IMPACT OF RAINFALL PATTERN ON COCOA YIELD IN MAMPONG COCOA DISTRICT IN THE ASHANTI REGION

BY

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DECLARATION

I hereby declare that this thesis is the results of my own work output and that no part has been presented elsewhere for another degree or previously published by any other person for the award of any academic reward in any university, except where due acknowledgment has been made from this or in other studies.

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ABSTRACT

This study sought to examine the impact of rainfall pattern on cocoa yield in Mampong Cocoa District covering total land area (hectres) of 782km^2 with 69 settlements in the Ashanti Region. Longitudinal research design was adopted for the study's data collection and analysis. Time series secondary data was employed to engage in quantitative analysis. The study adopted Auto Regressive Distributed Lag (ARDL) models to examine both short run (S-RN) and long run (L-RN) impact of rainfall and temperature patterns on cocoa yield over a period of 13 years (from 2003 to 2016). Pixel values for temperature were obtained from Landsat 7 Thermal Band, while rainfall values were gathered from CHIRPS. In addition, data on cocoa yield were gathered from Ghana COCOBOD's (2018) annual reports. The data were grouped in Microsoft Excel 2013, while Stata version 14 was used for the data analysis. The study found a significant L-RN (positive) relationship among change in cocoa yield and change in anRF and change in annual temperature (ΔanTmP) in the Mampong Cocoa District over time. However, both change in annual rainfall (ΔanRF) and change in anTmP have insignificant effect on change in annual cocoa yield in the S-RN period. It was therefore recommended that policies, programmes and interventions of the government and other stakeholder in the cocoa sector that would rely on rainfall and temperature pattern should be targeted for long term periods instead of short term. This is so because L-RN impact of rainfall and temperature on cocoa yield is highly significant; while the S-RN impact of rainfall and temperature cocoa yield is insignificant.

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DEDICATION

I dedicate this work to my dearest husband, Mr. Percy Offei.

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GLOSSORY OF TERMS/SYMBOLS

ADF	Augmented Dickey Fuller
ÆşƤĐ	Adjustment error correction coefficient
AnRF	Annual rainfall
AnTmP	Annual temperature
ARDL	Auto Regressive Distributed Lag
CIAT	Centre for Tropical Agriculture
CIAT	Centro Internacional de Agricultura Tropical
CUSUM	Cumulative Sum
FAOStat	Food and Agriculture Organization Statistics
GAIN	Global Agricultural Information Network
GDP	Gross Domestic Product
ICCO	International Cocoa Organization
IITA	Institute of International Tropical Agriculture
L1	Lag one/previous year interval of one
L-RN	Long run
MnTmP	Minimum temperature
MT	Metric Tons
MxTmP	Maximum temperature
OLS	Ordinary Least Square

S-RN	Short run
Δ	Change
ΔanCYLD	Change in annual cocoa yield
ΔanRF	Change in annual rainfall
ΔanTmP	Change in annual temperature
ΔMnRF	Change in minimum rainfall
ΔMnTmP	Change in minimum temperature
ΔMxRF	Change in maximum rainfall
ΔMxTmP	Change in maximum temperature

CHAPTER ONE: INTRODUCTION

1.0 Background to the Study

Globally, the available data show that yearly supply of cocoa has, for the past ten years, increased about twice, attaining about 3.6 million tonnes particularly from 2009-2010, but such an improvement is concentrated in a few cocoa producing countries (Kozicka, Tacconi, Horna & Gotor, 2018). ICCO (2018) also reports that global cocoa production increased significantly in the previous years. Thus cocoa production by Côte d'Ivôire alone in 2016/2017 was 600,000 tonnes higher than just three years before, while Ghana also recorded approximately 200,000 tonnes within the same period. Côte d'Ivôire and Ghana alone supply the highest proportion of world cocoa, making the two countries the leading producers of cocoa beans in the world (Asamoah & Owusu-Ansah, 2017; Camargo & Nhantumbo, 2016; Kroeger, Bakhtary, Haupt & Streck, 2017). Thus Ghana and Cote d'Ivoire alone account for more than 60 percent of global cocoa supply (World Bank Group, 2018).

Several prior studies (Asamoah & Owusu-Ansah, 2017; ICCO, 2018; Kozicka *et al*., 2018; USAID, 2017), cocoa serves as food and at the same time considered as an industrial crop which plays significant role in poverty reduction of poor countries in the tropical regions of the world. Even though cocoa is not seen as primary food or food-safety crop, production and export of cocoa are largely done by only a few farmers in some developing countries, particularly in Africa, Latin America, Asia and Oceania (Aboud & Şahinli, 2019; Kozicka *et al*., 2018) and that those farmers continue to remain in the poverty cycle. The study by Poelmans and Swinnen (2016) show that farmers who hold between 1 to 10 hectres of land cultivate a little higher than 90 percent of the estimated overall cocoa supply across the globe.

Other studies by International Cocoa Organization–ICCO (2013) and Food and Agriculture Organization Statistics–FAOStat (2018) have also estimated that a little over 5 million to about 6 million growers from Africa, Latin America, Asia and Oceania produce cocoa. Factually, the usual territory for cultivating cocoa trees is focused among the countries occupied in a belt between latitudes 10°N and 10°S because of their requirement for suitable climate dynamics, such as conducive temperatures, sufficient rainfall, right amount of moisture which can be managed by professional pollinators (ICCO, 2013).

Other prior studies (Fountain & Huetz-Adams, 2018; Kozicka *et al.*, 2018; World Bank Group, 2018) have recounted that on yearly basis, the value of finished product of cocoa such as chocolate, accrue billions of dollars, giving substantially great economic reward for cocoa-producing communities and for local and multi-national companies across the world. In 2013, for instance, FAOStat (2018) reported that tons of cocoa beans estimated at 4.6 million were produced in over 50 countries on roughly 10 million hectres of land with an overall export valued at US$ 15 billion. Cocoa, considered as cash crop, has enormous economic benefits, but such financial gains generated by the sector do not necessarily get down to those who produce the cocoa. Thus the ordinary cocoa farmer from the tropical regions, according to Hütz-Adams *et al*. (2016), remains poor, middle aged, and holds a meagre acreage of overaged cocoa farm.

Currently, the countries that produce cocoa across the world and ranked as the top cocoa suppliers include; Côte d'Ivoire, Ghana Cameroon and Nigeria in West Africa; Ecuador, Brazil, Peru, the Dominican Republic and Colombia in Latin America and Indonesia in South East Asia; and (Kozicka *et al.*, 2018). The records show that Côte d'Ivoire and Ghana remain the leading countries in the world that produce and export a larger proportion of cocoa than the remaining countries. Since 2017 to date the

Governments of Ghana and Cote d'Ivoire have set up a Joint Cocoa Commission to align and reform cocoa policies and programmes in the two countries classified as world's two leading cocoa producing countries (Fountain & Huetz-Adams, 2018).

As part of its report in 2011, the Centre for Tropical Agriculture (CIAT) forecasted that by 2030, the yearly maximum and minimum temperature in Ghana will rise which would have the tendency to reduce the current land cover for cocoa cultivation. Globally, Ghana is cited (Asante-Poku & Angelucci, 2013), in cocoa production ranking, as the third principal supplier and the second biggest exporter of cocoa beans after Cote d'Ivoire. Based on Ghana and Cote d'Ivoire's position in the cocoa industry, Aboud and Şahinli's (2019) SWOT analysis presents that opportunities provided within both internal and external environment could be capitalized by both Cote d'Ivoire and Ghana to enhance cocoa production in the cocoa industry.

Prior study (Global Agricultural Information Network-GAIN, 2012) has observed from available data which show that between the years 2010 and 2011, exports of cocoa from Ghana reached 1.4 million metric tons. In addition, recent statistics show that with regards to the global export of cocoa, Ghana has sustained its performance as the second largest exporter (in terms of quantity) of quality cocoa beans produced and exported between the periods of 2005 and 2011 (Asante-Poku & Angelucci, 2013). Indeed, Ghana's average yearly coco output over the last 30 years (330 kg/ha) is cited (Gockowski, 2007; Vigneri, 2007) among the lowest in the world and compares unfavorably to leading producers such as Cote d'Ivoire (580 kg/ha) and Indonesia (770 kg/ha). Low productivity translates to low incomes for cocoa farming households (Hainmueller *et al*., 2011). The Chief Executive Officer of Ghana Cocoa Board, Mr. Joseph Boahen Aidoo, as reported by Business and Financial Times (2019), has revealed that approximately 40 percent of the total 1.6million hectares of cocoa farms is unproductive – leaving the industry to rely on only 60 percent.

In spite of the myriad challenges like expensive inputs, poor infrastructure, reduced soil fertility, poor quality of cocoa seed that the leading cocoa-producing countries face, it is projected that they would constantly remain in the top position for a very long time. This is so because Côte d'Ivoire alone accounts for 33 percent of the cocoa production worldwide (FAOStat, 2018). Ghana also produces cocoa beans, with average total annual output of around 800,000 metric tonnes currently (USAID, 2017). Such improvement has largely attributed to Ghana's growth in the cocoa industry, which made positive gains to increase cocoa beans by about 269,000 tons. Cocoa producers in Central and Western cocoa growing regions of Africa now contribute to more than two-thirds of worldwide production of cocoa. The ICCO (2010) forecasted that yearly international cocoa production was expected to reach approximately 4.5 million tons by 2013. Conclusively, this production improvement is expected to be mainly come from West Africa countries (ICCO, 2008). Between 2009 and 2010, Ghana maintained its second largest position as a cocoa producer after a country like Cote d'Ivoire, constituting 21 percent of worldwide cocoa supply (World Cocoa Foundation, 2010).

