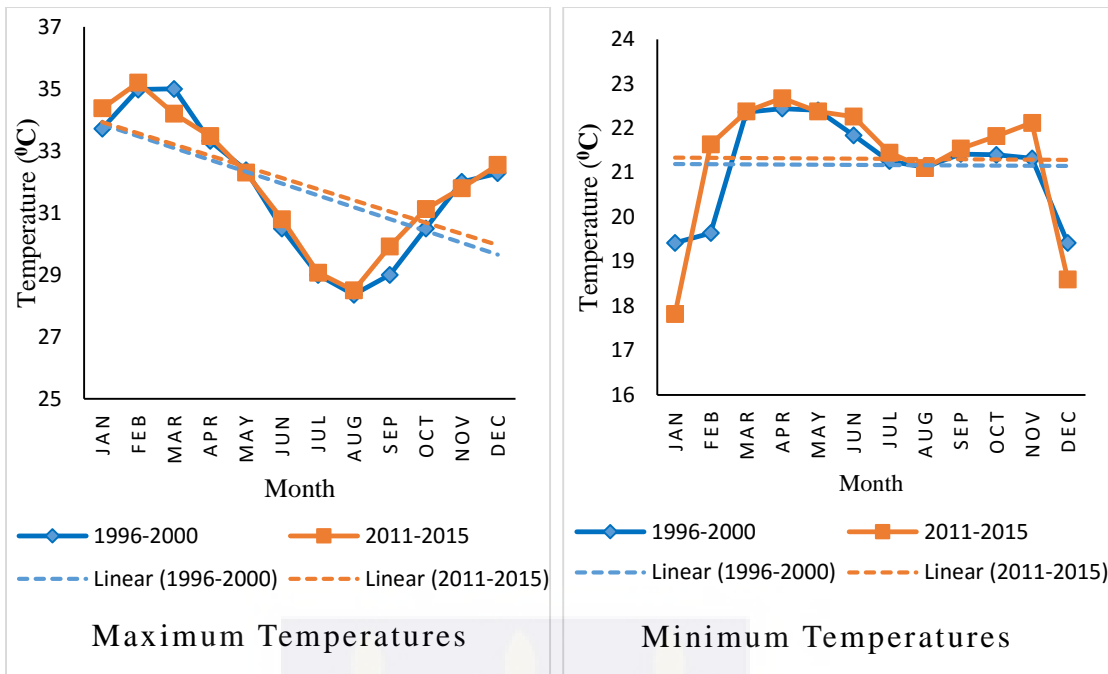


Figure 4.3: Change detection in maximum and minimum temperature ($^{\circ}$ C) between the years 1996 – 2000 and 2011 – 2015

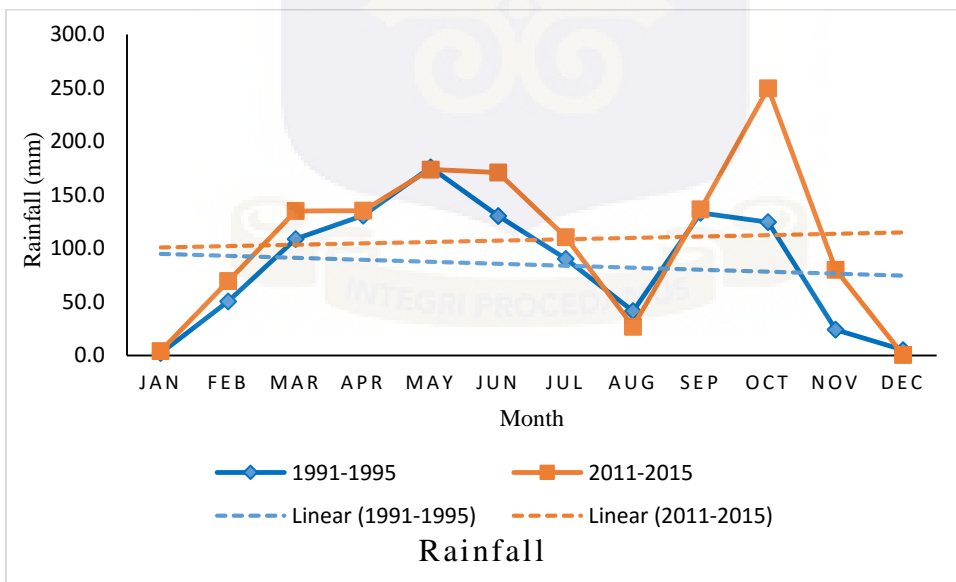


Figure 4.4: Change detection in rainfall patterns (mm) for Dormaa West District between the years 1996 – 2000 and 2011 – 2015

4.2.2 Determining how variations have occurred in temperature and rainfall amount for the District between the years 1991 to 2015

Variability in the temperature and rainfall patterns for the area as shown in the trend analysis were statistically proven by finding the coefficient of variation among the temperature and rainfall data. According to Kimengsi & Tosam (2013), greater reliability means less variability. Therefore, at 10% confidence level, when the coefficient of variation for a data is more than 10%, the data is not reliable and shows a significant variability in the data. On the other hand, when the coefficient of variation is less than 10%, the data is reliable and therefore indicates an insignificant variability in the data.

From Table 4.3, the coefficient of variation for temperature in the district is 0.9% indicating an insignificant variability in temperature over the 25 years (1991 to 2015) under study. While the coefficient of variation (CV) for rainfall in the district is 28.1% indicating a significant variability in rainfall amount over the 25 years under study.

From Table 4.3, x = Annual rainfall amount (mm) from 1991 to 2015, while k = Annual average temperatures ($^{\circ}\text{C}$) from 1991 to 2015.

Substituting, the values obtained from the temperature and rainfall data in table above

into the formulas $SD = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}}$ and $CV = \frac{SD}{\bar{x}} \times 100$, coefficient of variation

(CV) for rainfall is 28.1% while CV for temperature is 0.9%.

Table 4.3: Annual temperature and rainfall variability in the Dormaa West District

Year	Temperature (°C)			Rainfall (mm)		
	k	$k-\bar{k}$	$(k-\bar{k})^2$	x	$x-\bar{x}$	$(x-\bar{x})^2$
1991	26.3	-0.1	0.0	90.6	-8.7	76.4
1992	26.1	-0.3	0.1	74.2	-25.2	635.3
1993	26.5	0.1	0.0	69.6	-29.7	883.4
1994	26.4	0.0	0.0	84.2	-15.2	229.7
1995	26.2	-0.2	0.0	98.5	-0.8	0.7
1996	26.3	-0.1	0.0	91.0	-8.4	69.9
1997	26.5	0.2	0.0	77.2	-22.1	489.4
1998	27.0	0.6	0.4	68.2	-31.1	968.6
1999	26.1	-0.3	0.1	114.5	15.2	230.1
2000	26.3	-0.1	0.0	76.8	-22.5	506.9
2001	26.3	-0.1	0.0	87.6	-11.8	139.4
2002	26.1	-0.3	0.1	110.2	10.8	117.1
2003	26.4	0.0	0.0	92.7	-6.6	44.0
2004	26.2	-0.2	0.0	87.7	-11.7	135.8
2005	26.3	-0.1	0.0	91.4	-7.9	62.6
2006	26.3	-0.1	0.0	91.6	-7.8	60.3
2007	26.5	0.1	0.0	113.6	14.2	202.4
2008	26.2	-0.2	0.0	95.4	-3.9	15.5
2009	26.3	-0.1	0.0	93.1	-6.3	39.5
2010	26.7	0.3	0.1	108.0	8.6	74.3
2011	26.6	0.2	0.0	207.4	108.0	11668.9
2012	26.4	0.0	0.0	126.1	26.8	717.3
2013	26.7	0.4	0.1	96.0	-3.4	11.5
2014	26.6	0.2	0.0	102.0	2.7	7.0
2015	26.5	0.1	0.0	136.2	36.9	1358.6
Total	659.9		1.2	2483.9		18744.6
Average	26.4			99.4		
Standard Deviation (SD)	0.23				27.95	

Source: Ghana Meteorological Agency, 2017

4.2.3 Trends in cocoa production for Dormaa West District (1991 – 2016)

Cocoa production for the Dormaa West District from 1991 fluctuated until 2004 (18,327 MT) and 2006 (21,574 MT) when it shot beyond the normal trends of 1991 to

2000 cocoa output figures. From 2007 (21,351 MT) saw a decreasing trend until 2010 (15,482 MT). This trend later saw a swift turn of an increase in 2011 cocoa outputs (31,017 MT) which could not be maintained and therefore began to significantly decrease in 2012 (22,192 MT). The trend continued until 2016 (17,108 MT), falling below the 2004 production figures (18,327 MT). The trend in cocoa production for the district conforms to the trends in national cocoa output that shows an increasing trend until 2007. This increasing trends in output until 2007 is attributed to the increase in cultivated lands and partly due to improved practices such as fertilizer application and change in seed varieties from the “Amazon” to the “Hybrid” varieties (Kolavalli & Vigneri, 2011). On the other hand, the recent decrease in output from 2011 is attributed to seasonal bushfires, deforestation, poor farm maintenance, illegal mining activities and pest infestations as well as temperature and rainfall anomalies (Tawiah, 2015).

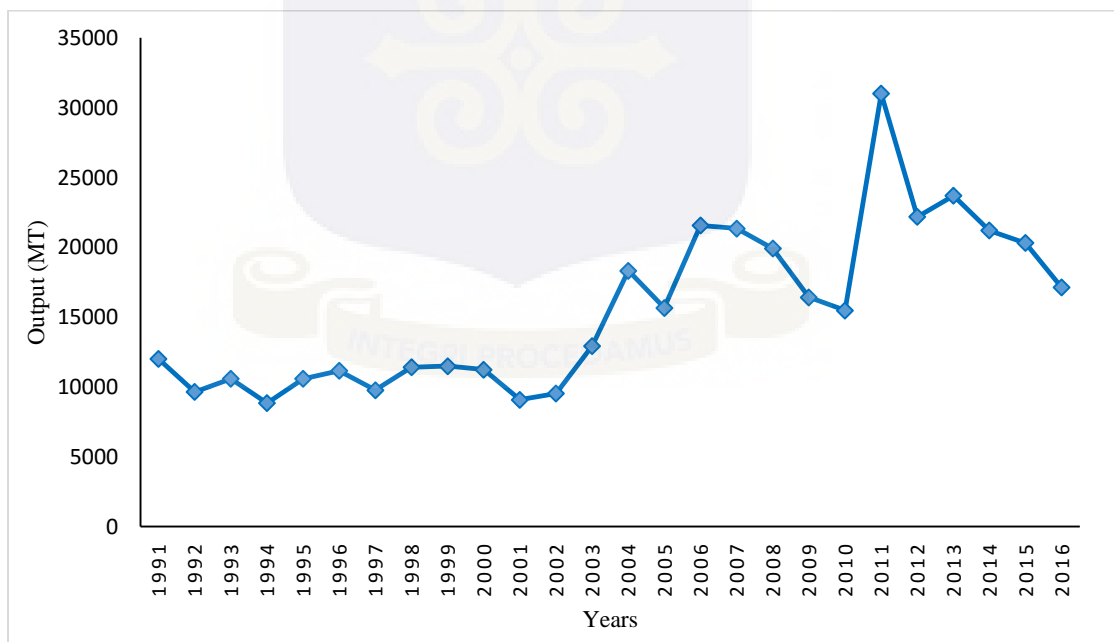


Figure 4.5: Trends in cocoa production for Dormaa West District (1991 – 2016)

From the trend analysis of temperature, rainfall, and cocoa production for Dormaa West District, there is a significant variation in temperature and rainfall pattern. These

variations are observed to be affecting cocoa production for the district, especially rainfall, as trends in the rainfall pattern for the district shows almost the same as the trends in cocoa yield. For instance, 2011 recorded the largest cocoa outputs (31,017 MT) in the district's output trends. In 2011, total annual rainfall amount saw its peak at 204.7mm. In addition, if trends in rainfall and temperature are to remain the same, the effects of temperature on cocoa production could be minimized. The increasing rainfall amount and months will make up for soil moisture losses due to evaporation and will lead to an increase in cocoa yields for the district.

4.2.4 Regression results: Effect of climate variability on cocoa production

From Table 4.3, the annual rainfall pattern for Dormaa ranges from 68.2mm to 207.4mm per annum. The results of the regression model estimation are presented in Table 4.4. The coefficient of rainfall is positive and statistically significant at 1% significance level. This indicates that rainfall has a positive effect on cocoa output in the Dormaa West District. Oyekale *et al.*, (2009) who estimated the impacts of climate change on cocoa production in Nigeria, found that the main climatic element was rainfall and has a significant impact on the growth and development of cocoa. Rainfall failure has the tendency to increase the cost of controlling diseases and pest, and reduce the quantity and quality of the cocoa beans. The regression coefficient of determination shows that variability in rainfall contributes 48.6% to variations in cocoa yields for the district, leaving 51.4% of the variations to other factors such as soil nutrients. This emphasizes the fact that rainfall affects cocoa yield more than any other environmental factor (Adjei-Nsiah & Kermah, 2012; Amos & Thompson, 2015), as cocoa is highly sensitive to drought and the pattern of its cultivation is related to rainfall distribution (Owoeye & Sekumade, 2016).

Table 4.4: Results of multiple linear regression analysis, cocoa output versus rainfall and temperature

Variable	Estimation coefficients	t	R with interaction	R without interaction
Constant	-220948.28	-2.030		
Rainfall (mm)	150.85	4.723	0.667**	0.697**
Temperature (⁰ C)	8377.60	2.026	0.286	0.357*
$R^2 = 0.567$, Adjusted $R^2 = 0.527$				

** , * Regression is significant at 0.01 and 0.05 (1-tailed) levels respectively

Temperature has a positive effect on cocoa output in the area, as the coefficient of temperature is positive and statistically significant at 5% probability level. The regression coefficient of determination indicates that temperature variability contributes 12.8% to variations in cocoa outputs for the district, leaving 87.2% of the variations to other factors. The significant effect of temperature on cocoa outputs in the district could be attributed to increases in minimum temperatures, which has exceeded the average minimum temperature threshold (18 to 21⁰C) (Figure 4.2) required for effective growth of cocoa (Anim-Kwapong & Frimpong, 2004). The increase in minimum temperatures is a contributing factor to the increases in average yearly temperatures for the Dormaa West District.