More so, in Ghana, available data (Wessel & Quist-Wessel, 2015) show that within 19 years (1995-2014), production of cocoa has progressively increased from approximately 300,000 tonnes to 900,000 tonnes. The study of Asante-Poku and Angelucci (2013) indicates that the key contributing factors that accounted for the rise in cocoa production in Ghana was the support measures that were out in place by the COCOBOD which happens to be the state-owned cocoa marketing board. The specific measures that were put in place to boost cocoa production include ready market price increase, the coming in of free disease and pest control policy, the introduction of subsidized hybrid beans, free and subsidized fertilizers, fungicides and insecticides as well as modern marketing services and the rehabilitation of cocoa roads in the communities where cocoa cultivation is done on the large scale (Asante-Poku & Angelucci, 2013). Another critical project that was also carried out was the extension of fertile land appropriate for cocoa in the growing area, particularly in the Western Region of Ghana. FAOStat (2015) reported that the cultivation zone expanded from 1.0 million hectres to 1.6 million hectres within ten years (i.e. 1995 to 2010). The expansion of the land cover for cocoa production has contributed largely to greatest deforestation it the forest belts across the country.

The study carried out by Institute of Statistical, Social and Economic Research-ISSER (2014) indicates that cocoa continues to be a major player, and a major foreign exchange earner for Ghana's economy contributing 2.2% of the agricultural sector's share to GDP. In addition, cocoa supports the livelihood of over 800,000 farm families in Ghana and millions of others along the cocoa value chain (USAID, 2017). The significance of cocoa production in Ghana's local economy cannot be underestimated. For instance, Bank of Ghana (2011) reported that the cocoa industry contributed over 9 percent of the country's overall GDP in the Agricultural sector.

In addition, in their estimation, Anim-Kwapong and Frimpong (2004) reported that the cocoa industry alone provide livelihood support to more than 800,000 smallholder households and the section of the society who relied largely on cocoa for a sizeable portion of their livelihood. It is also on record that the cultivation of cocoa in Ghana is focused exclusively on the forest regions/belt of the country, stretching from Ashanti Region to other regions such as the then Brong-Ahafo Region, Central Region, Eastern Region, Western Region, and Volta Region. These regions are mentioned (Anim-

Kwapong & Frimpong, 2004) as specific areas with suitable climatic conditions required for large-scale cocoa production, which come over with improved exports and accompanying foreign exchange paychecks which have been on the increase in recent times.

For instance, of the estimated 632,000 metric tons (MT) of beans of cocoa supplied in 2009-2010, Ghana shipped over a 50 percent of a million which stood at approximately 566, 700 MT of real beans of cocoa. These were transported to more than 25 countries across the world. ICCO (2010) also reported that this inroads positioned Ghana to be one of the greatest provider of quality cocoa beans, which was next to Cote d'Ivoire. These shipping of cocoa to other part of the world brought in over six billion United States Dollars (US$1.66m) in foreign exchange and constituted closely 21 percent of total commodities exports within the period (Bank of Ghana, 2011).

Relative to the records of other cocoa producing countries worldwide, it is estimated that more than 90 percent of cocoa produced in Ghana is cultivated on insufficient farmland (COCOBOD, 2012). In addition, Ghana COCOBOD (2012) has reported that cocoa production in Ghana is carried out in six out of the ten regions of Ghana with the Western Region having the highest production value which accounts for more that 50 percent of total production in the country. This is followed by the Ashanti Region, which also accounts for about 16 percent of total cocoa production. The summation of both Eastern Region and Brong Ahafo Regions cocoa production values account for about 19 percent of total production produced in Ghana (COCOBOD, 2012). Cocoa production typically requires anRF levels of about 1250 mm – 3000 mm, although levels of 1500 mm – 3000 mm are preferred (Institute of International Tropical Agriculture- IITA, 2009). Adequate temperature levels range from a minimum of 18-21^{o}C and a maximum of 30 – 32 ^{o}C (IITA, 2009). In Ghana, cocoa production as such typically takes place in the rain forest, deciduous forest and transitional zones (Asante-Poku & Angelucci, 2013).

1.1 Statement of the Problem

Recent statistics show that cocoa is one of cash crops that remains the highest foreign exchange earner for Ghana's commodities export, constituting 8.2 percent of the country's GDP, and it also accounted for 30 percent of total export earnings in 2010 (GAIN, 2012). In spite of these tremendous achievements in the cocoa sector, the recorded cocoa yield in Ghana, on the average, is approximately 25 percent less than the estimated average production level of the first 10 largest cocoa producing countries in the world, and closely 40 percent less than the average production level of the neighbouring Côte d'Ivoire respectively (Mohammed *et al*., 2011).

A number of factors are attributed to Ghana's low yields. Among the notable ones include, unpredictable rainfall pattern, pests and diseases such as black pod and mistletoes, the relatively old age of Ghana's cocoa trees, low investments into cocoa farming by both the state and individual farmers, as well as the absence of widespread row planting method (Mohammed *et al*, 2011). In an attempt by a numbers of researchers to delve into issues pertaining to Ghana's cocoa sector, several studies have been carried out from different perspectives. As observed by Owusu-Ansah (2016) in his study, climatic factors such as rainfall, temperature, sunshine, humidity, soil moisture and wind influence the level cocoa production in Ghana.

Wessel and Quist-Wessel (2015) have also observed from their study's findings that the average cocoa yields in Ghana remain low because the majority of farmlands producing the cocoa are old and extensive methods of cultivation are usually used in all farming activities. In this regard, farmers in cocoa growing areas wish to increase their cocoa output by establishing new farms specifically in the forest zones. The farmers' quest for new land has led to large-scale deforestation in the two leading producers of cocoa in Ghana and Côte d'Ivoire (Wessel & Quist-Wessel, 2015). Presently, little land is available for the expansion of the cocoa in the cocoa production areas in Ghana. Meanwhile, a further increase in production has to come from an increase in yield of the existing mature trees and the replanting of old unproductive cocoa farms. Several studies (Asare *et al*., 2010b; Wessel & Quist-Wessel, 2015; Asare *et al*., 2018a) have shown that majority of the cocoa producing countries in Africa have almost similar causes of low yield in their cocoa production.

Furthermore, Aikpokpodion and Adeogun (2011) have also identified that lack of access to improved planting materials has resulted in low yields of cocoa in Ghana. Additionally, the use of farmer-produced cocoa seeds has somewhat affected cocoa yields due to poor genetic and physical qualities of such cocoa seeds as well as the seeds' susceptibility to severe pests and disease infestation (Asare *et al*., 2010b). The study of Asare *et al*. (2018a) focused on cocoa farmers' access to improved hybrid seeds in Ghana; their implications for establishment and rehabilitation of cocoa farms. The objective of their study was to determine the socio-cultural factors that affect field performance of improved hybrid cocoa seeds in Ghana. A study by Owusu-Ansah (2016) was specifically carried out in the Asante Mampong Cocoa District in the Ashanti Region to the assessment of storage facilities for cocoa beans. From these plethora of studies carried out by different researchers, one common gap was identified which needs to be filled: data on the extent to which geographical variables such as rainfall and temperature affect cocoa yields is either scanty or nonexistent. It is against this background that this study sought to examine the impact of rainfall pattern on cocoa yields in the Mampong Cocoa District in the Ashanti Region of Ghana.

1.2 Aim and Objectives of the Study

The general objective of the study was to assess the impact of rainfall pattern on cocoa yields in Mampong Cocoa District in the Ashanti Region.

In order to achieve this aim, the following specific objectives were considered:

1. To analyze the long-run (L-RN) and short-run (S-RN) relationship between cocoa yield and annual rainfall (anRF) and annual temperature (anTmP) in the Mampong Cocoa District.
2. To examine the L-RN and S-RN relationship between cocoa yield and maximum rainfall (MxRF) and minimum temperature (MnTmP) in the Mampong Cocoa District.
3. To analyze the L-RN and S-RN relationship between cocoa yield and maximum temperature (MxTmP) and MnRF in the Mampong Cocoa District.
4. To test ARDL models' stability for predicting cocoa yield, using anRF, anTmP, MnRF and MxRF and MnTmP and MxTmP.

1.3 Research Hypothesis

Based on the specific objectives, the following hypotheses [Null (H_0) and alternative (H_1)] were tested:

1. **Ho:** There is no significant L-RN and S-RN relationship between cocoa yield and anRF and anTmP in the Mampong Cocoa District.

   H_1: There is a significant L-RN and S-RN relationship between cocoa yield and anRF and anTmP in the Mampong Cocoa District.
2. **Ho:** There is no significant L-RN and S-RN relationship between cocoa yield and MxRF and MnTmP in the Mampong Cocoa District.

H_1: There is a significant L-RN and S-RN relationship between cocoa yield and MxRF and MnTmP in the Mampong Cocoa District.

3. **Ho:** There is no significant L-RN and S-RN relationship between cocoa yield and MxTmP and MnRF in the Mampong Cocoa District.

   H_1: There is a significant L-RN and S-RN relationship between cocoa yield and MxTmP and MnRF in the Mampong Cocoa District.

4. **Ho:** There is coefficient instability in the error correction (ARDL) models employed to examine the impact of rainfall and temperature patterns on cocoa yield.

   H_1: There is coefficient stability in the error correction (ARDL) models employed to examine the impact of rainfall and temperature patterns on cocoa yield.

1.4 Significance of the Study

To begin with, findings from the study will provide policy makers players in the cocoa industry empirical evidence regarding relationship between rainfall pattern and cocoa yield. Thus the study will serve as policy direction to the key stakeholders such as Ghana COCOBOD and Quality Control Division in the cocoa sector. The models used in this study will serves as predictive tool that can be adopted or adapted by research analysts to forecast cocoa yields in Mampong Cocoa Districts and to the larger extent other cocoa growing areas in Ghana. The study is also expected to provide a deeper insight for the stakeholders in the cocoa industry to develop a well-informed strategies aimed at improving cocoa yields in the Mampong Cocoa Districts and even beyond. The study findings will also contribute to the academic literature on the between cocoa yields and geographical variables such rainfall, temperature, topography and land size.

1.4.1 Scope of the Study

The study was conducted in the Mampong Cocoa District in the Ashanti Region. Secondary data covering the period of thirteen (13) years (2003-2016) were obtained from Ghana COCOBOD, CHIRPS and Landsat 7 Thermal Band. The major concepts and variables of the study were limited to rainfall pattern and cocoa yields. However, other geographical variables such rainfall (minimum and maximum) and temperature (minimum and maximum) were incorporated in the models used in the study to predict cocoa yield in the Mampong Cocoa District in both long-run and short-run periods.

1.4.2 Organization of the Study

In terms of structure, the study was properly arranged into five chapters. Chapter one highlights the introductory aspect of the study. It highlights the study's background, the statement of the problem, the objectives and the research questions of the study. Other aspects of the introductory chapter are the scope of the study, the significance of the study, the limitations and the operational definition of terms. The next aspect, Chapter two focuses on the theoretical and empirical literature relevant to the study. Chapter three is devoted to the research methodology. Chapter four tackles data collection, analysis and discussion of the results. Chapter five being the final chapter summarizes the key findings, and presents the conclusions and recommendations based on the study's objectives as well as suggestions for further research.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

A number of researchers (Cooper, 2010; Marshall & Rossman, 2011), have explain that literature review links research studies to both previous and current dialogues in the literature, by bridging in possible gaps. In this regard, literature review provides a background for establishing the significance of a study, and also set benchmark for examining and comparing the results with other studies' findings. On the basis of that the first section of the chapter focuses on the review of concepts and theoretical framework that are relevant to the objectives of the study. The second section incorporated empirical studies to ascertain the gap in the problem under investigation. The last section of this chapter took into account the conceptual discussion aimed at providing the framework for the variables and concepts used in the study.

2.1 Historical Background of Cocoa Production in Ghana

Cocoa is one of the major cash crops in Ghana which gives approximately one-third of all send out inflows created into the nation. Agreeing to Sarpong *et al*. (2013) the cocoa industry in Ghana is seen as a major source of salary to agriculturists and other nearby trade people who locked in in both inside and outside exchange, transportation, and preparing of cocoa of cocoa beans. Records appear that there has been a noteworthy development in cocoa generation since the primary shipment of tons of cocoa from the shores of Ghana, which was once in the past known as the Gold Coast in 1885. As time went by, the volume of cocoa exported expanded quickly to 20,000 metric tons in 1908, and by 1911 Ghana was the worlds' driving cocoa maker, with 41,000 metric tons (Sarpong *et al*., 2013). The available records further appear that within the early 1920's, Ghana delivered between 165,000–213,000 metric tons, speaking to approximately 40 percent of the entire world yield. In 2009, be that as it may, the volume of cocoa delivered in Ghana, had shot up to 711, 000, which was approximately 14 percent of the entire world yield (Tutu, 2009).

In later times, report from Ghana COCOBOD shows that Ghana has recorded an exceptional volume of the supply of over one million metric tons in 2011. Indeed so, there is a requirement for continuous enhancement within the segment and the Government of Ghana (GoG) is committed to securing long run benefit and supportability of the cocoa supply chain. In compatibility of that, GoG has made sensible speculations in rebuilding the industry, making strides efficiency (World Bank, 2012). The most regular smallholder cocoa farms were to a great extent built up within the southeast. Ever since, the epicenter of generation has slowly moved to the west. By the early 1980s, the Ashanti Locale and Brong Ahafo Locale accounted for 35.5 percent and 18.5 percent, individually, of add up to yield. Nowadays, the Western Locale alone supplies more than half (56.5%) of the whole yearly cocoa trim. There are a few drivers behind this progressive westbound move.

To begin with, the most reasonable farmlands appropriate for cocoa generation in Ghana are generally constrained to the relatively high precipitation, within woody area that extend over the country's southern coastal zones (Ghana COCOBOD, 2012; World Bank, 2012). Besides, planters in the past found it much less demanding to forsake their ranches when their trees had gone past their profitable lifecycle in favour of clearing unused, virgin woody zones meant for farming activities. Before the recent times, the Western Region of Ghana signaled novice and on-the-move smallholder farmers with sufficient farmland that presented perfect conditions for cultivation of cocoa. This exercise reduced farmers' zeal to engage in big time cultivation, and it led to indiscriminate cutting down of trees and misfortune of biodiversity. In fact, improvement in supply of cocoa, up to date, were generally as a result of expansion of farmland instead of a well-managed crops or utilization of fertilizer (Sarpong *et al*., 2013).

On the whole, Ghana's cocoa generation regions gets adequate precipitation and supply of cocoa has not been opened to harmattan pressures. Be that as it may, the Harmattan winds are closely checked by the specialists within the cocoa industry as there does show up to be a causal connect between seriousness of Harmattan winds and cocoa yields and quality. Whereas numerous more seasoned smallholder farmers anticipated hardships coming about from the 1982-83 dry period, cocoa planters in their entirety recommended for improved subsidies but did not positioned themselves to take advantage of the situation. The early 1980s dry spell influenced various areas, but perhaps most severely, within the north. The overall losses in cocoa crops could not signal any critical impact even in the unexpected year of drought. Nonetheless, numerous climate variations recreated models forecast that cocoa production would be lost through unfavorable weather-conditions and this might in the long run lead to a significant increase within the foreseeable future (World Bank, 2012).

The World Bank (2017) evaluated that Ghana's major foreign exchange crop, cocoa, recorded between 20-25 percent of add up to outside trade profit. Thus Ghana contributes to about 20 percent of global cocoa exports and has good standing internationally for her high quality cocoa beans (which takes about 3 to 5 percent market premium). More importantly, Ghana is also known for its capacity to supply on forward, cocoa deals with little counterpart risk to buyers (World Bank, 2017). According to Suigoshi (2019), cocoa is the second largest export of Ghana after gold, and constitute approximately 15 percent of the country's export value. However, such important cash crop is not being cultivated by large scale farmers. Thus peasant farmers with little or no modern farming skills have been in charge in the production of cocoa in Ghana since its colonial era (Suigoshi, 2019).

Cocoa is predominant in the forest regions of Ghana. However, some people in the savanna belt engage in cocoa production as agricultural labour to earn income. Ghana traces it cocoa history to one of its legend and patriot, Tetteh Quarshie, who was said to have brought the cocoa seed to Ghana from Fernão do Pó in 1876. The first cocoa cultivation began in 1879, and the first export of cocoa beans was carried out in 1891 (Dickson, 1969). The price of cocoa started rising during this period after slave trade was eventually abolished in 1807. Some cash crops, including oil palm, cocoa and coffee were recognized as tradable commodities which were produced in larger quantities to replace the slave trade (Suigoshi, 2019).

In the cocoa cultivation business, whereas the people in the forest regions own large proportion of farmland, those in the savanna regions who migrate to the forest areas need to have sufficient capital to purchase or rent farmland or engage in the "abusa" or "abunu" (i.e. farm is divided into two or three) contract where land owners usually permit them to cultivate their subsistence crops on cocoa farmland (Suigoshi, 2019). This type of contract system led to the migration of the savanna people to southern forest regions and directly boosted the large scale production of cocoa in and around 20th Century (Kolavalli & Vigneri, 2011).

2.2 Prediction of the possible difficulties of the cocoa sector in the L-RN

Based on accessible information on climate variation, induction is being made that within the more far off future the West African position on the world cocoa showcase is uncertain. A study on end of the climate in West Africa (CIAT-Centro Internacional de Agricultura Tropical, 2011) predicts an increment in temperature which has the tendency to decrease the measure of the current cocoa developing area in Ghana and in Côte d'Ivoire. Within the range that will stay reasonable for cocoa generation, agriculturists ought to adjust their agronomic administration and present day cultivating hones to meet the unused conditions.

According to UNICEF (2014), the projected doubling of the West African population in the next 35 years and the development of large urban centres such as Abidjan, Accra and Lagos in the southern of the cocoa growing areas, are likely to result in a greater demand for food and higher food prices, which may shift farmers attention from cocoa production to food production.

Both climatic variation and population growth underline the necessity to produce more cocoa on less land. Another possible scenario has to do with the aspect of the rural-urban migration which is likely to lead to shortage of farm labour and migration of the future generation of cocoa farmers (Asare *et al*., 2018a).

2.3 Prospects for future Cocoa Production

The Universal Cocoa Organization (ICCO, 2014) predicts a 10 percent rise within the world cocoa generation and a 25 percent increment of the cocoa cost within the next 10 years ahead. Based on this expectation, the entire cocoa supply is anticipated to be around 4,700,000 tons in 2022-2023, with a supply shortage of 100,000 tons (ICCO, 2014). Recommendation is made by Wessel and Quist-Wessel (2015) that in case cocoa creating nations within the West Africa wish to maintain its current world advertised share of 10 percent increment in cocoa generation is required inside the another ten years' time. It is on record that whereas the past development of the farm attain contributed to an increment in generation, at show times, more cocoa has got to come from a better yields per hectare gotten from mechanized cultivating practices (ICCO, 2014).

In expansion, on-farm tests have appeared that with suitable cultivate upkeep and legitimate chemical inputs, evaluation is made and conclusion drawn that 50 to 100 percent higher yields are attainable (Wessel & Quist-Wessel, 2015). Past desires of players within the cocoa industry had continuously been that an increment in cost of cocoa in past a long time leads to higher yields within the ensuing year (Wessel & Quist-Wessel, 2015).

Hence cost increment empowers ranchers to give more time and monetary assets in their cocoa ranches and in arrange to organize and progress generation capacity. Other outside variables that restrain cocoa generation are credit and credit offices, a steady input and yield conveyance framework and reasonable specialized exhortation from expansion workplaces required to invigorate development.

To overcome these imperatives, there are continuous large-scale rehabilitations and replanting ventures in Côte d'Ivoire and Ghana started by the governments of the two nations. It is acknowledged that a 10 percent higher cocoa yield from West Africa can be realized within the another ten a long time, in case agriculturists will get a reasonable share of the anticipated higher world cocoa cost and can moreover advantage from the government bolster plans (Wessel & Quist-Wessel, 2015).

2.4 Ghana COCOBOD's New Agenda

As portion of the drive to extend generation to the focused on 1.5 million metric tons within the medium-term, the Ghana Cocoa Board has presented different interventions which include counting-hand fertilization, mass trimming, and CODAPEC-HITECH intervention practices as well as motoring slicing (Business and Financial Times, 2019).

Mr. Joseph Boahen Aidoo continued by saying that the fertilization, combined with fertilizer application and the cocoa cultivation water system, to some extent, is likely to reestablish cocoa generation; including that through model fertilization, per hectare surrender of the trim is anticipated to expand cocoa growth significantly.