In general, from the multiple linear regression of temperature and rainfall effect on cocoa output, shows a positive effect of variability in climate (temperature and rainfall) on cocoa production for the district, and statistically significant at 1% significance level. The regression coefficient of determination shows that climate variability accounts for 56.7% variation in cocoa outputs in the Dormaa West District, leaving 43.3% of the variations to other factors such as soil nutrients, fertilizer application, pest and disease control, and other climatic variables. This means that the two climatic

variables (rainfall and temperature) influence outputs of cocoa from the area (Ngoong & Forgha, 2013; Adeniyi & Ogunsola, 2014). The results conform to a similar study by Anim-Kwapong & Frimpong (2004), who using a multiple regression analysis stated that 60% of variations in outputs of cocoa beans could be explained by variations in climatic variables such as annual rainfall and total sunshine duration for Tafo cocoa district. From the multiple linear regression where there is an interaction between rainfall and temperature, temperature becomes insignificant (Table 4.4) as the increasing rainfall amount makes up for soil moisture losses due to evaporation.

In conclusion, there is a significant variation of 28.1% in the rainfall pattern for the Dormaa West District, and this has impacts on the overall cocoa outputs for the district, it accounts for 48.6% of the total variations in cocoa output *ceteris paribus*. The slight (0.9%) variation in temperature is significant to variations in cocoa outputs for the district, as it contributes 12.8% of the total variations in cocoa outputs for the district *ceteris paribus*. Climate variability has significantly affected cocoa outputs for Dormaa West District of the Brong-Ahafo Region. Cocoa farmers in the district must have been adopting new and improved management practices to increase their cocoa outputs. However, for the effectiveness of an adaptation, it must include the extent to which the people believe that there have been some changes in the climate, their awareness of the type and form of change, and knowledge on available and future technology (Kurukulasuriya & Rosenthal, 2003),

4.2.5 Farmers' Perception on the relationship between Climate Variability and Cocoa Production

i. Farmers' perceived variability and changes in climate

Perceptions of farmers on climatic conditions are often based on past observations and recent climatic events, which influence their decisions on adaptive behaviour (Ndamani & Watanabe, 2015; Ehiakpor *et al.*, 2016). Three main climatic variables (Rainfall, Temperature, and Sunshine) were used as indicators for this study of farmers' perception on climate variability. From Figure 4.6, 84.4% of the respondents agreed to an increase in temperature for the district, with 15.6% indicating that there has not been any change in temperature. In addition, the majority (96.1%) of the respondents said rainfall in the district has decreased, and only 3.9% of the respondents claim rainfall for the district has rather increased.

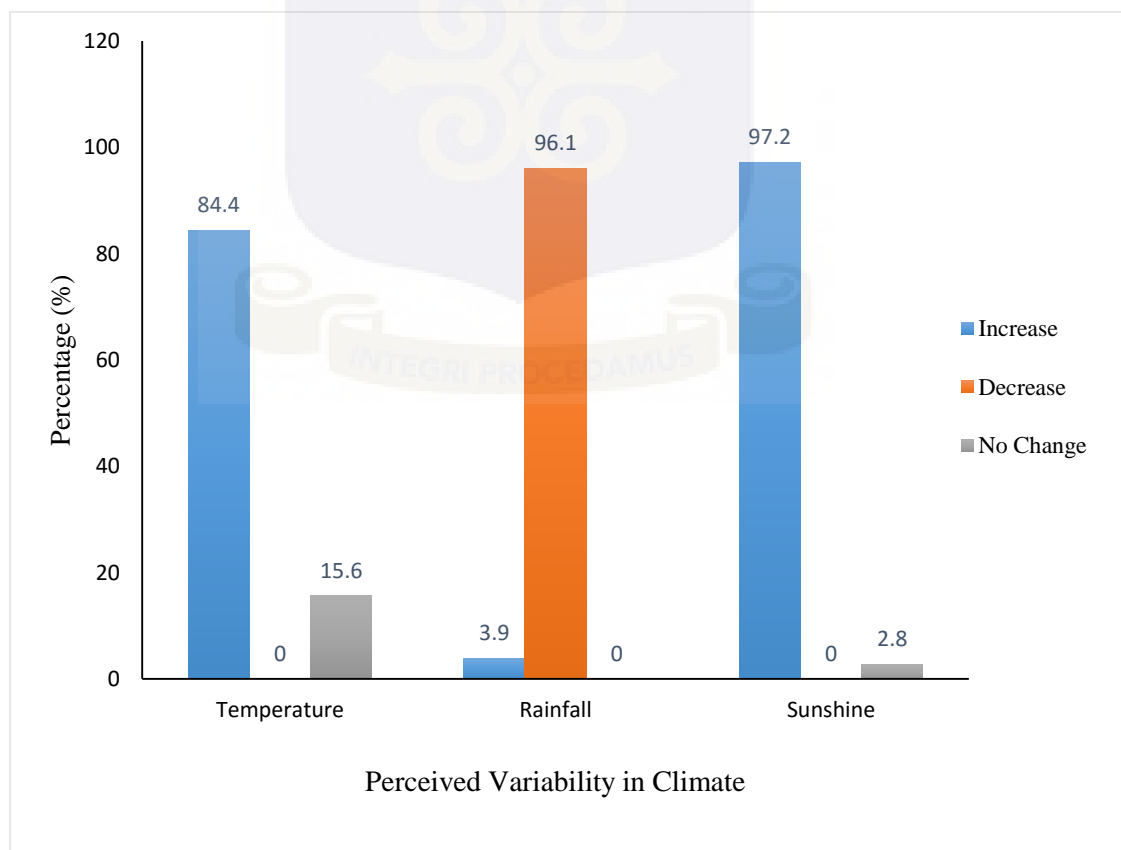


Figure 4.6: Farmers perceived variability and change in climate.

When probed further, it was realized that the respondents compared rainfall in only 2015 to rainfall in 2016 and that is why 96.1% of the respondents indicated a decrease, even though historical rainfall for the district shows an increasing trend. The year 2015 was an El-Nino year, where changes in temperature and air surface pressure in the tropical Pacific led to below average rainfall. Finally, 97.2% agreed that sunshine amount received had greatly increased over the past years in which they have observed the changes.

ii. Farmers awareness of climate variability and change

The awareness of farmers of climate variability is high. From Figure 4.7, 96% of the respondents admitted that they have heard about climate variability and change. Only 4% said they have never heard about it. Though some (4%) of the respondents claimed they have not heard of it in any way, all (100%) the respondents admitted that they have witnessed some sort of variability in temperature, rainfall, and sunshine amount in the district.

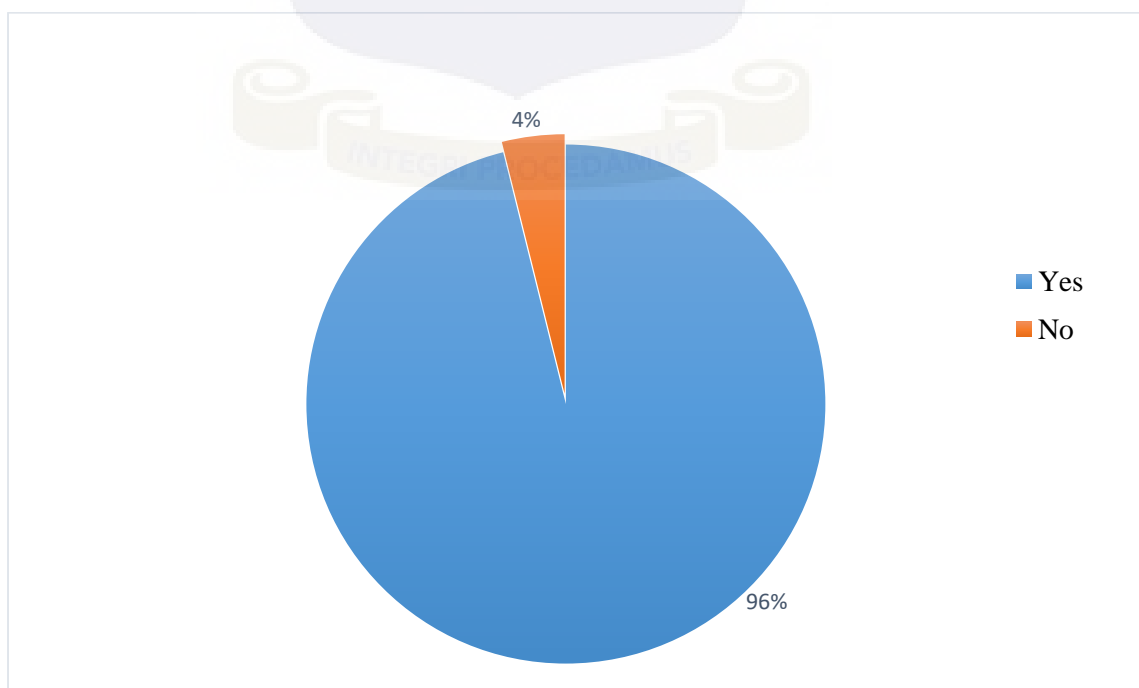


Figure 4.7: Farmers awareness of climate variability and change

iii. Farmers source of information about climate variability and change

Availability of better climate and agricultural information helps farmers make comparative decisions among alternative management practices and this allows them to choose measures that make them cope well with variability in the climatic condition (Di Falco *et al.*, 2011). From figure 4.8 below, it is evident that radio plays a significant role in spreading information among these farmers, as 96% of the respondents who have heard about climate variability and change. Sixty-five percent (65%) said they heard about it on the radio, followed by extension officers (17%), Extension officers, (according to the farmers) educate farmers on farm management and new methods of farming. During the interaction, extension officers take the opportunity to educate the farmers on climate variability and change, and things to do to reduce the impacts it can have on their farms.

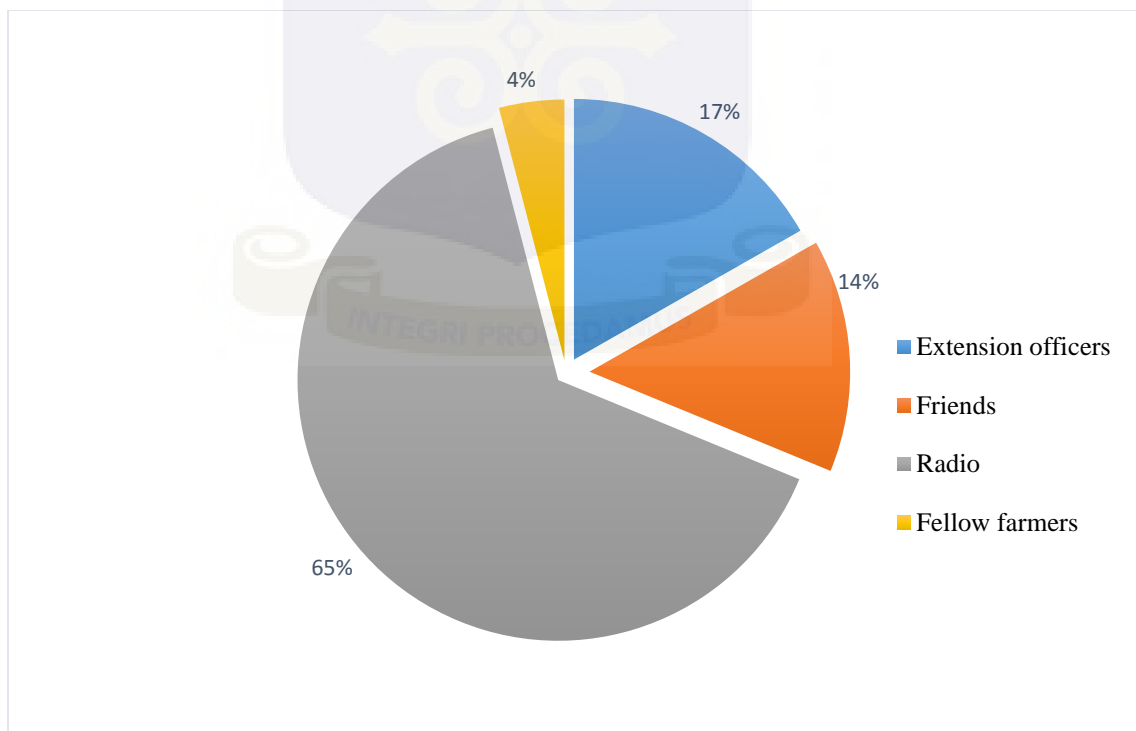


Figure 4.8: Farmers source of information about climate variability and change

Fewer farmers received information through friends (14%) and fellow farmers (4%). This shows that the media plays an important role in informing cocoa farmers in the district about climate variability and change which eventually translates to the kind of adaptation option they may use.

iv. How long variability in the climate have been noticed by farmers in Dormaa West District

From figure 4.9 below, it can be observed that majority (42%) of the respondents have noticed variability in the temperature and rainfall pattern in the district for 6 to 10 years. 38% have observed the change for 1 to 5 years, and 20% have observed it for 11 to 15 years. This shows that even though climate variability and change has been evident for decades, farmers of the Dormaa West District have not realized it for long.

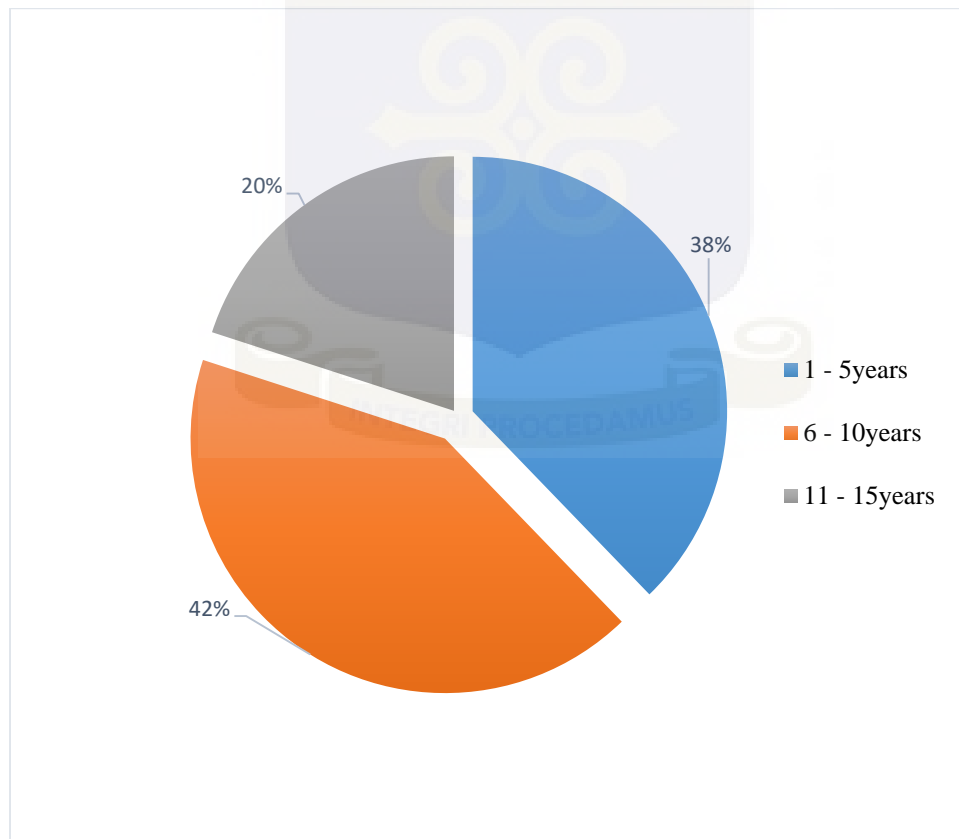


Figure 4.9: How long farmers in the district have noticed this variability in the climate

v. **Determining whether socio-demographic characteristics relates to farmers notice of variability in climate of the Dormaa West District**

The majority of the farmers had realized climate variations in the last 10 years. To understand this phenomenon, cross-tabulation and chi-square test of independence were used to determine whether farming experience and educational background of the respondents had some significant relationship with how long they had noticed this variability.

There is a significant relationship between the farming experience of the respondents and how long they have noticed this variability in the rainfall pattern and temperature in the district ($X^2 = 69.41$, $p = 0.00$) (Table 4.5). That is, how long these farmers have noticed variability in climate, vary significantly by how many years they have been involved in farming. None (0%) of the farmers who have farmed for 1 to 5 years had realized the changes within 6 to 10 years. The majority (92.3%) have only realized the changes within that same period with which they have been farming (1 to 5 years). Also, 53.7% representing the majority of respondents who have farmed for 26 years and above happen to have realized the changes for 6 to 10 years.

Table 4.5: Cross-tabulation of how long respondents have noticed variability in the climate against their farming experience

Variable Significance = p < 0.05	Noticed of variability in the climate, Freq. (F) and Percentage (%)			
	1 - 5years	6 - 10years	11 - 15years	Total
Total Respondents	68 (38%)	76 (42%)	36 (20%)	180 (100%)
1 - 5 years	12 (92.3%)	0 (0%)	1 (7.7%)	13 (100%)
6 - 10years	21 (87.5%)	1 (4.2%)	2 (8.3%)	24 (100%)
11 - 15years	1 (10%)	9 (90%)	0 (0%)	10 (100%)
16 - 20years	11 (20%)	33 (60%)	11 (20%)	55 (100%)
21 - 25years	13 (35.1%)	11 (29.7%)	13 (35.1%)	37 (100%)
26years & above	10 (24.4%)	22 (53.7%)	9 (22.0%)	41 (100%)

$$X^2 = 69.41, df = 10, p = 0.00$$

Source: Field data, 2017

There is a significant relationship between farmers' educational background and how long they have noticed this variability in the rainfall patterns and temperature in the district ($X^2 = 58.53, p = 0.00$) (Table 4.6). That is, how long these farmers have noticed variability in climate; vary significantly by the level of education they have obtained.

Table 4.6: Cross-tabulation of how long respondents have noticed variability in the climate against their educational background

Variable	Noticed of variability in the climate, Freq. (F) and Percentage (%)			
	1 - 5years	6 - 10years	11 - 15years	Total
Total Respondents	68 (38%)	76 (42%)	36 (20%)	180 (100%)
Primary	11 (37.9%)	16 (55.2%)	2 (6.9%)	29 (100%)
JHS	49 (46.7%)	23 (21.9%)	33 (31.4%)	105 (100%)
O-Level	1 (3.7%)	26 (96.3%)	0 (0%)	27 (100%)
Non-Formal	7 (36.8%)	11 (57.9%)	1 (5.3%)	19 (100%)

$X^2 = 58.53, df = 6, p = 0.00$

Source: Field data, 2017

vi. Farmers perceived causes of climate variability in the Dormaa West District

Farmers know about the causes of variability in the climate of the area. The majority (52.8%) of the respondents attributed it to cutting down of trees (deforestation) which have become rampant in the district and thereby affecting the local climate of the area (Figure 4.10). About 36% of the respondents attributed the cause to land degradation that is due to soil erosion and human activities such as the application of agrochemicals. About 6% of the respondents believe climate variability is punishment from God or a natural phenomenon and nothing can be done about it.

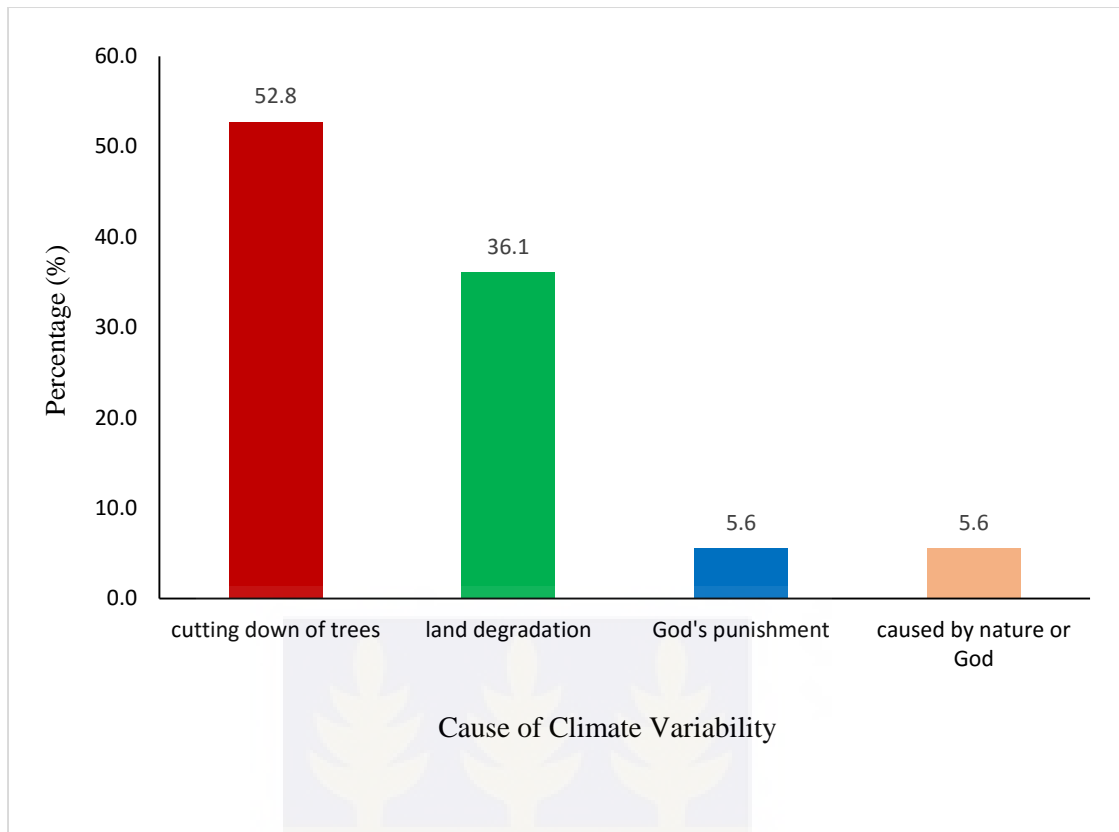


Figure 4.10: Farmers perceived causes of climate variability and change

vii. Expert advice on how to minimize the causes of climate variability and change

Despite farmers' knowledge about the causes of climate variability in the district, it was realized, there had been little efforts by experts in giving advice on how to mitigate the change. Not many fora and workshops have been organized on how and why there is the need to avoid some activities being done by the farmers and other members in the district. From Figure 4.11, the majority (66%) of the respondents claimed, they had not received any expert advice yet. On the other hand, 34% claimed to have gotten some expert advice on things to do to minimize their activities that impact the local climate of the area. The common ones amongst them are saving the forest through afforestation and by not setting fire or smoking in their farms as a way to prevent bushfires that destroy the forest. The Ghana Fire Service spearheads such advocacy.

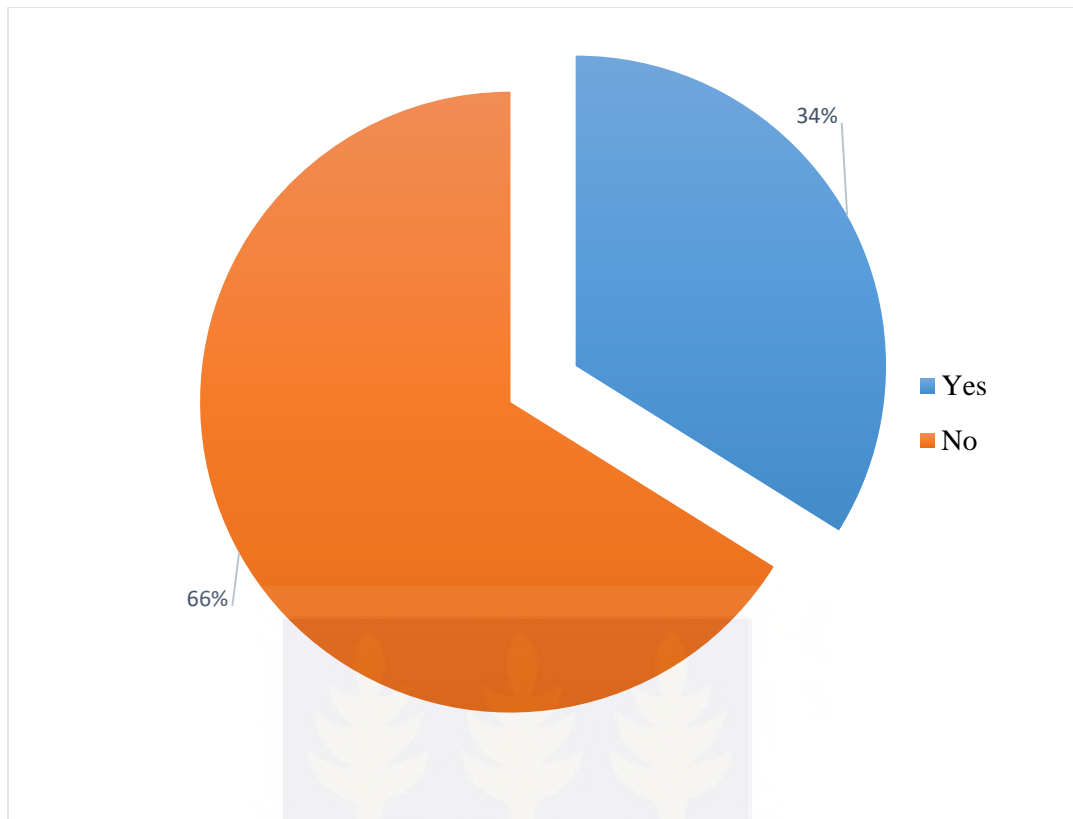


Figure 4.11: Farmers response to whether they have received expert advice on how to reduce the causes of climate variability

viii. Farmers perceived impacts of climate variability on cocoa production

Farmers were asked on how climate variability affect their cocoa production. Majority (61.7%) of the respondents said due to the variability (especially increases in temperature and sunshine) new cocoa trees come under stress and eventually die off (Figure 4.12). About 18% said variability in climate sometimes causes a delay in maturity of the cocoa beans. About 12%, claim variability in climate has made them realize unfamiliar pest and diseases that were not found in the area. The most likely impact of climate change on cocoa production according to Ojo & Sadiq (2010) is the shift in the geographical distribution of host and pest/diseases that alter cocoa yields. A few (7.8%) respondents said it is now difficult for them to get rid of pest and disease as they have become somehow resistant to the pesticides. Therefore, they have to spray

many times than the usual four (4) times in a growing season and sometimes have to change the type of pesticides they use on their farms.