2.4.1 Impact of Rainfall and Temperature on Cocoa

Realistically, there has been a long time belief, based on facts, that cocoa is exceedingly delicate to variations in climatic conditions starting from morning to evening, to precipitation and introduction of water into the soil, texture of soil and atmospheric temperature as a result of great impacts on evapo-transpiration which has long-lasting coordination among the existing variables (Emmanuel, 2018). Cocoa output depend largely on environmental variables extending from different components such as precipitation, different levels of temperatures, and distribution of soil. Thus when it rains heavily within the period where the cocoa has a lot of flowers, the expected yield would eventually fall. For instance, as reported by Universal Cocoa Organization (ICCO, 2010), at least average cocoa tree requires not less than 1450mm of precipitation to flourish very well. Generally, cocoa requires sufficient precipitation, temperatures, and accurate relative humidity to attain the expected increase in production and development within the confined regions suitable (20◦ N and 20◦ S of the Equator) suitable for cocoa cultivation.

Ameyaw *et al*. (2018) have specifically estimated that every healthy cocoa trees require between 21–23 ˚C of temperatures and 1000–2500 mm of rainfall on yearly basis to attain the expected yield. In Wiah's (2017) estimation, the advancement of different cocoa types which can withstand higher temperature and relatively moderate rainfall is required, especially in the stretch of cocoa growing areas in Ghana, where moved forward climatic variety procedures are critical to maintain cocoa supply (Hutchins *et al*., 2015). According to Owusu-Ansah (2016) environmental variables such as temperature, rainfall, humidity, sun energy, wind, and moisture of soil influence production of cocoa in absolute terms. It is estimated in the report of World Cocoa Foundation (2010) that world supply of cocoa dropped from an unparalleled peak of 3.5 million tons recorded within the years 2003/2004 to 3.3 million tons in 2004/2005. It was found that the lower production in the two countries (i.e. Côte d'Ivoire and Ghana) leading cocoa producing globally accounted for the sharp fall of cocoa beans production in overall output in the international market. Thus Côte d'Ivoire and Ghana were negatively affected by weather tempted setbacks in cocoa yield which hit West Africa very hard in the era of main crop season in the latter part of the year 2004. Within this same period, the supply of cocoa in Côte d'Ivoire decreased from approximately 1.41 million tons from 2003 to 2004 to a little over one million tons between the years 2004/2005.

2.4.2 Review of other Studies

Ali (1969) happens to be one of the first researchers whose study was set to determine the general impact of rainfall on yield of cocoa. The study estimated that cocoa yields from a large-scale experiment are considered to be on ten (10) and twelve (12) sites, above the period of seven years, in the stretch of Ghana's Eastern and Ashanti Regions. The study's finding however established a direct statistically significant association between cocoa returns and the pattern of rainfall at a given time periods of years within which the study targeted.

On the contrary, the findings showed a negative relationship between cocoa output and the pattern of rainfall at other time periods (Ali, 1969). Although the study results of

Ibn-Musah *et al*. (2018) showed a negative relationship between MxRF and cocoa production, their regression coefficient of determination estimation showed that a very high weather positively affect cocoa yield and could explain approximately 45 percent of the variation in cocoa yield.

Evidence from Ibn-Musah, *et al*. (2018) empirical study data output exhibited that relatively high or maximum precipitation unfavorably deteriorates production of cocoa in normal terms. Thus cocoa yields boom when rainfall pattern is evenly disseminated and not focused on some specific months and ignoring other equally-important months with little or no rains. In addition, whereas unfavorable temperature in its maximum positively affects all other key factors that affect cocoa yields, unfavorable temperature in its minimum were found to be contributing negatively on cocoa production. However, unfavorable temperature in its minimum bring about cocoa disease like black pod which cause cocoa yield to go downward (Ibn-Musah *et al*., 2018).

Ibn-Musah *et al*. (2018) further maintained that it could be difficult to adopt cultivation period to examine and address the impact of unfavorable rainfall in its maximum on cocoa because cocoa is a perennial crop.

In that regard, creating a safe cocoa assortment that will be able to resist both extraordinary conditions will be a key in relieving extraordinary impacts on cocoa yields. Anim-Kwapong and Frimpong (2004) carried out an assessment of the effect of climate variations on cocoa generation in Ghana, employing a 30-year period climatic information and Common Circulation Models in conjunction with Basic Climate Models (SCM). In Ghana, it is projected that production in the agricultural sector would adversely be affected as a result of the expected variations in rainfall pattern and unpredictable temperature increase (Barimah *et al*., 2014).

Ibn-Musah *et al*. (2018) have reported in their study that the year-around rainfall pattern in regions where cocoa is grown in Ghana exceeds 2000mm. Also, prior studies (Anim-Kwapong & Frimpong, 2004; Stanturf *et al*, 2011) have observed that in between the months April–July and September –November, two rainfall periods are usually recorded, while from the month July to August, dry season is encountered with relatively high weather condition in terms of humidity. More so, there has always been a harmattan season between November and the February on the yearly twelve-month calendar. Owusu-Ansah (2016) reports in his study that the mean annual rainfall of Mampong Cocoa District is between 800 mm and 1500 mm and is bimodal and fairly distributed.

According to Boote *et al*. (2011), the 21st century keeps seeing some levels of decline in cocoa yields in Ghana, stretching from about 2.5 percent and approximately 10 percent as atmospheric temperature goes up in other agronomic classes.

Using regression analysis in the Ordinary Least Square (OLS) form, the study findings of Ibn-Musah, *et al*., (2018), which sought to examine the effect of temperature on crop yields (including cocoa) at various levels, showed a decrease in yield as a result of an increase in MxTmP within the period under study.

In forming theoretical bases, Korolev (2007) employed the distribution of day-to-day rainfall trend to examine the impact of seasonal rainfall pattern on enhanced maize production under different types of fertilizer and soil conditions. Thus Korolev (2007) developed seven (7) unique rainfall pattern distributions for the overall three (3) periodic rainfall values of 900 mm, 600 mm and 300 mm in descending order, which represented high, average and low rainfall seasons respectively.

Asare *et al*. (2018a) employed multiple linear regression in their study to show an interface of sex and the size of land used in areas in Ghana where cocoa is grown and found that variables such as size of farm, the size of land used and sex have statistically significant impact on existence rate of relocated amalgam cocoa plantlets within the studied two (2) specific dry seasons. Ibn-Musah *et al*. (2018), based on their GCM (i.e. General Circulation Model) which has been considered as one of the robust models forecasted a sustained temperature increase and downward trend in rainfall in areas where more cocoa is produced in Ghana from the year 2020 to the year 2080.

The standard multiple regression data analysis of Kozicka *et al*. (2018) revealed that around 60 percent of the changes within the supply of cocoa was predicted by the combination of the early year's overall anRF, in addition to precipitation within the two dried out months and add up to temperature (daylight length). In this manner, a constant fall in yield from 2020 to 2080 can be anticipated. Agreeing to Laven and Boomsma (2012), output improvement change altogether over distinctive farms and suppliers.

The model was extended (Läderach *et al*., 2013) to reflect the variations in evapotranspiration as a result of increased temperature and relatively low rainfall, which might be especially significant within the cocoa producing regions in Côte d'Ivoire and Ghana. Kozicka *et al*. (2018) also found that climatic factors greatly influence cocoa production. As part of their study analyses, Anim-Kwapong and Frimpong (2004) also reported that in producing countries, the pattern of cropping cocoa is related to rainfall distribution. Crop yields are a function of commodity prices, prices of inputs, available water and climate.

2.4.3 Conceptual Framework

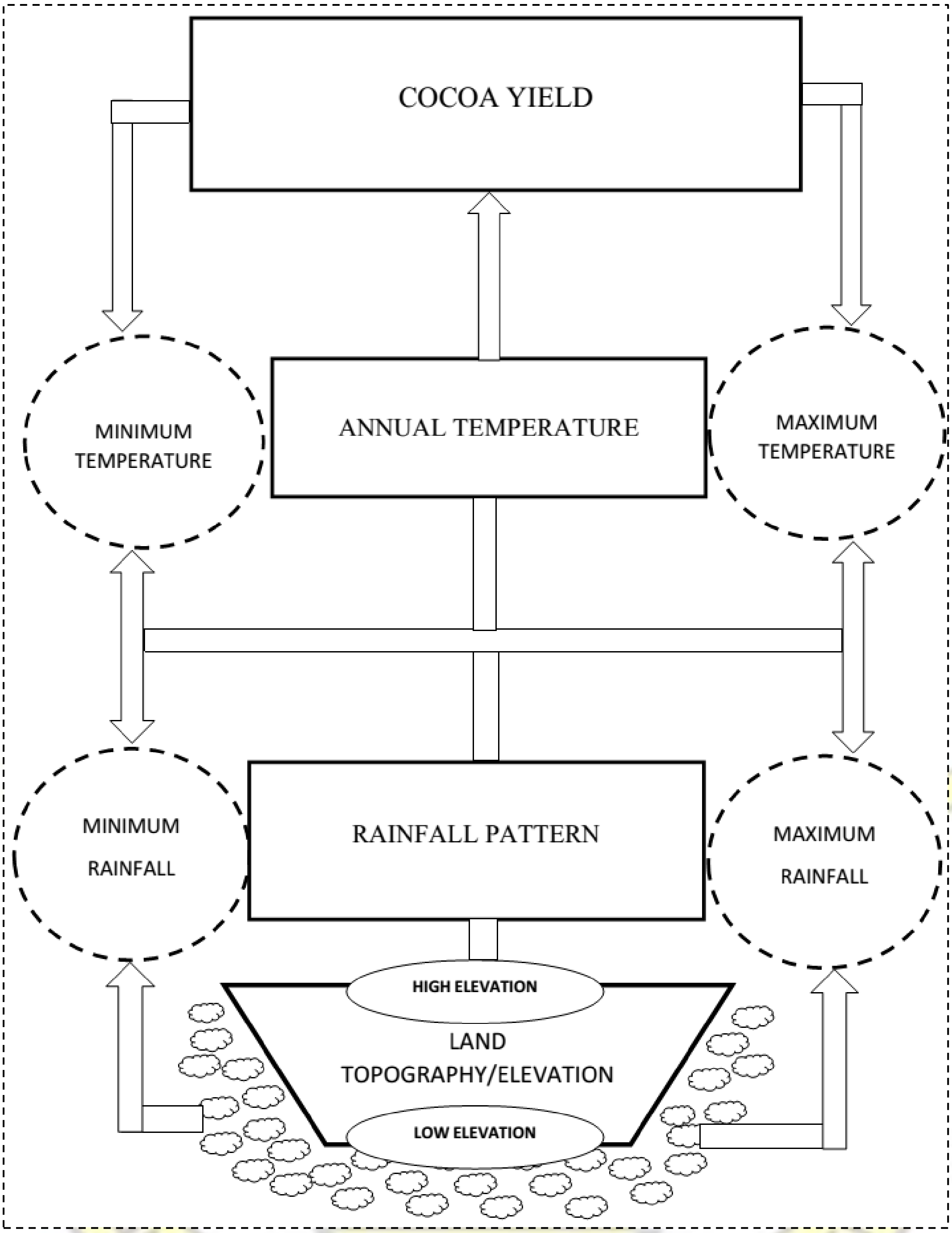

Figure 2. 1: Conceptual framework cocoa yield, rainfall and temperature
Source: Author's construct (2019)