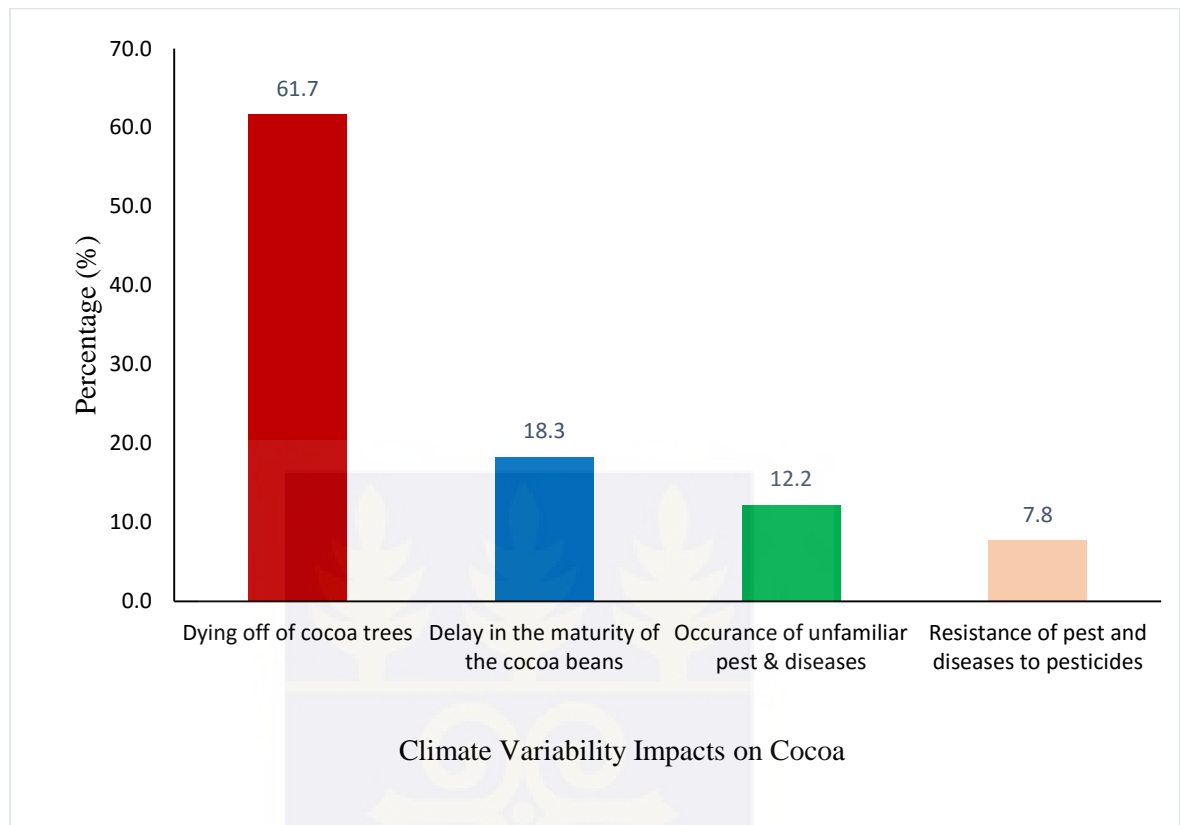


Figure 4.12: Farmers perceived impacts of climate variability on cocoa

ix. Other factors perceived by farmers to affect cocoa production in the Dormaa West District

In order to infer whether the respondents were not blaming every loss in yield to variability in climate, the farmers were asked about what other factors apart from variability in climate, affect their cocoa production and yields. From figure 4.13 below, it is observed that 67.8% of the respondents said increases in pest and diseases affect their cocoa yield. According to Anim-Kwapong & Frimpong (2004), black pod disease is the most destructive of a number of diseases that attack the developing and ripping cocoa pods. Inability to effectively apply pesticides to the cocoa farms, was another cause of yield loss reported by 26% of the respondents. The farmers attributed this to the fact that cost of hiring the mechanized spraying machine is high. Sometimes farmers

combine both pesticides and liquefied fertilizer, which somehow reduce the effectiveness of the agrochemicals.

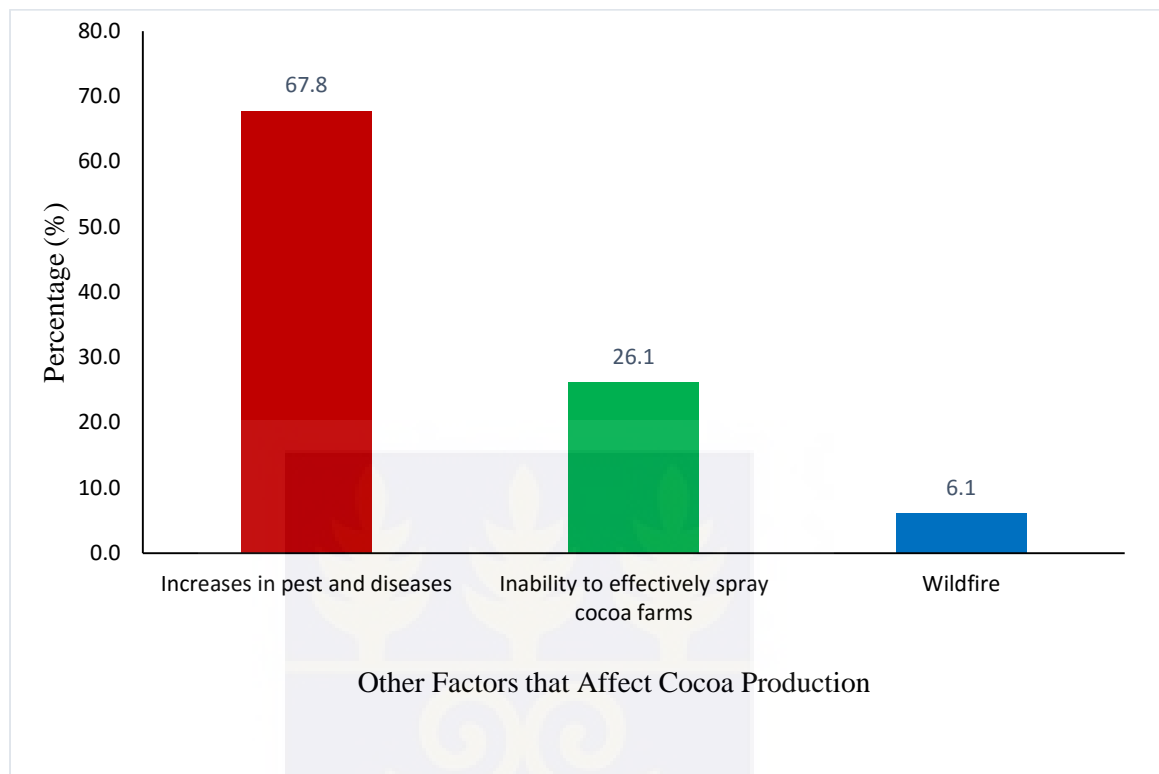


Figure 4.13: Other factors perceived by the farmers to be affecting cocoa production in the Dormaa West District

4.3 Micro-Adaptation Measures Used to Improve Output on Cocoa Fields in the Dormaa West District

The impacts of climate change are most evident in crop productivity because it represents the greatest concern to producers as well as consumers, compared to growth cycle, and therefore the producer is satisfied to some extent as far as yield remains consistent (Hatfield & Prueger, 2015). It is for this reason that the concept of adaptation measures to maintain and if possible increase output has become a great concern in the field of agriculture. Adaptation is arguably an important approach to minimize the impacts of climate variability on smallholder farmers whose vulnerability is projected

to increase without adaptation (Niggol Seo & Mendelsohn, 2008; Ehiakpor *et al.*, 2016).

4.3.1 Description of the adaptation measures adopted by farmers

In order for the farmers to overcome their vulnerabilities, pose to them by climate variability on cocoa production in the Dormaa East District, these farmers have adopted some micro-adaptation measures. These measures help to overcome the challenges brought about as a result of climate variability and change on cocoa production, which eventually affects output. Respondents were provided a list of twelve (12) micro-adaptation measures commonly used among crop farmers to assess whether they use or do not use these measures. These adaptation measures are such that a farmer uses more than one strategy in a growing season or over a long period.

Therefore, this section was to find out which among these adaptation options are widely used among the farmers in the Dormaa West District (Figure 4.14).

i. Using improved cocoa variety

It was realized that majority (93.9%) of the farmers have adopted the use of improved cocoa varieties such as the hybrid, which is popularly known among the farmers in the district as *Abrewa bedi*. This is because the hybrid cocoa varieties take a shorter time to mature, usually between 3 to 4 years as compared to the Amazonia type which takes 5 to 6 years. In addition, they are high yielding and produce pods all year round (Aneani & Ofori-Frimpong, 2013). According to Burke & Lobell (2010), decisions to switch crop variety cannot be made on the basis of climate alone. Different varieties have different input requirements and cost associated with their production. The Hybrid cocoa variety only ensures a continuous higher yield with lots of fertilizer and pesticide application (Franzen & Mulder, 2007). In addition, it is a full sun grown cocoa variety,

which gives higher yield with little or no shade compared to the Amazonia, which is highly sensitive to excessive sunshine.

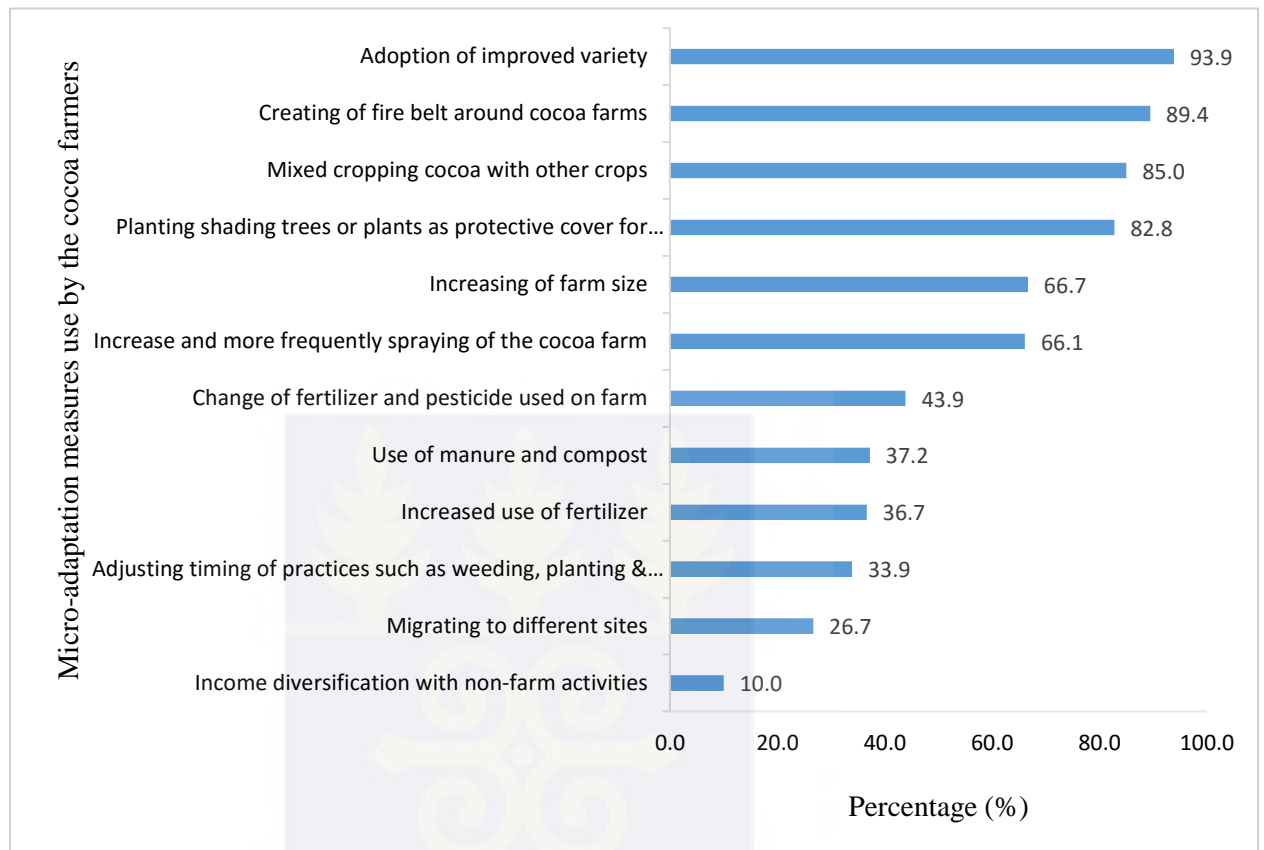


Figure 4.14: Micro-Adaptation measures used by cocoa farmers in the Dormaa West District

ii. Creating fire belts

It was also realized that (89.4%) of the respondents agreed to the creation of fire belts around their cocoa farms as a way to curb bushfires from destroying their farms in times of harsh weather conditions. The fear of seasonal bushfires among other socio-economic factors in the era of impacts of worsening climatic parameters caused nearly the collapse of cocoa farming in most parts of the transitional zone of the Brong-Ahafo (Kyere, 2016). The respondents made known that anti-bushfire committee has been established in the various communities, whose aim is to create awareness on bushfires

and ensure farmers do not set fire in their farms, especially in the dry seasons. Punishment for such have been specified, which has helped minimize bushfire in the district.

iii. Mixed cropping or crop diversification

Crop diversification reduces the local communities' dependence on cocoa as their main major cash crop and in most vulnerable areas, serves as a step in the progressive replacement of cocoa-based systems to a more heat and drought resistant based systems (Schroth *et al.*, 2016). In the study, it was realized that majority (85.0%) of the respondents engage in mixed cropping activities to help lessen their vulnerability to temperature and rainfall anomalies. According to Codjoe *et al.*, (2013) crop diversification reduce vulnerability by serving as an insurance to rainfall and temperature variability as different crops are affected differently by climatic events. Crops commonly grown by the farmers include plantains (87.3%), cassava (68.7%), cocoyam (52.4%). These crops perform well under the prevailing climatic conditions, have short maturity cycle and are readily available for consumption all year. In this case, the farmers are able to rely on these farm produces to feed their families without necessarily having to spend money to purchase food for the family. From observation, most of these households engaged in livestock, with fowls and goats as the common livestock found in the households.

iv. Growing shading plants and trees

About 83% of the respondents agreed that they grow shade trees or plants as a protective cover for seedlings. They explained that the excessive sunshine destroys the seedlings, and therefore these farmers grow protective covers most especially plantains on their new cocoa farm to provide shade for the cocoa seedlings as they grow. According to

the farmers the shade trees or plants are planted a year before cocoa seedlings are transplanted. Plantains serve as food for the household and support family income until the cocoa begins to bear fruit. Maintaining an adequate number (12-20) of trees per hectare on farm is very crucial for a good growth and subsequent crop yield (Codjoe *et al.*, 2013). One challenge with this measure in the communities studied was the operation of illegal chainsaw operators. They often destroy cocoa farms by cutting down desirable trees in farms. The practice does not encourage farmers to leave trees in their farms.

v. Increasing farm size

About 66.7% of the respondents resorted to field area expansion of cocoa farm as a way to increase output, which eventually translates into higher farm income. Virgin forest lands apart from increasing the farmers' cropland, have high soil fertility and low crop disease level that results in higher cocoa yields with low fertilizer and pesticide applications, which translates into higher net income of the farmer (Anim-Kwapong & Frimpong, 2004). Farmers hire new lands for farming at a cost. Few of these farmers are able to make outright purchase of new lands, as these lands are limited and expensive to acquire. Farm expansion has been the source of development and expansion of Ghana's cocoa industry (Oguntade & Fatunmbi, 2012). The practice of increasing farm size is widely criticized by researchers to have resulted in high forest depletion, environmental degradation and the adverse effect of climate change (Anim-Kwapong & Frimpong, 2004; Aneani & Ofori Frimpong, 2013).