Figure 2.1 depicts the conceptual framework developed based on the study's objective. The assumption is that the conceptual framework would establish the relationship between cocoa yield which was treated as predicted variable, and anTmP, anRF, MxRF, MnRF, MxTmp, MnTmP and land topography/elevation considered as independent variables.

However, in order to examine the effect of low and high rainfall, temperature and elevation on cocoa yield, MnRF and MxRFs, MnTmP and MxTmP have been incorporated into the regression models adopted to develop the study's conceptual framework. The underlining assumption for the interconnections among these variables is that the high or low land elevation and MnTmP or MxTmP may influence the rainfall pattern, which is one of the major environmental factors that affects cocoa yield. It is assumed that the rainfall, temperature and land elevation would either affect cocoa yield individually or jointly at different time frame. In addition, the nature of the topography may also determine the water holding capacity which would directly or indirectly influence the cocoa trees which produce the yields of the cocoa. These assumptions are based on Oettli and Camberlin's (2005) observation that variations in rainfall coincides with seasonal atmospheric circulation changes, and that slopes, in terms of land topographical structure, contribute to rainfall variability. Thus in examining how various topographical factors interrelate with atmospheric transmission to produce seasonally varied rainfall fields, Oettli and Camberlin (2005) concluded that land elevation partly determines the pattern of rainfall across seasons. In terms of rainfall and cocoa yield, assumption is made based on Emmanuel's (2018) supposition that cocoa is highly responsive to climatic variation from the appearance of sun, to heavy rainfall and showers, soil texture and atmospheric temperature as a results of evapo-transpiration, and that cocoa yield is a function of natural factors such as rainfall and temperature.

Emmanuel (2018) concluded that rainfall cannot be ignored in determining cocoa yields, because when there is a heavy rainfall in the period where cocoa trees bring forth flowers, an increased cocoa yield would eventually be reduced. This assumption confirms ICCO's (2010) study's finding that cocoa needs not less than 1450 mm of rain water to grow fine on average fertile soil.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This particular chapter sought to discuss the research methods adopted for the study. To start with, the chapter discusses the appropriate research design which was used in the study, followed by the presentation and description of the area where the study was carried out. The chapter further highlights discussion of data sources, data collection procedures and model specification and definition of the variables. The last section of the chapter took into account how the study's data were processed and analyzed.

3.1 Research Design

Longitudinal research design was adopted for the study's process of collecting data and analytical procedure which was deemed fit for the study. In this regard, quantitative analysis was employed to analyze the collected data. Thus based on time series data, quantitative analyses approaches were adopted to provide empirical basis for the current problem under investigation based on past data, and to also re-examine the past dataset for making future predictions using empirical models. Time series analytical method, according to Velicer and Fava (2003), is an appropriate statistical approach which is needed for an essential category of longitudinal study designs. A research design of that nature normally takes into consideration one subject or a specific research unit that are calculated recurrently at consistent limit within a larger number of observations.

This necessitated the uses of longitudinal data methodology in specific data analysis in a manner that the study's main objectives would be achieved. This approach involves the longitudinal units of observations over the twenty-four year period to estimate and predict the dependent variable (cocoa yields) for the period under investigation.

The study however made use of Auto Regressive Distributed Lag (ARDL) model considered to be more robust to examine both S-RN and L-RN relationship between some specific independent variables (MnRF, MxRF, MnTmP and MxTmP) and the dependent variable (cocoa yields) employed in the study. Ideally, ARDL models use Ordinary Least Square (OLS) form of regression technique to examine the magnitude of change in the explained variable as a result of unit changes in the explanatory variable. In the case of the models employed in this study, magnitude of change in the explained variable (cocoa yield) as a result of unit changes in the specific predictor variables (MnRF, MxRF, MnTmP and MxTmP).

Thus the use of ARDL model (Jayaraman, Choong & Kumar, 2011) would serve as empirical gauge for the key stakeholders and potential investors in the cocoa industry to predict future cocoa yields in Ghana by analyzing the trends and behavior of rainfall pattern, MnTmP and MxTmP. In this regard, the OLS approach, as adopted by Ibn-Musah *et al*. (2018) and Croissant and Millo (2008) was employed to examine the impact of MnRF, MxRF, MTmP and MxTmP on cocoa yield in the Mampong Cocoa District.

3.2 Study Area

The study was carried out at Mampong Cocoa District in the Ashanti Region. The Mampong Cocoa District covers a total land area of 782km^2 with 69 settlements. The capital for the Municipality is Mampong. According to Owusu-Ansah, the area has a coordinates of latitude 7°4’ North and 1°24’ West. It is estimated that about 58 percent of the area classified as Mampong Cocoa District is purely rural (Owusu-Ansah, 2016). GhanaDistricts.com (2011) reported that Mampong Cocoa District shares boundaries with five cocoa districts in Ashanti region, namely Juaso, Nkawie, Brofoyedru, Bekwai and Offinso, also in political region, Brong East region (precisely, Techiman Cocoa District). According to 2011 District Progressive report, the total area covered by cocoa is around 27912.18 hectares, while remaining 21,555.70 hectares are used for building and farming activities which include plantain, yam, cassava and various varieties of vegetables.

3.3 Cocoa District

Technically, Mampong is one of twelve (12) cocoa growing Districts in Ashanti Region under Cocoa Health and Extension Division (CHED) under the auspices of Ghana COCOBOD. It comprises nine (9) political Districts, namely Mampong Municipal, Afigya Sekyere, Sekyere East, Ejura Sekyere Dumase, Sekyere Central, Kwabere and part of Sekyere Afram Plains. The size of the Cocoa District is about 526,066 hectres (Cartography Department, CHED, 2019). Although the area is a transitional zone, cocoa farmers embrace the idea of cultivation as a business venture and for that matter, a lot of farmers are engaged in cocoa farming as major source of livelihood. One of the major challenges cocoa farmers face is the spread and devastation caused by swollen shoot virus disease which results in yield losses. Although cocoa is the major cash crop in the area, some farmers engage in yam cultivation. Farmers within the District have access to extension services provided by CHED coupled with the supply of inputs to boost production as well as pest control and diseases. Figure 3.1 depicts the map of Mampong Cocoa District.

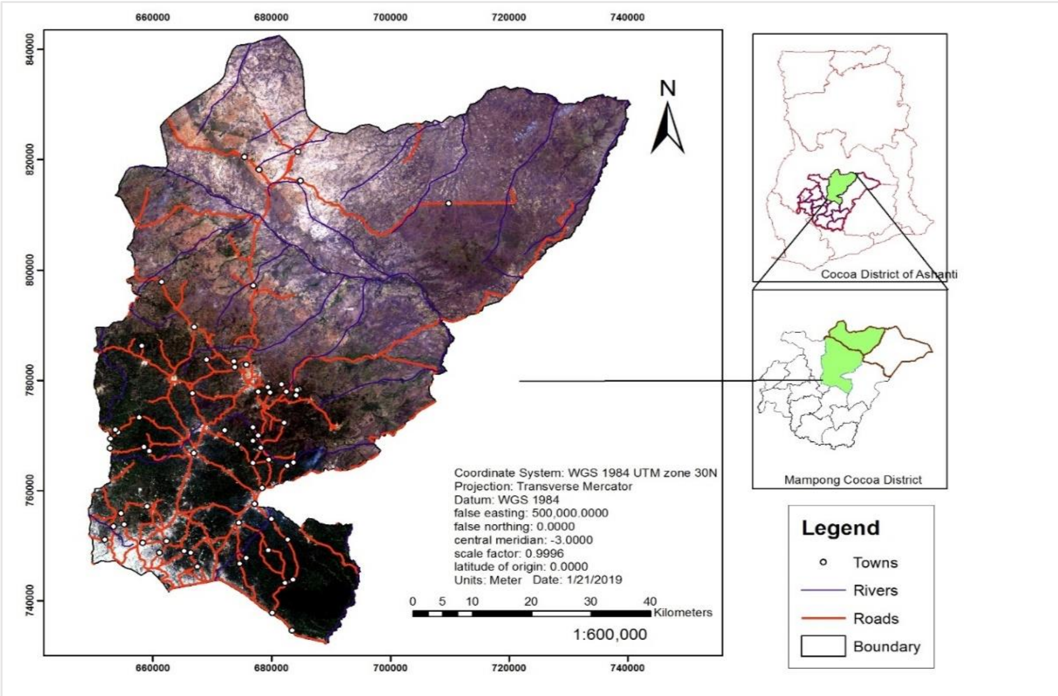

Figure 3. 1: Map of Mampong Cocoa District

Source: Cartography Department (CHED, 2019)

3.4 Population Size, Structure and Composition

The actual population size of Mampong Municipal, according to the reported figures in the 2010 Population and Housing Census, stood at 88,051.

According to Ghana Statistical Service (2014) district analytical report, the Mampong District has a sex ratio (male: female) of 94 (100:96 or 1: 0.96). The population of the district's population exhibits a wide base pyramid which shows a small number of elderly persons. The age dependency ratio for Mampong Municipal 84.1 (100: 85.9 or 1: 0.86), the age dependency ratio for males is higher (86.9 or 1: 0.84) than that of females (81.6 or 1: 0.83).

Table 3.1: Distribution of households engaged in farming activities by Sex and population engaged Cocoa farming

	Population in occupied unit (Households)			Population engaged in cocoa farming		
Sex	*Male*	*Female*	*Total*	*Male*	*Female*	*Total*
Cocoa	**3,514**	**3,567**	**7,081**	**1,378**	**1,253**	**2,631**

Source: Ghana Statistical Service (2014)

3.4.1 Climate

Mampong Municipal has an average yearly rainfall of 1,270 mm and two major rainy seasons. The least rainy season starts in March and ends in August whiles the minor is between September and November. The remaining months spans the harmattan dry season. According to Meteorological Service, Mampong (2010), as cited in Ghana Statistical Service's (2014) 2010 Population and Housing Census, National Analytical Report, the average yearly temperature is 27^0C which shows variations in average monthly temperature ranging between 22^0C - 30^0C.

3.4.2 Vegetation

The Mampong Municipality covers the wet semi-equatorial forest zone in the Ashanti Region of Ghana. As a result of several human activities like farming, burning of charcoal, cutting down of tree and indiscriminate bush burning, the forest vegetation, especially the North-eastern belt, is reduced to Savannah. More so, the plant life in their natural form can only be found within a forest reserve known as the Kogyae Natural Forest Reserve, which has a total land cover of 115 km^2.

3.4.3 Relief and Drainage

The elevation of Mampong Municipality is fairly low-lying in the southern part of the district and steadily surges towards the northern part of the area. The peak is about 2400 m above average sea level while the lowest point is 135 m above mean sea level, according to Meteorological Service, Mampong (2010) cited in Ghana Statistical Service's (2014) 2010 Population and Housing Census, National Analytical Report. There is an escarpment, which is an extension of the Kintampo-Bisa ranges. The plains is drained by a number of rivers and streams, which include River Afram, Sene, Sasebonso and Kyirimfa.

3.4.4 Economy

The main stay of the economy of Mampong Municipality is agriculture which employs approximately 67.3 percent of the total labour force in the area. However, production of agricultural crops is at the subsistence form, which requires greater improvement in terms of mechanization to boost agricultural productivity to ensure food security and also for export to provide livelihood for the inhabitants and foreign exchange for the country at large. The main crops cultivated in the area include maize, cassava, plantain and cocoyam (Ministry of Food and Agriculture, 2017). The service sector is the next contributor to the local economy after agriculture, employs about 17.2 percent of the total population, while commerce, in the form of petty trading, constitutes 8.5 percent. Manufacturing on the other hand employs about 8.9 percent of the population, while only 3.2 percent are employed by other income generating activities.

3.5.1 Sources of the Study's Data

Secondary data were used as the principal source of data gathered for the study. The rationale for adopting secondary data hinges on Smith's (2008) observation that the key advantages associated with the use of secondary data analysis are the cost minimization and suitability it provides. More so, the study could to rely on primary data because the researcher, upon visiting to Mampong Cocoa District, found that most of the cocoa farmers do not keep records on their cocoa yields. Since the data have already been collected by someone else, making use of such available data has little financial obligation to the collection of secondary data. In addition, as observed by Smith *et al*. (2011), secondary data usually use large samples that are more characteristic of the target population and this allows for greater cogency and more generalizable findings.

The study of this nature required the use of secondary data, and that time series data covering the period of thirteen (13) years, starting from 2003 to 2016 were used for the study. Specifically, the pixel values for anTmP, MxTmP and MnTmP were obtained from Landsat 7 thermal band, while the anRF, MnRF, MxRF values were gathered from CHIRPS. The necessary classifications were done to ensure that condition of precision is met. In addition, the data on cocoa yield were gathered from Ghana COCOBOD (2018) and Quality Control (2018) annual reports. Atmospheric temperature and actual rainfall recorded were assumed the major factors that determine weather conditions in Ghana. In this regard, stationarity test on temperature and rainfall was conducted using Augmented Dickey-Fuller (ADF) for determining unit root. As applied by Coles (2001) this approach was considered appropriate to pave way for non-stationarity test in the model parameters of temperature and rainfall adopted as variable of interest in this study.

3.5.2 Satellite Imagery

Satellite images of the study area used in this study were retrieved from the Google Earth explorer where different datasets are available and could be freely accessed. In this study, the satellite images that were used are Landsat 7 Thermal Band. The shape files for pre-processing with required attributes and spatial reference were obtained from the Google street map and ESRI.

3.5.3 Acquisition and Processing of the Satellite Images

Rigorous validation of the study area is essential to help in deciding when and how to utilize the dataset, correctly interpret results, and provide feedback to improve the datasets. The validation of the satellite datasets and Mampong boundary shape files requires an independent dataset that can validate across the spatial extent and over the timespan of the product. For similar datasets, different sources of imagery exist that meet these requirements of using independent dataset. In light of this, datasets and shape files were validated using multiple approaches.

In the process of gathering the required rainfall data, annual rainfall values from 2003 to 2016 covering the whole Africa were obtained from CHIRPS. The area of interest (Mampong Cocoa District) was cropped out from the data to obtain only Mampong Cocoa District. All the rainfall values (pixel values) in the Mampong Cocoa District were added to obtain the estimated rainfall values for each year for the Mampong Cocoa District. The values were classified, coded and used for the study's analysis. Figure 3.2 and Figure 3.3 depict rainfall maps for 2005 and 2010 in Mampong Cocoa District

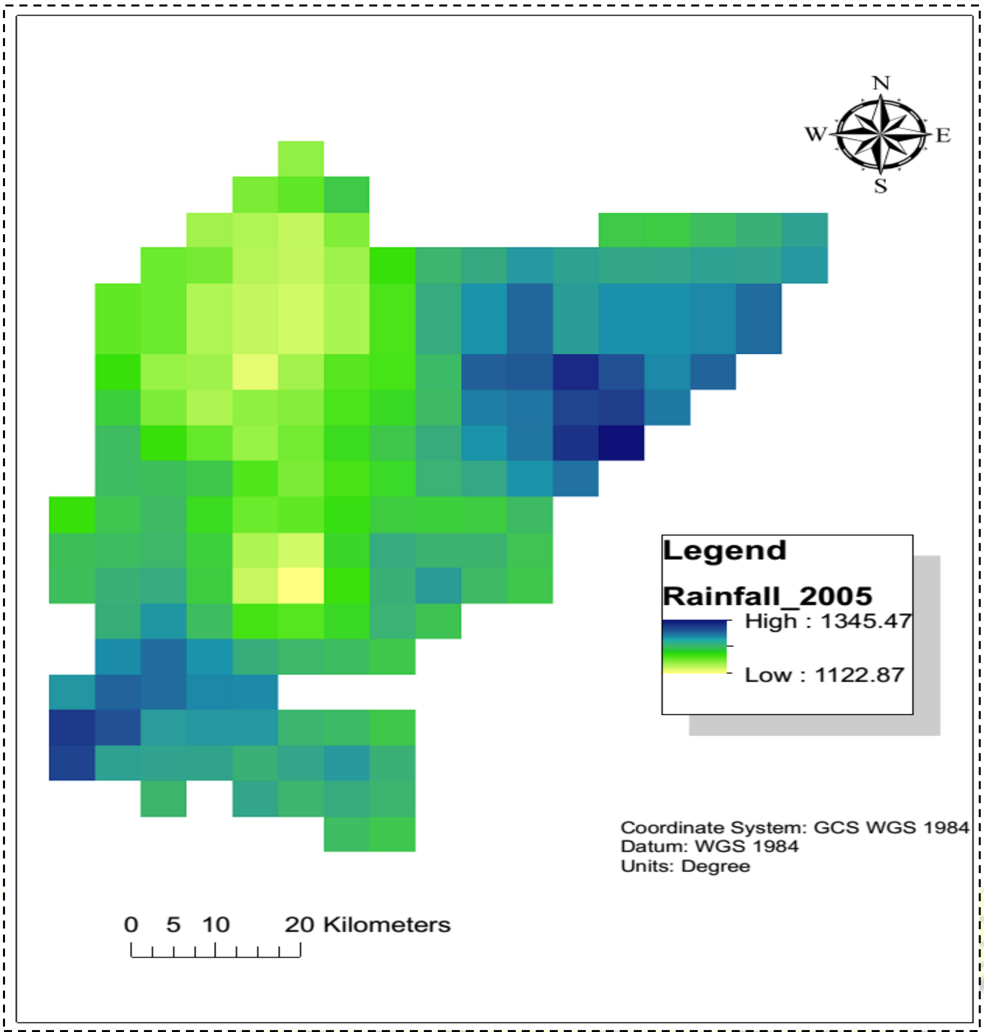

Figure 3. 2: Rainfall pattern for 2005 in Mampong Cocoa District

Source: CHIRPS Data (2003-2016)