vi. Frequent spraying of cocoa farm

Frequent spraying of cocoa farms is a practice adopted by about 66% of the respondents. In general, farms that cultivate hybrid cocoa varieties practice frequent

spraying. About 73% said they would adopt this adaptation measure if they had enough money. They attributed their inability to adapt to such measure to limited supply of pesticides provided by the government and the fact that the cost of purchasing and applying these pesticides are high. Therefore, these farmers combine the little they receive with the traditional insect control methods such as weeding, pruning, and disposal of waste, which is also associated with the production of high-quality cocoa. On the average, cocoa farmers sprayed their farms four (4) times (August, September, October, and December) in a growing season but due to harsh weather conditions, they sometimes spray their farms about six (6) times in a year. The commonly used pesticides brands by cocoa farmers are Akete power (Bifenthrin) and Confidor 200SL (Imidocloprid) which are the government-approved pesticides.

vii. Change in fertilizer and pesticide usage

About 44% of the respondents said they sometimes change the fertilizer and pesticides type they use on their farm to observe if they can get any positive changes in output. *“Mr. Stephen Taah of Diabaa said he had adopted to a type of fertilizer known as ‘OK’, which he heard of on the radio”*. On the other hand, 66.1% of the respondents said they only rely on whatever the government supply to them each growing season, and therefore, do not make the decision to change. Even though they might have carried out some changes in the fertilizer type they use on their farms sometime past, it was never their decision to make those changes.

viii. Use of organic manure

Chicken droppings (*Akoko bin*) have been one of the commonly used organic manure among the crop farmers in the district. From the survey conducted, 37.2% of the respondents said they still use chicken droppings in their farms to support the fertilizer

they apply on their farms. Some (62.8%) of the respondent said, they do not use the chicken droppings anymore as it harms the cocoa rather than helping to improve quantity. This, an agricultural officer said is due to their inability to effectively apply the chicken droppings on the crops that make it harmful to the crops, but not necessarily that chicken droppings are poisonous.

ix. Increased fertilizer application

Even though farm intensification such as increasing fertilizer application is a good way to improve crop outputs in several parts of the world, only 36.7% of the respondents are able to increase the amount of fertilizer they use on their farms. The remaining 63.3% claimed they are unable to increase the quantity of fertilizer they apply on their farms due to the high cost of purchasing extra fertilizer, and therefore, have to rely on what the government provides for them, which is limited to 7.5 bags of fertilizers per hectare of cocoa farm.

x. Adjusting practices such as weeding, planting and harvesting

It was realized from the study that about 34% of the respondents have made adjustments in their farm practices. These farmers have adopted line and peg done at 10 feet by 10 feet between the cocoa seedlings when planting the cocoa to ensure each cocoa tree gets enough aeration and at an angle 45 degrees to the farmer's shadow to allow some amount of sunlight. Engaging in such methods minimize seedling mortality. In addition, the farmers indicated that they now often weed their farms to ensure weeds do not compete with the cocoa for the limited soil nutrients and also helps in pest and disease control. The farmers indicated that the use of weedicides to control weeds is not encouraged as these weedicides often affect the other food crops on the farm. According

to Aneani & Ofori-Frimpong (2013), cocoa farmers are to weed their farms 4 times in a year, as recommended by CRIG.

xi. Migration to new sites

The practice of migration to new sites as an adaptation measure was not common among the farmers studied. About 73% of the farmers had never moved from their present site. Cocoa is a perennial crop and requires consistent maintenance to boost yield. The respondents (27%) who ever migrated did so because they were moving back to their hometowns as they had travelled to other regions previously. According to Kyere (2016), most cocoa farmers who moved to the Western Region after the 1983 bushfires have returned to establish new cocoa farms in their original place of residence outside of the Western Region.

xii. Off-farm income activity

Only 10% of the respondents were involved in off-farm income generating activities such as tailoring and trading in household items. Ninety percent (90%) said they strictly rely on only agriculture as their source of income. Farmers have sought to improve their incomes through diverse activities, but it seems that majority of these farmers still derive their incomes from cocoa farming and food crops associated with cocoa. Farmers have sought to improve their incomes through diverse activities. However, it is obvious that over 50% of their incomes is from cocoa and food crops associated with cocoa (Anim-Kwapong & Frimpong, 2004). From observation majority of farmers engaged in off-farm activities lived in the district's capital (Nkrankwanta), where there has been some level of development and presence of several social amenities. This creates an enabling environment for commercial activities compared to the other towns in the

district and therefore the people gradually are thinking of other income sources apart from farming.

xiii. Destroying and replacing pest infested cocoa tress

Informal discussions with some respondents revealed that, an adaptation measure used by a few farmers in the community, is destroying and replacing of pest and diseases infested cocoa trees with new ones. The practice is classified as costly compared to the clearing of new lands for cultivation; hence, well-to-do farmers mainly engage in the practice. The reason to adopt such an adaptation strategy is security of lands in the area. Many farmers find it economical to expand their farms rather than to replace old and diseased trees, as it takes as twice as the cost to clear an old cocoa farm as it does to clear a forest (Kolavalli & Vigneri, 2011).

4.3.2 Correlation Analysis: Socio-demographic characteristics and micro-adaptation measures

A Spearman correlation analysis established the relationship between the socio-demographic characteristics of the individuals and the kind of micro-adaptation measures they decide on.

From the results (Appendix 4.2), it can be concluded that averagely the relationship between socio-demographic characteristics of farmers in the Dormaa West District and the kind of micro-adaptation measures they use on their farms is weak ($-0.4 < x < 0.4$). This means that there is a minimal variation in the micro-adaptation measure adopted by a farmer in the Dormaa West District and his socio-demographic characteristics. This implies that irrespective of the individual differences that exist among the various farmers in the districts, they seem to adapt similar micro-adaptation measures.

4.3.3 Perceived barriers to the adoption of micro-adaptation measures in the Dormaa West District

Even though farmers in the district are using some micro-adaptation strategies to help improve their crop yield, they seem to face some challenges that hinder their decisions to adapt fully to these measures. From the survey, it was realized that majority (67.2%) of the respondents complained of some challenges that have become barriers to their adoption of these micro-adaptation strategies.

In Figure 4.15, the major barriers as described by the farmers, are presented. About 96% of the respondents listed expensive farming inputs (cutlasses, spraying cans, fertilizers, and pesticides) as the most important barrier.

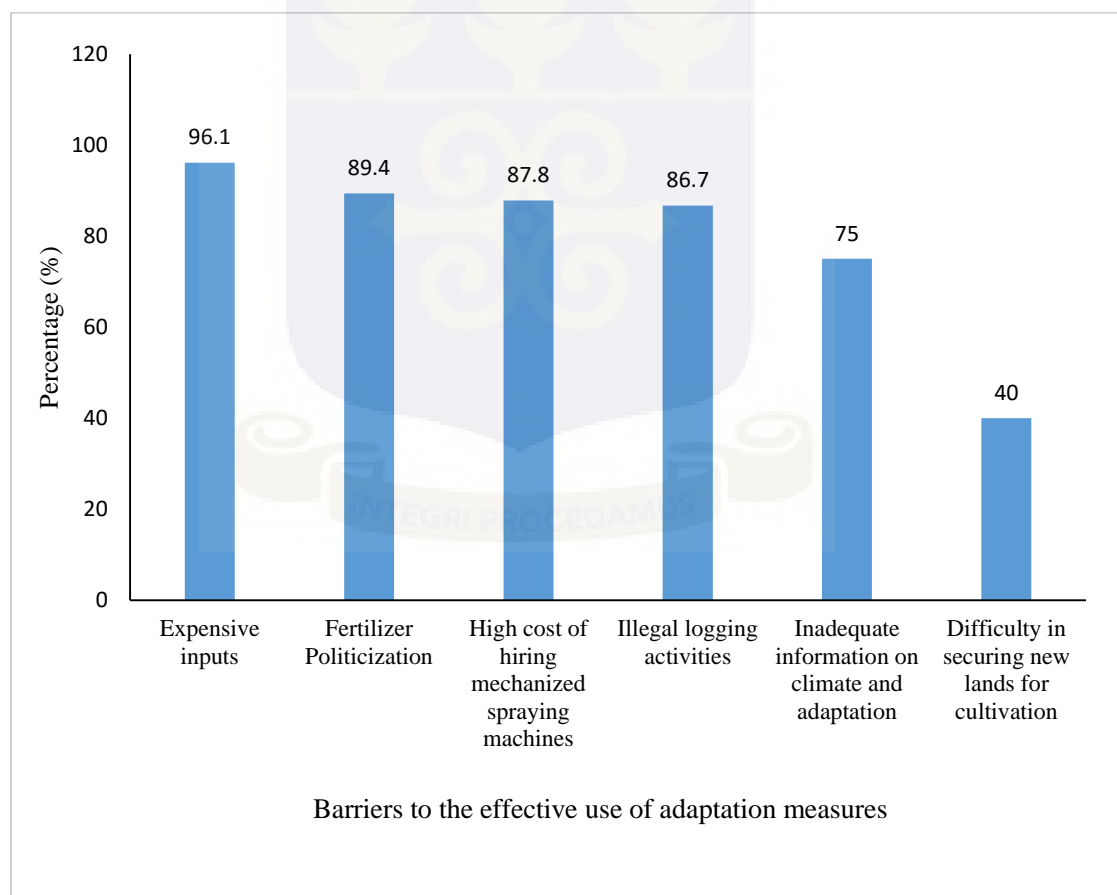


Figure 4.15: Factors that hinder farmers' decision on the use of an adaptation measure

This was followed by what the farmers described as “the politicization of fertilizer distribution to farmers” (89.4%). Farmers claimed that fertilizer from the government do not get to the right farmers and in some cases, they get less than what they deserve according to the farm size. Fertilizers are sold back to the farmers at higher prices. In addition, 87.8% of the respondents said the cost of hiring mechanized spraying machines to equip them to spray several hectares of cocoa farms is a hindrance for them to adopt frequent spraying of farms against pest and diseases. Another barrier in relation to cost that the respondents spoke about, was the cost of hiring chainsaw operators to cut down highly infected cocoa trees.

Illegal logging by chainsaw operators in the district was also described to be a major (86.7%) hindrance to their decision to leave the 12-20 trees per hectare on their farms. These chainsaw operators according to the respondents destroy their farms in the quest to log a single tree in the farm. Sometimes they receive threats of death from the operators in their attempt to stop them. Farmers themselves destroy the trees rather than to leave them for illegal chainsaw operators to destroy their farms.

Inadequate information on climate variability and adaptation measures also serves as a barrier to the use of these measures as 75% of the respondents attested to this. According to the respondents, they do not get a full understanding of the need to implement certain strategies on their farm and therefore fear the risk of losing more than what they could predict. This makes it difficult for them to make decisions on changing their existing strategies or adopting new ones. According to Akinagbe & Irohibe (2014), limited knowledge, expertise, data and specific climate change institution to take on climate variability and change issues is a major challenge to applying agricultural adaptation measures in Africa.

Lastly, some respondents (40%) said they find it difficult to secure new lands for cultivation and therefore are unable to increase their farmlands.

4.3 Effects of Micro-Adaptation Measures on Farmers Net Income in the Dormaa West District

Variability and change in climate alter the development of cocoa pods, pests and diseases that affect cocoa trees, causing low crop yield that affects farm income (Agbongiarhouyi *et al.*, 2013). The effect of micro-adaptation measures on the net farm income of cocoa farmers was estimated with a random effect balanced panel regression model.

The result of the random effect model shows that all the socio-demographic factors except age of farm were significant. The economic factors apart from quantity of pesticides bought were significant. Agronomic practices; using an improved cocoa variety, increase spraying of the cocoa farms against pest and diseases and use of organic manure have a positive effect on the net farm income of cocoa farmers in the district (Table 4.7). Adopting these adaptation measures reduces the influence of the climatic factors on cocoa outputs. The coefficients of these micro-adaptation measures are positive and statistically significant at 1% level. This indicates that the increasing use of these micro-adaptation measures (agronomic practices) by a farmer is most likely to maintain and probably increase their level of on-farm net income in events of increasing climate variability.

Table 4.7: Results of random effect model of micro-adaptation on net farm incomes of cocoa farmers.

Variable	Estimate	Std. Error	t-value
Socio-demographic Factors			
Age of respondents	-3.8355e+02	7.6150e+01	-5.0367***
Level of education	-1.6957e+02	5.2919e+01	-3.2044**
Number of dependents	-2.4191e+02	6.0434e+01	-4.0029***
Farming experience	5.0794e+02	4.8360e+01	10.5035***
Land ownership	-4.1823e+02	7.2362e+01	-5.7796***
Age of cocoa farm	6.5320e+01	5.1036e+01	1.2799
Economic Factors			
Production cost	1.8566e+00	4.1057e-01	4.5220 ***
Quantity of fertilizer bought	-2.8010e+02	3.9157e+01	-7.1534***
Quantity of pesticide bought	-4.5132e+01	3.7991e+01	-1.1880
Number of hired labour use	2.0714e+02	2.5180e+01	8.2264***
Climate/Weather Factors			
Rainfall	-1.2191e+01	2.9476e+07	0.0000
Minimum temperature	-1.2352e+03	1.0605e+09	0.0000
Adaptation Measures			
Improve cocoa variety	2.3202e+03	2.4361e+02	9.5245***
Increased spraying of cocoa farms	1.1230e+03	1.1844e+02	9.4815***
Increased use of fertilizer	4.1492e+00	1.4339e+02	0.0289
Change in fertilizer type	-1.3477e+03	1.2505e+02	-10.7774***
Increased farm size	4.9556e+02	1.6327e+02	3.0353**
Non-farm activity	-1.4496e+03	1.7687e+02	-8.1958***
Mixed cropping	-1.4970e+02	2.1481e+02	-0.6969
Growing shaded plants and trees	1.2775e+02	1.0073e+02	1.2682
Creating Fire Belt	1.8678e+02	1.8637e+02	1.0022
Use of organic manure	6.5503e+02	1.2375e+02	5.2933***
Migration	2.5309e+02	1.6996e+02	1.4891
Adjusting practices weeding, planting & harvesting	2.1964e+03	1.3641e+02	16.1022***
(Intercept)	3.9081e+04	3.6419e+10	0.0000
Goodness of Fit Indicators			
R-Square		0.73395	
Adjusted R-Square		0.72155	

F-Statistics	59.1975
p-value	<2.22e-16 (0.00)

Significance: 0 '***', 0.001 '**', 0.01 '*', 0.05 '.'