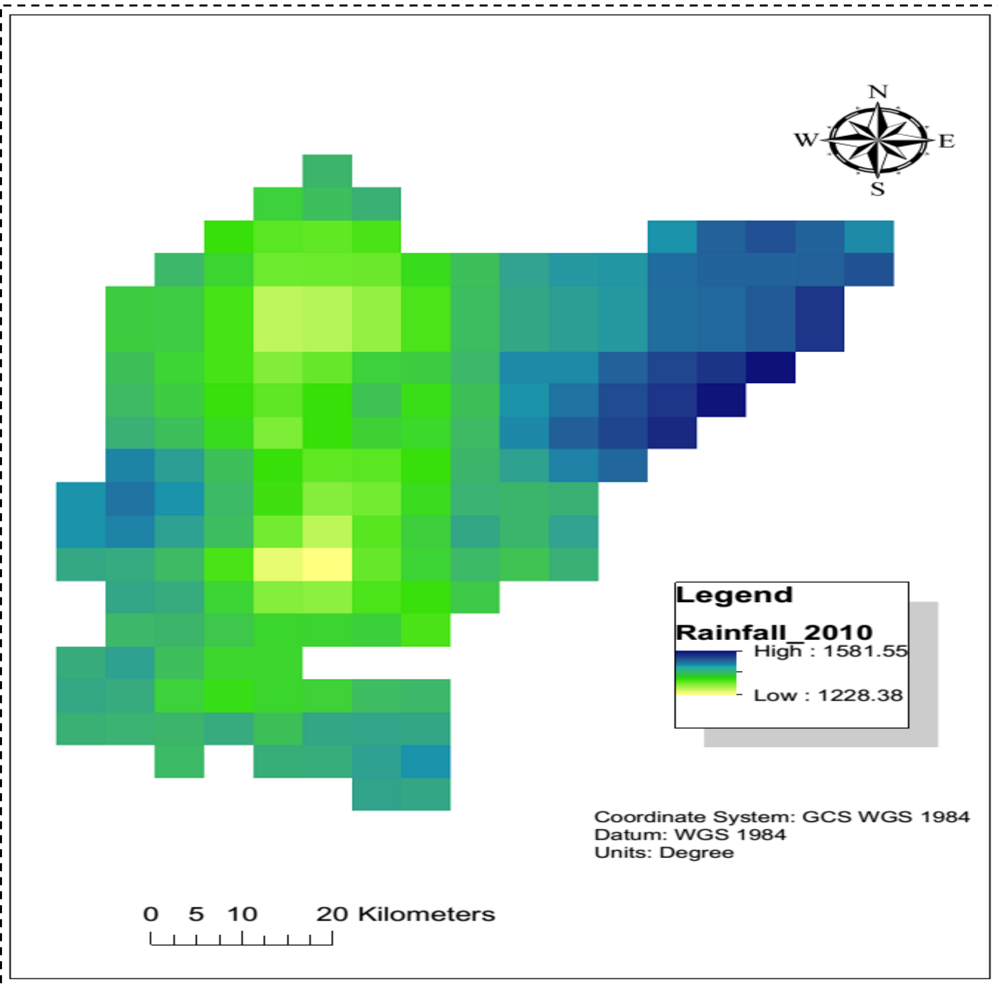

Figure 3. 3: Rainfall pattern for 2010 in Mampong Cocoa District

Source: CHIRPS Data (2003-2016)

Annual rainfall value for 2005 was 1226.57 mm with corresponding annual cocoa yield of 46638 mt, while annual rainfall value in 2010 recorded 1396.66 with corresponding annual cocoa yield of 96659 mt. These relative rainfall and cocoa yield figures on the surface, indicate that high rainfall is associated with high cocoa yield, while low rainfall brings about low cocoa yield. This observation cannot provide enough evidence to infer that cocoa requires more rainfall to produce more yield. Hence the need to employ robust analytical tool such as ARDL Model to examine the magnitude at which low or high temperature influence cocoa yield in both long run and short run period. Figure 3.4 and Figure 3.5 also exhibit the actual temperature values for 2005 and 2010.

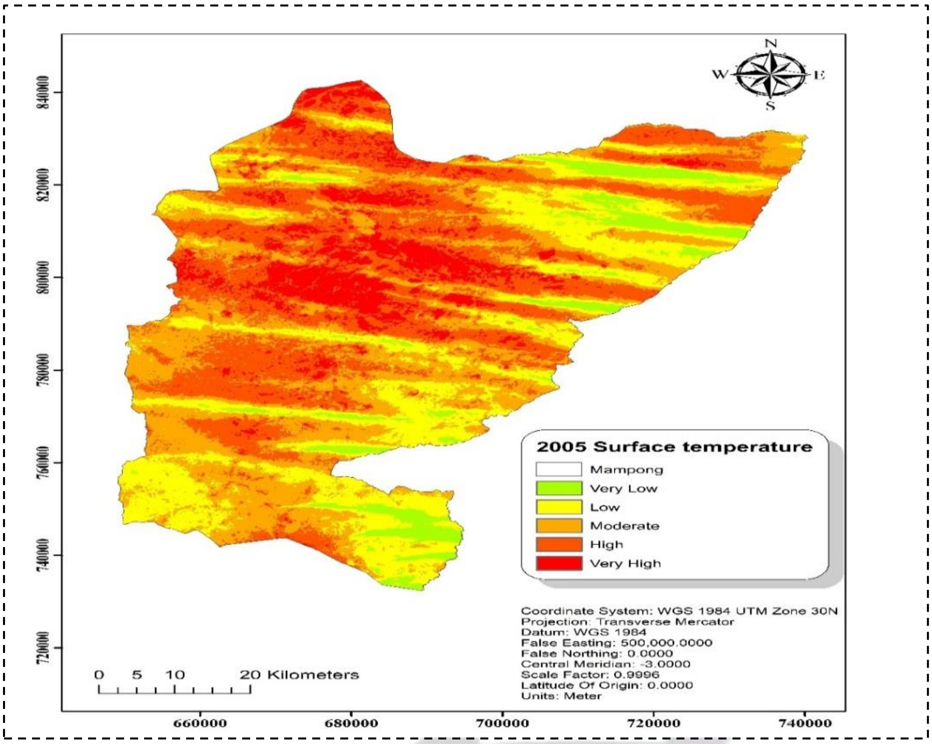

Figure 3. 4: Surface temperature for 2005 being the least

Source: Landsat 7 Thermal Band Data (2003-2016)

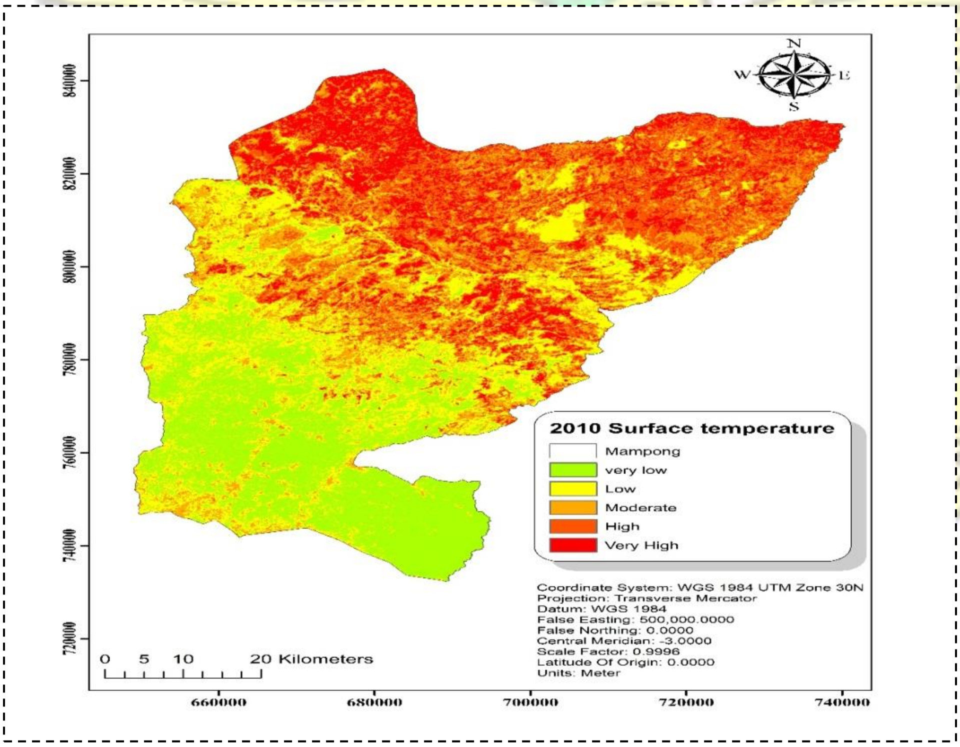

Figure 3. 5: Surface temperature for 2010 being the highest

Source: Landsat 7 Thermal Band Data (2003-2016)

As depicted in Figure 3.4 and Figure 3.5, the classified images for the thirteen years (from 2003-3016) shows average annual temperature of 36.85 ^{0}C for the 13 year period. The gathered data (Table 3.4) indicate that the least temperature (25.37^{0}C) was recorded in 2005, with corresponding cocoa yield 46,638 mt in the same year. On the other hand, the highest temperature (54.89^{0}C) was recorded in 2010 with the corresponding cocoa yield 96,659 ^{0}C. These figures suggest that the higher the temperature, the more cocoa yield is obtained and vice versa. Whether or not this assumption would hold requires rigorous analysis to ascertain such claim. This triggered the adoption of ARDL Models to examine the L-RN and S-RN relationship between temperature and cocoa yield.

3.5.4 Model Specification

There are two widely used models, namely, time series and panel model. These models are developed based on the properties of the data collected (time series and cross sectional). This study selected a district (Mampong Cocoa District) over a period of time, thus, time series model would be developed. According to Varma (2016), time series data are considered as data that were carefully collected over a specified time frame on one or more variables. The difference between time series and panel model is that, time series consider one unit, in this case a country (Ghana) while panel considers more than one units (two or more countries). In other words, when a set of data used for a study considers one unit over a period of time, then time series study is deemed appropriate for that study, thus, time series model was employed to undertake the study at within only one cocoa district (i.e. Mampong Cocoa District).

3.6.1 Data Analytical and Estimation Techniques

The study employed quantitative and descriptive analysis by making use of charts such as graphs and tables. To be able to make a reliable analysis with time series data, the researcher had to perform a test for non-stationarity to assess the stationarity of the time series data. To avoid the tendency of having a spurious regression, the variables were individually tested for the presence of an identified unit root. The violation of a unit root assumption meant that the data exhibiting time series characteristics were non-stationary. This procedure was necessary to help prevent the tendency of having a bogus regression which could taint the entire analytical process.

3.6.2 Pre-Estimation Test for Stationarity

Pre-estimation tests were conducted using appropriate non-statistical and statistical test tools to ensure that assumptions underlining the analytical technique (ARDL models) were not violated. Among the key pre-estimation tools used include visual inspection, Augmented Dickey-Fuller test and Bounds test for ARDL models.