Source: Field data, 2017

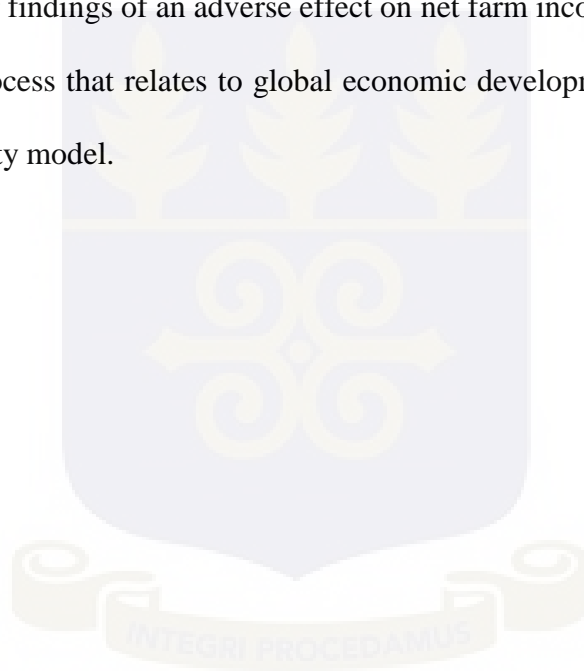
Aneani & Ofori-Frimpong (2013) analysed the yield gap and some factors of cocoa yield in Ghana and found that planting poor cocoa varieties have negative impacts on cocoa yield. This they indicated, can reduce cocoa yield by 28.1 (kg/h) due to the highly genetic variations among the cocoa varieties. The adoption of improved cocoa varieties increase cocoa yields by at least 45% (Edwin & Masters, 2005). This implies that growing improved cocoa varieties increases yield and for that matter the farmer's income. According to Scialabba & Müller-Lindenlauf (2010), the use of organic manure reduces the financial risk of farm operations, since farmers are less dependent on external inputs like synthetic fertilizers. They do not have to borrow money to purchase extra fertilizers and are therefore financially less affected in case of crop failure.

In addition, socio-economic practices; increasing farm size and adjusting practices such as weeding, planting and harvesting have a positive effect on the net farm income of cocoa farmers in the district (Table 4.7). The coefficient of these micro-adaptation measures is positive and statistically significant at 1% level. This shows that the increasing use of these micro-adaptation measures (socio-economic practices) by a cocoa farmer is likely to maintain and probably increase the net farm income level of the farmer in events of increasing climate variability. Aneani & Ofori-Frimpong (2013) analysed the yield gap and some factors of cocoa yield in Ghana found that frequency of weeding cocoa farms has a positive effect on cocoa yield, which can lead to an

increase of 55.09 (kg/h) of cocoa. Farm expansion has been the source of development and expansion of Ghana's cocoa industry (Oguntade & Fatunmbi, 2012), as the virgin forest lands apart from increasing the farmers' cropland, have high soil fertility and low crop disease level (Anim-Kwapong & Frimpong, 2004). According to Aneani & Ofori-Frimpong (2013), clearing of virgin forest lands increases deforestation, which has influenced the local climate of the district (Ghana Statistical Service, 2014). Therefore, even though increasing of farm size shows positive, its use as an adaptation measure must be modified through the use of agroforestry to ensure a win-win situation of increased yields and decreased deforestation (Witjaksono, 2016).

On the other hand, change in fertilizer type, and off-farm income activity have a negative effect on the net farm income of cocoa farmers in the district (Table 4.7). The coefficients of these micro-adaptation measures are negative and statistically significant at 1% level. This implies that the increasing use of these micro-adaptation measures by the farmer is likely to maintain and probably decrease his net farm income in events of increasing climate variability. The inference relies on the fact that these new fertilizer types, apart from their high cost have not been tested and approved by the Cocoa Research Institute Ghana (CRIG). Therefore, they may not be efficient to cause higher yield as perceived by the farmers, but rather increase the farmer's cost of production against his income. In addition, off-farm income activities will cause a decrease in on-farm income and not necessarily, the farmers' total income. *Madam Afia Agyeiwaa of Brofoyedu, a study community in the district, who is a tailor and a cocoa farmer, gave an account of how she experiences low cocoa yields due to her inability to get enough time for the farming.* According Berhe (2016), adaptation through on-farm management practices has statistical significance and positive effects on incomes of households, unlike creating alternative income options.

In general, the random effect model of micro-adaptation measures on the net farm income of cocoa farmers in the district with the F-statistics of 59.1975 is statistically significant at 1% significance level. This indicate a joint influence of the independent variables on the net farm income of the farmers (dependent variable). The model coefficient of determination shows that the combine effect of all the independent variables accounts for 73.4% variation in cocoa farmers' net farm income. This indicates that climate variability and the use of micro-adaptation measures by cocoa farmers have high influence on the net farm income of cocoa farmers. Huda (2015), suggest a similar findings of an adverse effect on net farm income as climate change is a continuous process that relates to global economic development using its estimated climate variability model.



CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATION

5.0 Introduction

This chapter presents the summary of the study, conclusions, and recommendations based on the findings of the study.

5.1 Summary of the Study

The study assessed climate variability and implications of farm-level (micro) adaptation decisions by cocoa farmers in the Dormaa West District on their net income levels. The study was based on both secondary data and data from a field survey. Secondary data on climate (temperature and rainfall) and cocoa outputs were obtained from the Ghana Meteorological Agency and the Ghana Cocoa Board respectively. The field survey assessed the kinds of micro-adaptation measures used by 180 cocoa farmers in the district. The survey was conducted based on their knowledge about climate variability and change, adaptation measures, and cocoa production, with production information for three consecutive years (2013, 2014 and, 2015) collected from the farmers. With the data analysis, three specific issues were carried out:

1. Determine how climate variability affect outputs of cocoa farms in Dormaa West District
2. Identify specific micro-adaptation measures used to improve output on cocoa fields in Dormaa West District
3. Determine the effect of the micro-adaptation measures on the income of cocoa farmers.

The first analytical section focused on the relationship between cocoa outputs and climate variability (temperature and rainfall) in the district. The study found that there

has been a 28.1% and 0.9% variability in average rainfall and temperature trends respectively for the period 1991 to 2015. The regression results showed that average rainfall has a positive effect on cocoa outputs in the District, at 1% significant level, while temperature had a positive effect on cocoa outputs for the District at 5% significant level. Variability in rainfall accounts for 48.6% of the variations in cocoa outputs, while variability in temperature accounts for 12.8% of the variations in cocoa outputs. Results of the multiple linear regression model show that a combined effect of rainfall and temperature accounts for 56.7% variations in cocoa outputs for Dormaa West District.

For the effectiveness of an adaptation to climate variability, it must include the extent to which the people believe that there have been some changes in the climate, their awareness of the type and form of change, and knowledge on available and future technology. Farmers' perceptions on climate variability and cocoa production were analysed. The study revealed that farmers in the district perceive a decrease in average rainfall and an increase in temperature levels and sunshine hours. The majority of the respondents had noticed these variabilities for 6 to 10 years. The causes of these variabilities included deforestation and land degradation. Radio is their major source of information on climate variability and adaptation. It was realized that little education on how to prevent or minimize activities that indirectly tend to affect the local climate of the area has been done by stakeholders. Farmers perceived that climate variability results in low crop outputs. Drought and high temperatures cause seedling mortality and increases in pest and diseases infestation.

The second analytical section of the study focused on the micro-adaptation measures used by cocoa farmers to improve outputs on cocoa fields in the Dormaa West District. Farmers have resort to some micro-adaptation measures perceived to be efficient in

helping to reduce their vulnerability. The widely used micro-adaptation measures in a descending order were: the use of improved cocoa variety, creating fire belts, mixed cropping, planting shade trees and plants, increasing farm size, increase and more frequently spraying of the cocoa farm, change fertilizer and pesticide used on the farm and, use of organic manure, an increase in fertilizer application, adjusting farm practices, migration to new sites and off-farm income diversification activities. In an attempt to implement these adaptation measures, farmers in the district are faced with some challenges such as expensive inputs, subsidized fertilizer supply politicization, inadequate information on climate adaptation measures, and illegal logging activities. Despite the background differences that existed among the farmers in the districts, they seem to be adapting to similar adaptation measures.

The third and final section of the study assessed the effects of the micro-adaptation measures employed on farm net incomes using an Advanced Ricardian Model. A random effect balanced panel data model was applied to estimate the effects. The results from the estimated model suggested that five of the micro-adaptation measures used by the cocoa farmer in the district significantly affects their net income positively. The first three are agronomic practices, (i) Growing an improved cocoa variety, (ii) Increasing spraying of the cocoa farms against pest and diseases, (iii) Use of organic manure, and the last two are socio-economic practices, (iv) Increasing farm size and (v) Adjusting practices such as weeding, planting and harvesting. Two of the micro-adaptation measures, (i) Change in fertilizer type and (ii) Engaging in non-farm income activities have a negative significant effect on the net incomes of the cocoa farmers in the Dormaa West District. In general, climate variability and the use of micro-adaptation measures by cocoa farmers in the Dormaa West District accounts for 73.4% variation in their net farm income.

5.2 Conclusion

The climate variability challenge of the Dormaa West District shows an increasing rainfall and temperature trends for the period 1991 to 2015, which has a significant effect on cocoa outputs from Dormaa West District. The five most important micro-adaptation measures that farmers have adopted are the use of improved variety, creating fire belts, mixed cropping, planting protective covers, increased farm size and frequent spraying of the cocoa farm. Fertilizer politicization, the high cost of inputs and illegal logging activities remain the challenges to farmer adoption of micro-adaptation measures by cocoa farmers in Dormaa West District.

Farmers in the Dormaa West District will continue cocoa production as rainfall is increasing, and the use of these micro-adaptation measures increase their farm net income. Agronomic practices and socio-economic practices are important determinants of net farm income. Focusing on non-farm income and frequent change in the type of fertilizer applied on cocoa farms reduces farm net income. Adopting efficient micro-adaptation measures reduces the influence of the climatic factors on farm income.

5.4 Recommendations

The study, therefore, makes these recommendations:

1. Forest management programme: The forestry commission in collaboration with COCOBOD should organize and promote more programs that seek to discourage forest depletion in and around the district to help boost the local average rainfall amounts to make up for soil moisture losses due to evaporation.
2. Sensitization campaigns: Frequent education and information about climate variability and its adaptation strategies should be carried out by stakeholder organizations. Farmer field school approach can be promoted since it will

ensure that farmers in the district have a clear understanding of the weather patterns and the required adaptation options to employ.

The on-farm adaptation measures, especially, the agronomic practices related to improved cocoa varieties, pest and disease management and organic manure application as well as fire belts, planting protective cover and use of approved agrochemicals should be promoted in the district. This will help increase cocoa yields that will translate into higher income for cocoa farmers, the cocoa industry, and contribute more to the country's national cocoa output for export.

3. Efficient supply of inputs: Greater efforts should be made by the COCOBOD at making enough agrochemicals, especially pesticides used in controlling pest and diseases and fertilizers, readily available and fairly distributed among cocoa farmers. Effective application of adequate quantities will boost yields.
4. Future research: A wider geographical spatial spread with other climatic variables (sunshine and humidity) should be analysed. This will help identify areas where cocoa production will be highly favourable and areas where farmers are changing from cocoa production to other crops due to harsh weather conditions. This will make the COCOBOD identify the areas they can channel more resources to ensure a sustained cocoa outputs for the country.

REFERENCES

- Adeniyi, O. R., & Ogunsola, G. O. (2014). Cocoa Production and Related Social-Economic and Climate Factors: A Case Study of Ayedire Local Government Area of Osun State, Nigeria. *Agricultural Science*, 2(4), 1–13. <https://doi.org/10.12735/as.v2i4p01>
- Adjei-Nsiah, S., & Kermah, M. (2012). Climate Change and Shift in Cropping System: From Cocoa to Maize Based Cropping System in Wenchi Area of Ghana. *British Journal of Environment and Climate Change*, 2(2), 137–152. <https://doi.org/10.9734/BJECC/2012/1220>
- Afrane, G. & Ntiamoah, A. (2011). Use of Pesticides in the Cocoa Industry and their impacts on environment and food chain, Pesticides in the Modern World - Risks and Benefits, Dr. Margarita Stoytcheva (Ed.), ISBN: 978-953-307-458-0, InTech, <http://doi.org/10.5772/17921>
- Agbongiarhuoyi, A. E, Abdulkarim, I. F, Fawole, O. P, Obatolu, B. O., Famuyiwa, B. S. & Oloyede, A. A. (2013). Analysis of farmers' adaptation strategies to climate change in cocoa production in Kwara State. *Journal of Agricultural Extension*, 17(1), 10–22.
- Akinagbe, O. M., & Irohibe, I. J. (2014). Agricultural adaptation strategies to climate change impacts in Africa: a review. *Bangladesh Journal of Agricultural Research*, 39(3), 407-418.
- Amos, T. T., & Thompson, O. A. (2015). Climate Change and the Cocoa Production in the Tropical Rain Forest Ecological Zone of Ondo State, Nigeria. *Journal of Environment and Earth Science*, 5(1), 36–42.
- Aneani, F., & Ofori-Frimpong, K. (2013). An Analysis of Yield Gap and Some Factors of Cocoa (*Theobroma cacao*) Yields in Ghana. *Sustainable Agriculture Research*, 2(4), 117-127. <https://doi.org/10.5539/sar.v2n4p117>
- Anim-Kwapong, G. J., & Frimpong, E. B. (2004). *Vulnerability of Agriculture to Climate Change- Impact of Climate Change On Cocoa Production*. Vulnerability and Adaptation Assessment Under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2). Cocoa Research Institute of Ghana, 2, 1–30.
- Antle, J. M., & Capalbo, S. M. (2010). Adaptation of agricultural and food systems to climate change: An economic and policy perspective. *Applied Economic Perspectives and Policy*, 32(3), 386–416. [https://doi.org/10.1093/aep/32\(3\)/386](https://doi.org/10.1093/aep/32(3)/386)
- Appiah, M. R., K. O., Sackey, S. T., & Afrifa, A. A. (1992). The consequences of cocoa production on soil fertility in Ghana : A review. *Ghana Journal of Agricultural Science*, 30, 183–190.

- Asante-Poku A., & Angelucci F. (2013). Analysis of incentives and disincentives for cocoa in Ghana. *Technical notes series*, MAFAP, FAO, Rome.
- Baah, F., Anchirinah, V., & Amon-Armah, F. (2011). Soil fertility management practices of cocoa farmers in the Eastern Region of Ghana. *Agriculture and Biology Journal of North America*, 2(1), 173–181. <https://doi.org/10.5251/abjna.2011.2.1.173.181>
- Below, T., Artner, A., Siebert, R., & Seiber, S. (2010). Micro-level Practices to Adapt to Climate Change for African Small-scale Farmers. *A Review Of Selected Literature. IFPRI Discussion Paper*, 953(February), 1-28. <https://doi.org/10.1007/s00267-008-9197-0>
- Berhe, M., Hoag, D., Tesfay, G., Oniki, S., & Kagatsume, M. (2016). Effects of adaptation to climate change on income of cattle owners in the pastoral and agro-pastoral communities of Northern Ethiopia. In *2016 AAAE Fifth International Conference, September 23-26, 2016, Addis Ababa, Ethiopia* (No. 246974). African Association of Agricultural Economists (AAAE).
- Boateng, D. O., Nana, F., Codjoe, Y., & Ofori, J. (2014). The impact of illegal small-scale mining (Galamsey) on cocoa production in Atiwa district of Ghana. *International Journal of Advance Agriculture Research*, 2, 89–99.
- Boon E., & Ahenkan A. (2011). Assessing Climate Change Impacts on Ecosystem Services and Livelihoods in Ghana: Case Study of Communities around Sui Forest Reserve. *18th Commonwealth Forestry Conference*
- Burke, M., & Lobell, D. (2010). Food security and adaptation to climate change: What do we know?. *Climate change and food security* (pp. 133-153). Springer Netherlands.
- Challinor, A. J., & Wheeler, T. R. (2007). Crop yield reduction in the tropics under climate change: Processes and uncertainties. *Agricultural and Forest Meteorology*, 148(3), 343–356. <https://doi.org/10.1016/j.agrformet.2007.09.015>
- Codjoe, F. N. Y., Ocansey, C. K., Boateng, D. O., & Ofori, J. (2013). Climate Change Awareness and Coping Strategies of Cocoa Farmers in Rural Ghana. *Journal of Biology, Agriculture and Healthcare*, 3(11), 19–29.
- Croissant, Y., & Millo, G. (2008). Panel data econometrics in R: The plum package. *Journal of Statistical Software*, 27(2), 1–43. <https://doi.org/10.1186/1478-7954-4-13>
- Ghana Cocoa Board. (2016). *Regional Cocoa Purchases*. Retrieved from: http://www.cocoaboard.gh/weekly_purchase.php

- Deschenes, O., & Greenstone, M. (2007). The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather: Comment. *The American Economic Review*, 97(March), 354–385. <https://doi.org/10.1257/aer.102.7.3761>
- Di Falco, S., Yesuf, M., Kohlin, G., & Ringler, C. (2011). Estimating the Impact of Climate Change on Agriculture in Low-Income Countries: Household Level Evidence from the Nile Basin, Ethiopia. *Environmental and Resource Economics*, 52(4), 457–478. <https://doi.org/10.1007/s10640-011-9538-y>
- Edwin, J., & Masters, W. A. (2005). Genetic improvement and cocoa yields in Ghana. *Expl. Agric.*, 41, 1-13. <http://dx.doi.org/10.1017/S0014479705002887>
- Ehiakpor, D. S., Danso-Abbeam, G., Baah, J. E., & Yildiz, F. (2016). Cocoa farmer’s perception of climate variability and its effects on adaptation strategies in the Suaman district of the western region, Ghana. *Cogent Food & Agriculture*, 2(1), 1-12. <https://doi.org/10.1080/23311932.2016.1210557>
- Eriksen, S. E. H., & O’Brien, K. L. (2007). Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, 7(4), 337–352. <https://doi.org/10.3763/cpol.2007.0717>
- Food and Agriculture Organization (2013). *Climate Agriculture Sourcebook*.
- Fofana, I. (2011). Simulating The Impact Of Climate Change And Adaptation Strategies On Farm Productivity And Income: A Bioeconomic Analysis. *IFPRI - Discussion Papers*, (1095), 1-28. Retrieved from <http://www.ifpri.org/sites/default/files/publications/ifpridp01095.pdf>
- Franzen, M., & Mulder, B. M. (2007). Ecological, economic and social perspectives on cocoa production worldwide. *Biodiversity and Conservation*, 16(13), 3835–3849. <https://doi.org/10.1007/s10531-007-9183-5>
- Ghana Statistical Service. (2014). 2010 Population and Housing Census: District Analytical Report for Dormaa West District.
- Hatfield, J. L., & Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes*, 10, 4–10. <https://doi.org/10.1016/j.wace.2015.08.001>
- He, B., Huang, L., & Wang, Q. (2015). Precipitation deficits increase high diurnal temperature range extremes. *Scientific Reports*, 5, 12004. <https://doi.org/10.1038/srep12004>
- Huda, F. A. (2015). *Economic Assessment of Farm Level Climate Change Adaptation Options : Analytical Approach and Empirical Study for the Coastal Area of Bangladesh*. (Doctorial dissertation). Humboldt University.

- Hutchins, A., Tamargo, A., Bailey, C., & Kim, Y. (2015). Assessment of Climate Change Impacts on Cocoa Production and Approaches to Adaptation and Mitigation: A Contextual View of Ghana and Costa Rica. *International Development Studies*, 1-22.
- IPCC (2014). *Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectorial Aspects. The contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.
- Kimengsi, J. N., & Tosam, J. N. (2013). Climate Variability and Cocoa Production in Meme Division of Cameroon: Agricultural Development Policy options. *Greener Journal of Agricultural Sciences*, 3(8), 606–617.
- Knowles, N., Dettinger, M. D., & Cayan, D. R. (2006). Trends in snowfall versus rainfall in the western United States. *Journal of Climate*, 19(18), 4545-4559.
- Kolavalli, S., & Vigneri, M. (2011). Cocoa in Ghana: Shaping the success of an economy. *Yes, Africa can: success stories from a dynamic continent*, 201-218. <https://doi.org/10.1596/978-0-8213-8745-0>
- Kumi, E., & Daymond, A. (2015). Farmers' perceptions of the effectiveness of the Cocoa Disease and Pest Control Programme (CODAPEC) in Ghana and its effects on poverty reduction. *American Journal of Experimental Agriculture*, 5 (7). pp.257-274. ISSN 2231-0606
- Kurukulasuriya, P., Rosenthal, S. (2003). *Climate Change and Agriculture: A Review of Impacts and Adaptations*, World Bank Climate Change Series (World Bank Environment Department, Washington, DC), 91, 1-106. <https://doi.org/10.1017/CBO9781107415324.004>
- Kyere, E. Y. (2016). *Farmers Perception on Climate Change, Its Manifestations in Small Holder Cocoa Systems and Shifts in Cropping Pattern in The Forest-Savanna Transitional Zone of Ghana* (Master of Philosophy Thesis). KNUST.
- Läderach et al. (2013). Predicting The Future Climatic Suitability for Cocoa Farming of the World's Leading Producer Countries, Ghana and Cote d'Ivoire. International Center for Tropical Agriculture (CIAT), Managua, Nicaragua. *Climatic change*, 119(3-4), 841-854.
- Lawal, J. O., & Emaku, L. A. (2007). Evaluation of the effect of climatic changes on Cocoa Production in Nigeria: Cocoa research institute of Nigeria (CRIN) as a case study. *African Crop Science Conference Proceedings*, 8, 423–426.
- Masseti, E., & Mendelsohn, R. (2011). Estimating Ricardian Models With Panel Data. *Climate Change Economics*. 2(4), 301 - 319

- Mendelsohn, R. (2012). the Economics of Adaptation To Climate Change in Developing Countries. *Climate Change Economics*, 3(2), 1250006. <https://doi.org/10.1142/S2010007812500066>
- Mendelsohn, R. (2000). Efficient adaptation to climate change. *Climatic Change*, 45(3), 583–600. <https://doi.org/10.1023/A:1005507810350>
- Müller-Kuckelberg, K. (2012). Climate change and its impact on the livelihood of farmers and agricultural workers in Ghana. *Preliminary Research Results. General Agricultural Workers' Union of GTUC. Friedrich Ebert Stiftung (Fes)*. 1-47
- Nair, K. P. (2010). Cocoa (*Theobroma cacao* L.). *The agronomy and economy of important tree crops of the developing world*, 131-180.
- Ndamani, F., & Watanabe, T. (2015). Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: A micro-level study in Ghana. *Water (Switzerland)*, 7(9), 4593–4604. <https://doi.org/10.3390/w7094593>
- Ngoong, J T. Forgha, N. G. (2013). An Analysis of the Socio-Economic Determinants of Cocoa Production in Meme Division, Cameroon. *Greener Journal of Business and Management Studies*, 3(6), 298–308.
- Nhemachena, C., & Hassan, R. M. (2007). *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa*, International Food Policy Research Institute.
- Niggol Seo, S., & Mendelsohn, R. (2008). A Ricardian Analysis of the Impact of Climate Change on South American Farms. *Chilean Journal of Agricultural Research*, 68(1), 69–79.
- Nwachukwu, I. N., Ezeh, C. I., & Emerole, C. O. (2012). Effect of Climate Change on Cocoa Productivity in Nigeria. *African Crop Science Journal*, 20(s2), 487–491.
- Oguntade, A., Fatunmbi, T., & Okafor, C. (2012). Effects of Farmers' Field School on the Technical Efficiency of Cocoa Farmers in Nigeria. *Journal of Biology and Life Science*, 4(1), 135–144. <https://doi.org/10.5296/jbls.v4i1.2531>
- Ojo, A. D., & Sadiq, I. (2010). Effect of climate change on cocoa yield: A case of Cocoa Research Institute of Nigeria (CRIN) farm, Oluyole local government, Ibadan, Oyo State. *Journal of Sustainable Development in Africa*, 12(1), 350-358.
- Owoeye, R. S. & Sekumade, A. B. (2016). Effects Of Climate Change On Cocoa Production In Ondo State, Nigeria. *Journal of Social Sciences Research*, 10(2), 2014-2025
- Oyekale, A. S., Bolaji, M. B., & Olowa, O. W. (2009). The effects of climate change on cocoa production and vulnerability assessment in Nigeria. *Agricultural Journal*, 4(2), 77-85.

- Oyekale, A. S. (2015). Climate change induced occupational stress and reported morbidity among cocoa farmers in South-Western Nigeria. *Annals of Agricultural and Environmental Medicine*, 22(2), 357–361.
- Passel, S. V., Massetti, E., & Mendelsohn, R. (2012). A Ricardian Analysis of the Impact of Climate Change on European Agriculture. *Nota Di Lavoro*.
- Pilo, M., Ahamadou, A. M., & Tobias, W. (2016). Impact Of Adaptation Strategies On Farm Households' Farm Income: A Bio-Economic Analysis, 63(10), 1–7. <https://doi.org/10.7498/Aps.63.104215>
- Sagoe, R. (2006). Climate Change and Root Crop Production in Ghana. *A Report Prepared for Environmental Protection Agency (EPA)*, Accra-Ghana.
- Sarr, B. (2012). Present and future climate change in the semi-arid region of West Africa: A crucial input for practical adaptation in agriculture. *Atmospheric Science Letters*, 13(2), 108–112. <https://doi.org/10.1002/asl.368>
- Schroth, G., Läderach, P., Martinez-Valle, A. I., Bunn, C., & Jassogne, L. (2016). Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities, and limits of adaptation. *Science of the Total Environment*, 556, 231–241. <https://doi.org/10.1016/j.scitotenv.2016.03.02>
- Scialabba, N. E. H., & Müller-Lindenlauf, M. (2010). Organic agriculture and climate change. *Renewable Agriculture and Food Systems*, 25(2), 158-169.
- Tawiah, A. (2015). *2014 - 2015 Cocoa Commodity Report*, 1–16. Retrieved from: <https://www.modernghana.com/print/621813/1/2014?2015?cocoa?commodity?report.html>
- United Nations Framework Convention on Climate Change (2007). *Climate Change Impact, Vulnerability, and Adaptation in Developing Countries*. UNFCCC Secretariat, Martin-Luther-King-Street 8, 53175 Bonn, Germany.
- Verbeek, M. J. C. M. (2004). *A Guide to Modern Econometrics, 2nd Edition*. Chichester, England Hoboken: John Wiley and Sons Ltd.
- Witjaksono, J. (2016). Cocoa Farming System in Indonesia and Its Sustainability Under Climate Change. *Agriculture, Forestry and Fisheries*, 5(5), 170–180. <https://doi.org/10.11648/j.aff.20160505.15>
- Woodridge, M. J. (2003). *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: The MIT Press. Massachusetts London, England.

APPENDICES

Appendix 3.1:

Climate Variability and Cocoa Production: The Implications of Micro-Adaptation Measures on Cocoa Farmers' Income

Farmer Questionnaire

I am an MPhil second year student of the University of Ghana pursuing a Master of Philosophy degree in Climate Change and Sustainable Development and I am conducting a research on “**Climate Variability and Cocoa Production: The Implications of Micro-Adaption Measures on Cocoa Farmers' Income**”. In view of this, I humbly request that you fill this questionnaire to aid in my data collection.

Please, any information you will give is strictly confidential and will not be given to a third party.

A. BACKGROUND INFORMATION

1. Sex..... (a) Male (b) Female
2. Age..... (a) 30-39years (b) 40-49years
(c) 50-59years (d) 60years and above
3. Level of education..... (a) Primary (b) JHS (c) SHS
(d) O-Level (e) Tertiary (f) Non-formal
4. How many dependents do you have in your house?
5. How many years have you been farming? (a) 1-5years (b) 6-10years
(c) 11-15years (d) 16-20years (e) 21-25years (f) 26 years and above (Specify).....
6. Who is the owner of the land you are farming on?
- (a) Myself (b) Family (c) A friend (d) Am renting

7. How old is your farm? (a) 1-10years (b) 11-20years
(c) 21-30years (d) 31-40years (e) 41-50years (f) 51years and
above (Specify).....
8. What type of farming practice are you engaged in?.....
(a) Mixed cropping (b) Monocropping
9. What is your farm size?.....
10. What cocoa variety do you grow?.....
11. What type of labour is employed?..... (a) Family (b) hired
labourers
(c) both family and hired labourers
12. What kind of inputs do you use for your farming?
.....
.....

B. KNOWLEDGE AND TREND OF CLIMATE VARIABILITY

13. Have you heard of climate variability and change before? ... (a) Yes (b) No
14. If yes, how did you hear about it?..... (a) Extension officers (b) Friends
(c) Radio (d) Fellow farmers (e) Farmers Association (f) Other (Specify)
.....
15. Have you realized any variability in the weather patterns of this area?
(a) Yes (b) No
16. For how long have you realized these changes in the weather?
(a) 1-5years (b) 6-10years (c) 11-15years (d) 16-20years (e) 21years &
above
17. What climatic variables have you realized these changes in for this
period?..... (a) Temperature (b) Rainfall (c) Sunshine amount

18. What kind of changes have you observed in the climate variables?

(a) Temperature: (I) Increased (II) Decreased

(b) Rainfall: (I) Increased (II) Decreased

(d) Sunshine amount: (I) Increased (II) Decreased

19. What do you think could be the cause of this variability in the climate in the

area?..... (a) Cutting down of trees (b) Burning of firewood (c) Land

degradation (d) God's punishment to humankind (e) caused by nature or

God (f) Other (specify)

20. Have you ever received any expert advice from any stakeholders of agriculture

(such as MoFA) on the effects of this variability on your cocoa farming?

(a) Yes (b) No

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

you?.....

C. IMPACTS OF CLIMATE VARIABILITY ON COCOA PRODUCTION

21. What impacts of climate variability have you observed on your cocoa

farm?..... (a) Delay in the maturity of cocoa beans (b) Resistance of

pest and diseases to pesticides (c) Occurrence of unfamiliar pest and

diseases on the farm (d) Reduction in quality of cocoa beans (e) dying off of

cocoa trees (f) Other (Specify).....

22. Have these impacts affected your cocoa yields over the past 10years?

(a) Yes (b) No

23. What changes in yield have you observed with this impacts on your cocoa

farm? ... (a) Increased cocoa yield (b) Decreased cocoa yield (c) No

change in cocoa yield

24. What other factors apart from the direct effects of variability in the climatic variables affect your cocoa yields? (a) Increases in pest and disease (b) Difficulty in weed control (c) Wildfires (d) Inability to effectively spray cocoa farms (e) Inadequate fertilizer application Other (Specify)...

.....

D. COPING AND ADAPTATION MEASURES

25. Do you know about adaptation measures used by cocoa farmer?.....

(a) Yes (b) No

If yes, what do know about adaptation

.....

.....

26. Do you use these adaptation measures?..... (a) Yes (b) No

27. Which among these adaptation measures do you used for the past 4 years on your cocoa farm?.....

NO	MICRO-ADAPTATION	YES	NO	DON'T KNOW
1	Adoption of improved cocoa variety			
2	Increased and more frequently spraying of the cocoa farm			
3	Increased use of fertilizer			
4	Change of type of fertilizer and pesticides used on farm			
5	Increasing of farm size			
6	Income diversification through non-farm activity			
7	Mixed cropping cocoa with other crops			

8	Planting shading trees or plants as protective cover for seedlings			
9	Creating of fire belt around cocoa farms			
10	Use of manure and compost			
11	Migrating to different sites			
12	Adjusting practices such as weeding, planting, and harvesting			
13	Other (Specify)_____			

28. How did you hear about your choice of adaptation?.....

- (a) Extension officers (b) Friends (c) Radio (d) Fellow farmers
 (e) Farmers Association (f) Other (Specify).....

29. In general, how long have you been using these adaptation measures?

.....

30. Why have you kept on using the selected adaptation measures for this period?

.....

31. Do you have in mind of changing these adaptation measures?.....

- (a) Yes (b) No

32. Why?

.....

33. Do you sometimes face some challenges in implementing these adaptation measures? (a) Yes (b) No

If yes, what are these challenges?

.....

.....
.....

34. If NO to all the measures above, what has been your constraint to the adoption of any of these measures?..... (a) Traditional belief (b) Lack of information on climate variability and adaptation (c) Lack of finance to help cope with changes in the climate (d) Lack of labour force (e) Other (Specify).....

E. EFFECTS OF ADAPTATION MEASURES ON FARMERS INCOME

35. How have your selected adaptation measures affected your income since the year 2013? (a) Increased farm income (b) Decreased farm income (c) No change in farm income

36. How many bags or bottles of fertilizer did you buy in addition to what the government provided for your farm since 2013/14 growing season?..... (a) 2013/14 (b) 2014/15 (c) 2015/16

37. How many bottles of pesticide do you buy in addition to what the government provided for your farm since 2013/14 growing season?..... (a) 2013/14 (b) 2014/15 (c) 2015/16

38. On the average, how many bags of cocoa were you able to sell each season in each of the three growing seasons?..... (a) 2013/14 (b) 2014/15 (c) 2015/16

39. On the average, how much money does it cost you to use your selected adaptation options? (a) 2013/14 (b) 2014/15 (c) 2015/16

40. On the average, how much money do you get after each growing season since 2013/14?

(a) 2013/14 (b) 2014/15 (c) 2015/16

41. What are some of the challenges faced by your household as a whole in times of low-income returns from the use of these adaptation measures?

.....
.....



Appendix 4.1: Temperature, Rainfall variables and Cocoa yields in the Dormaa West District

Year	Y (MT)	Y ²	X (mm)	X ²	X*Y	K (°C)	K ²	K*Y
1991	12017	144408289	90.6	8211.4	1088940	26.3	691.7	316047.1
1992	9648	93083904	74.2	5498.2	715399.2	26.1	681.2	251812.8
1993	10586	112063396	69.6	4848.8	737138.5	26.5	702.3	280529.0
1994	8846	78251716	84.2	7089.6	744833.2	26.4	697.0	233534.4
1995	10586	112063396	98.5	9708.8	1043074	26.2	686.4	277353.2
1996	11169	124746561	91.0	8279.5	1016286	26.3	693.0	294023.9
1997	9781	95667961	77.2	5965.0	755419.2	26.5	704.7	259644.8
1998	11412	130233744	68.2	4655.8	778678.8	27.0	730.8	308508.7
1999	11502	132296004	114.5	13116.0	1317267	26.1	680.6	300058.4
2000	11244	126427536	76.8	5904.6	864007.7	26.3	692.8	295951.5
2001	9092	82664464	87.6	7665.0	796004.6	26.3	689.1	238665.0
2002	9535	90916225	110.2	12138.5	1050519	26.1	679.3	248505.9
2003	12938	167391844	92.7	8597.9	1199676	26.4	695.4	341185.8
2004	18327	335878929	87.7	7691.3	1607278	26.2	687.3	480472.9
2005	15663	245329569	91.4	8361.6	1432251	26.3	692.1	412067.4
2006	21574	465437476	91.6	8389.0	1975999	26.3	691.0	567126.5
2007	21351	455865201	113.6	12901.2	2425118	26.5	704.2	566602.2
2008	19924	396965776	95.4	9104.3	1901082	26.2	686.9	522174.8
2009	16430	269944900	93.1	8661.4	1529085	26.3	690.6	431766.7
2010	15482	239692324	108.0	11658.6	1671669	26.7	712.4	413240.4
2011	31017	962054289	207.4	43005.5	6432237	26.6	707.9	825259.0
2012	22192	492484864	126.1	15910.7	2799243	26.4	698.1	586331.1
2013	23700	561690000	96.0	9208.0	2274213	26.7	715.3	633876.3
2014	21191	449058481	102.0	10405.9	2161675	26.6	705.2	562755.9
2015	20306	412333636	136.2	18554.3	2765967	26.5	704.2	538870.5
Total	385513	6776950485.0	2483.9	265531.0	41083058	659.9	17419.6	10186364

Source: Ghana Cocoa Board and Ghana Meteorological Agency, 2016

Appendix 4.2: Results of the Spearman correlation between socio-demographic characteristics of the farmers in Dormaa West District and the kind of micro-adaptation measures they use

Variable	Adoption of improved variety	Increase and more frequently spraying of the cocoa farm	Increased use of fertilizer	Change of fertilizer and pesticide used on farm	Increasing of farm size	Off-farm income activity	Mixed cropping	Planting shading trees or plants	Creating fire belt	Use of manure and compost	Migrating to different sites
Age of respondents	-0.237	-0.022	0.009	-.265**	.247**	0.002	-0.102	-0.002	-.247**	0.111	0.082
Educational level	-0.003	0.006	-0.016	-.151*	-.215**	-.176*	-.161*	0.006	-0.132	-0.074	0.008
Years of farming	0.04	0.012	-.286**	-.281**	.367**	0.123	0.048	-.286**	-0.051	0.016	-0.067
Farm age	-0.031	-0.102	.271**	-0.037	-.208**	0.053	-.392**	0.096	.214**	0.042	0.114
Type of labour	0.126	0.057	.243**	-.160*	-.197**	.245**	0.044	-0.113	.258**	-0.032	.324**
Number of dependents	0.048	-.251**	0.076	-0.017	-0.089	0.081	-.272**	.297**	0.132	0.067	.234**
Land ownership	0.071	-.244**	.286**	.182*	-.292**	-0.018	-.211**	-0.053	0.133	.185*	.174*
farming practice	-0.131	.390**	-0.098	-.372**	-0.075	.236**	.594**	-.323**	0.026	-0.089	-0.133
Cocoa variety	-0.054	-.246**	0.06	0.092	-.180*	0.124	-.156*	0.038	.255**	.165*	0.047
Heard of climate change	-.051	-.144	.093	-.170*	-.081	.067	-.085	-.092	-.069	.155*	.121
Know about adaptation measures	-.182*	.375**	.333**	-.043	-.324**	.075	.125	.125	.384**	.064	.160*

** . Correlation is significant at the 0.01 level (2-tailed). * . Correlation is significant at the 0.05 level (2-tailed).

Appendix 4.3: Random effect balanced panel model.**a. R output: random effect model**

```

> summary(model10)
Oneway (time) effect Random Effect Model
(Swamy-Arora's transformation)

call:
plm(formula = Income ~ Age + Education + Dependents + YrsOfFarmn +
     LandOwner + FarmAge + Labor + ImprveVar + IncrseSpryn + IncrseFert +
     ChngFertType + IncrseFarmSize + NonFarmActv + MxdCropn +
     ShadTrees + FireBelt + ManureCompost + Migration + ChngFarmPrac +
     Fertilizer + Pesticide + Rainfall + MinTemp + MaxTemp + PdnCost,
     data = E, effect = "time", model = "random")

Balanced Panel: n=180, T=3, N=540

Effects:
              var   std.dev share
idiosyncratic 8.854e+05 9.409e+02   0
time          1.758e+17 4.193e+08   1
theta: 1

Residuals :
  Min. 1st Qu.  Median 3rd Qu.    Max.
-4930.0 -468.0    21.2   532.0  2780.0

Coefficients :
              Estimate Std. Error t-value Pr(>|t|)
(Intercept)  3.9081e+04  3.6419e+10  0.0000  0.999999
Age          -3.8355e+02  7.6150e+01 -5.0367  6.562e-07 ***
Education    -1.6957e+02  5.2919e+01 -3.2044  0.001437 **
Dependents   -2.4191e+02  6.0434e+01 -4.0029  7.176e-05 ***
YrsOfFarmn   5.0794e+02  4.8360e+01 10.5035 < 2.2e-16 ***
Landowner    -4.1823e+02  7.2362e+01 -5.7796  1.298e-08 ***
FarmAge       6.5320e+01  5.1036e+01  1.2799  0.201157
Labor        2.0714e+02  2.5180e+01  8.2264  1.587e-15 ***
ImprveVar    2.3202e+03  2.4361e+02  9.5245 < 2.2e-16 ***
IncrseSpryn  1.1230e+03  1.1844e+02  9.4815 < 2.2e-16 ***
IncrseFert    4.1492e+00  1.4339e+02  0.0289  0.976926
ChngFertType -1.3477e+03  1.2505e+02 -10.7774 < 2.2e-16 ***
IncrseFarmSize 4.9556e+02  1.6327e+02  3.0353  0.002525 **
NonFarmActv  -1.4496e+03  1.7687e+02 -8.1958  1.988e-15 ***
MxdCropn     -1.4970e+02  2.1481e+02 -0.6969  0.486189
ShadTrees    1.2775e+02  1.0073e+02  1.2682  0.205295
FireBelt     1.8678e+02  1.8637e+02  1.0022  0.316712
ManureCompost 6.5503e+02  1.2375e+02  5.2933  1.781e-07 ***
Migration    2.5309e+02  1.6996e+02  1.4891  0.137062
ChngFarmPrac 2.1964e+03  1.3641e+02 16.1022 < 2.2e-16 ***
Fertilizer   -2.8010e+02  3.9157e+01 -7.1534  2.924e-12 ***
Pesticide    -4.5132e+01  3.7991e+01 -1.1880  0.235388
Rainfall     -1.2191e+01  2.9476e+07  0.0000  1.000000
MinTemp     -1.2352e+03  1.0605e+09  0.0000  0.999999
PdnCost      1.8566e+00  4.1057e-01  4.5220  7.611e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Total Sum of Squares: 1703900000
Residual Sum of Squares: 453310000
R-Squared: 0.73395
Adj. R-Squared: 0.72155
F-statistic: 59.1975 on 24 and 515 DF, p-value: < 2.22e-16

```

b. R output: Breusch-Pagan test of individual heterogeneity among the farmers

studentized Breusch-Pagan test

```
data: bp  
BP = 165.5, df = 25, p-value < 2.2e-16
```

c. R output: Hausman test for comparing fixed effect and random effect models

Hausman Test

```
data: Income ~ Age + Education + Dependents + YrsOfFarmn + LandOwner + ...  
chisq = 1.0799e-12, df = 22, p-value = 1  
alternative hypothesis: one model is inconsistent
```