3.6.3 Visual Inspection

Using time series plot (graph) visual inspection was employed to examine whether the series' general slopes follow deterministic or stochastic trend over time (i.e. either downward or upward). This pre-estimation test is based on Gujarati's (2004) observation that prior to one's pursuance of a formal test, would highly appropriate to design the time series under investigation for the adopted data; such pictorial graph provides an initial clue on how the nature of the adopted time series would be.

3.6.4 ADF Test for Unit Root

To perform stationarity test for time series data, the common method which is widely applied ADF (Dickey & Fuller 1979; Brooks, 2014) which most researchers adopt to test for a unit root. Thus the assumption is that any time series containing a definite unit root is considered as non-stationary (Haq & Larsson, 2016). In this study, Dickey Fuller

(Dickey & Fuller, 1979) test for stationarity was adopted to examine the direction of integration in the actual series used in the study in order to avoid spurious regression results. Lag length was also tested in order to know how time periods back the explanatory variables to influence the explained variable. The study further took into consideration bounds testing for cointegration (ARDL) technique utilized mostly by Pesaran, Shin and Smith (2001). This was so because apart from the data size being relatively small, as per the unit root test, the assumption is that some of the variables of interest adopted in this study were found to be stationary in their levels, while others are stationery at I(0). A time series data is said to have stationarity if a change in time does not effect a change in the data set (Glen, 2016). Test for stationarity is very necessary because it enables the researcher to determine whether the changes that were seen in the actual series were merely as a result of the passage of time. There are a number of ways for performing a stationarity test, however, for the purposes of this research, the stationarity test would be carried out by running a unit root experiment employing the ADF and Philip-Perron tests. Thus the essence of the stationarity test is to enable the researcher to prevent the occurrence of bogus regression which has the tendency to affect the validity of the entire analysis in the study. The implication of the absence of a unit root will give room for the use of ARDL model (Ekpo et al., 2011). It is therefore necessary to carry out pre-test to examine the series' stationarity in order to ensure that robust analysis is made.

The use of ADF test was deemed appropriate for the study because it has the ability to examine the presence of serial correlation. Serial correlation occurs when a stochastic error term of one time period is transferred to another time period. As observed by Ang (2008), the ideal approach (Phillips & Perron, 1988) is considered as a universal of the ADF test.

The ADF test is usually employed to either accept or reject the null hypothesis that seems to suggest that a given data is not stationary, which implies that such data distribution has in them a unit root. However, a rejection of the null hypotheses also implies that the data having time series features contain no unit root and that such series remain stationary.

3.7.1 Cointegration Test

The main test for cointegration used in examining the long-run relationship between cocoa yield and rainfall and temperature pattern was bounds test for cointegration designed for ARDL models.

3.7.2 Bounds Testing for ARDL models

The cointegration test for ARDL models (Pesaran *et al*., 2001) was adopted to examine the L-RN relationship between time series variables that exhibit non-stationarity characteristics. In this regard, this study specifically made use of ARDL model to empirically ascertain the relationship between rainfall (minimum and maximum) and cocoa yield. The relationship between cocoa yield and other variables such as MnTmP and MxTmP were also examined.

The study of Jayaraman *et al*. (2011) also reported that the cointegration used in the ARDL model demonstrates more or less a universal vigorous model specification technique which makes use of previous years' values of the explained variable and the previous years' values of the explanatory variables, within which a particular S-RN effect can be unswervingly measured, and the L-RN relationship can also be inversely estimated. These could be ensured to transform all the variables adopted from their levels into their natural logarithm form.

The reason for using ARDL model is that it allows the use of previous years' values of an observation to make future predictions about the value of that observation. The following are the ARDL models showing S-RN and L-RN relationship between the explained and explanatory variables:

3.7.3 S-RN Estimated Model

$$\Delta \mathrm{CYD}_t = \alpha_0 + \sum_{i=1}^{n} \beta_i \, \Delta \mathrm{CYD}_{t-i} + \sum_{i=0}^{n} \phi_i \, \Delta \mathrm{anTmP}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{anRF}_{t-i} \sum_{i=0}^{n} \phi_i \, \Delta \mathrm{minTmP}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{maxTmP}_{t-i} + \sum_{i=0}^{n} \phi_i \, \Delta \mathrm{minRF}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{maxRF}_{t-i} + \varepsilon t \quad (4.1)$$

3.7.4 L-RN Error Correction Model

$$\Delta \mathrm{CYD}_t = \alpha_0 + \sum_{i=1}^{n} \beta_i \, \Delta \mathrm{CYD}_{t-i} + \sum_{i=0}^{n} \phi_i \, \Delta \mathrm{anTmP}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{anRF}_{t-i} \Delta \mathrm{minTmP}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{maxTmP}_{t-i} + \sum_{i=0}^{n} \phi_i \, \Delta \mathrm{minRF}_{t-i} + \sum_{i=0}^{n} \Phi_i \, \Delta \mathrm{maxRF}_{t-i} + \Phi_i ECT + \varepsilon t \quad (4.2)$$

3.8.1 L-RN Component of ARDL Model

$$\Delta \mathrm{CYD}_t = \partial_1 \mathrm{anTmP}_{t-i} + \partial_2 \mathrm{anRF}_{t-i} + \partial_3 \, \mathrm{minTmP}_{t-i} + \partial_4 \mathrm{maxTmP}_{t-i} + \partial_5 \mathrm{minRF}_{t-i} + \partial_6 \mathrm{maxRF}_{t-i} + \varepsilon_t \quad (4.3)$$

3.8.2 Post Estimation Tests

Post-estimation tests were carried out to ensure that the study's analysis presents reliable results. Among the post-estimation tests conducted include test for Serial Correlation/Autocorrelation, white test and model stability (CUSUM) test.

3.8.3 Serial Correlation/Autocorrelation

Post estimation test for Serial Correlation/Autocorrelation was employed to examine the likelihood of association between actual lag value of the explained variable and exact variable of interest itself. In this regard, Durbin-Watson d statistic (Breusch, 1978; Godfrey, 1978) test for autocorrelation was adopted.

Serial correlation/autocorrelation explains whether the lag of a variable correlates with the variable itself. This test was done to test whether or not the null hypothesis (Ho) that indicates that the established model is affected by the existence of auto correlation should be rejected. The assumption is that the stochastic error terms in the various time periods are not correlated (they do not affect/influence each other).

3.8.4 White Test

White test was conducted as part of post estimation test to assess the null hypothesis which states that the models in the series suffer from heteroskedasticity. Heteroskedasticity occurs when the variation found in the stochastic error terms are different in the various observations within different time periods. The assumption is that the variation in the stochastic error terms in each model in the series is constant.

3.9.1 Plots of Cumulative Sum (CUSUM) Test

The study adopted CSUM test to examine the stability of models employed to assess both L-RN and S-RN relationship among cocoa yield and rainfall (anRF, MnRF and MxRF) and temperature (anTmP, MnTmp and MxTmP).

The study therefore sought to analyze the stability among these variables incorporated in the ARDL models used in this study. The essence of the CUSUM test in theory is to ascertain the stability of the L-RN parameters together with the S-RN movements for the ARDL models (Turner, 2010). The CUSUM test has been utilized by Pesaran and Pesaran (1997) to test the stability of the L-RN coefficients. Thus the test applied to the residuals of the cointegration models (ECM). If the CUSUM plot statistics remains inside the bounds considered to be critical, then it indicates the stability of estimated coefficients (Ketenci, 2009). The null hypothesis (H_0) which claims that there is coefficient instability in the error correction model employed to examine the impact of rainfall and temperature patterns on cocoa yield in the Mampong Cocoa District where the study was carried out.

If graph of CUSUM actual statistics falls outside the 5 percent alpha level critical bounds, then the H_0 of coefficients' instability in the ECM cannot be rejected. However, there would be enough evidence to fail to accept the H_0 if graph of CUSUM statistics remain inside the 5 percent alpha level critical bounds (Turner, 2010; Zeileis *et al*., 2002).

3.9.2 Data Processing and Analysis

The study made use of two statistical software packages to process the data collected from the secondary sources for the study. These statistical packages include Microsoft Excel 2013 version and Stata 14. Before the dataset was processed, a thorough evaluation was done (Kiecolt & Nathan, 2008) to ensure their appropriateness for the research topic. The secondary data in their raw form, were organized, coded and grouped under their individual heading as part of the data entry in the Microsoft Excel 2013 version. Pixel values for temperature were obtained from Landsat 7 Thermal Band, while rainfall values were gathered from CHIRPS, and were grouped and organized in Microsoft Excel 2013. Stata version 14 was used for the data analysis. The well-organized data were then exported to the Stata for rigorous analysis to be carried out. However, pictorial plots and well-designed charts depicting some trend, frequencies and their corresponding actual percentages were generated from Stata 14. Additionally, some data results were presented in tables when the need arose.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 Introduction

This specific chapter focuses on the data results presentation and discussion of the data output obtained in the study. The data presentation is based on the specific objectives the study sought to achieve as well as the research hypotheses of the study. It is worth noting that first differences were considered for all the adopted variables to examine their stationarity. First differences of the series were considered appropriate for the analysis, because the series in their levels were identified to be non-stationary. Both ARDL (autoregressive distributed lagged) model and ECM (error correction mechanism) models were employed in the analysis. In that regard, both pre-estimation and post estimation tests were conducted to ensure that the models used in the study were correctly specified and the conclusions made from the models were valid and satisfactory.

4.1 Series Stationarity Test

4.2 Time Series Plot

Time series line plots, as shown in Figure 4.1, were employed to undertake visual inspection of the stationarity of the series was conducted for both the levels and differences of the series. It is observed that the entire series do not look stationary in levels. Thus their general slopes follow constant trend over time (i.e. either downward or upward).

However, as observed from the time series plots, the stationarity test results showed that all the series in their level were not stationary, but all of them were stationary in their first difference form. Thus as exhibited Figure 4.1 the first differences of all the series look stationary.

In this regard, no trend in the differences and all are centered about zero. Since this method is a mere inspection, more robust tests considered as formal tests for stationarity, were undertaken to assess the stationarity of the series.

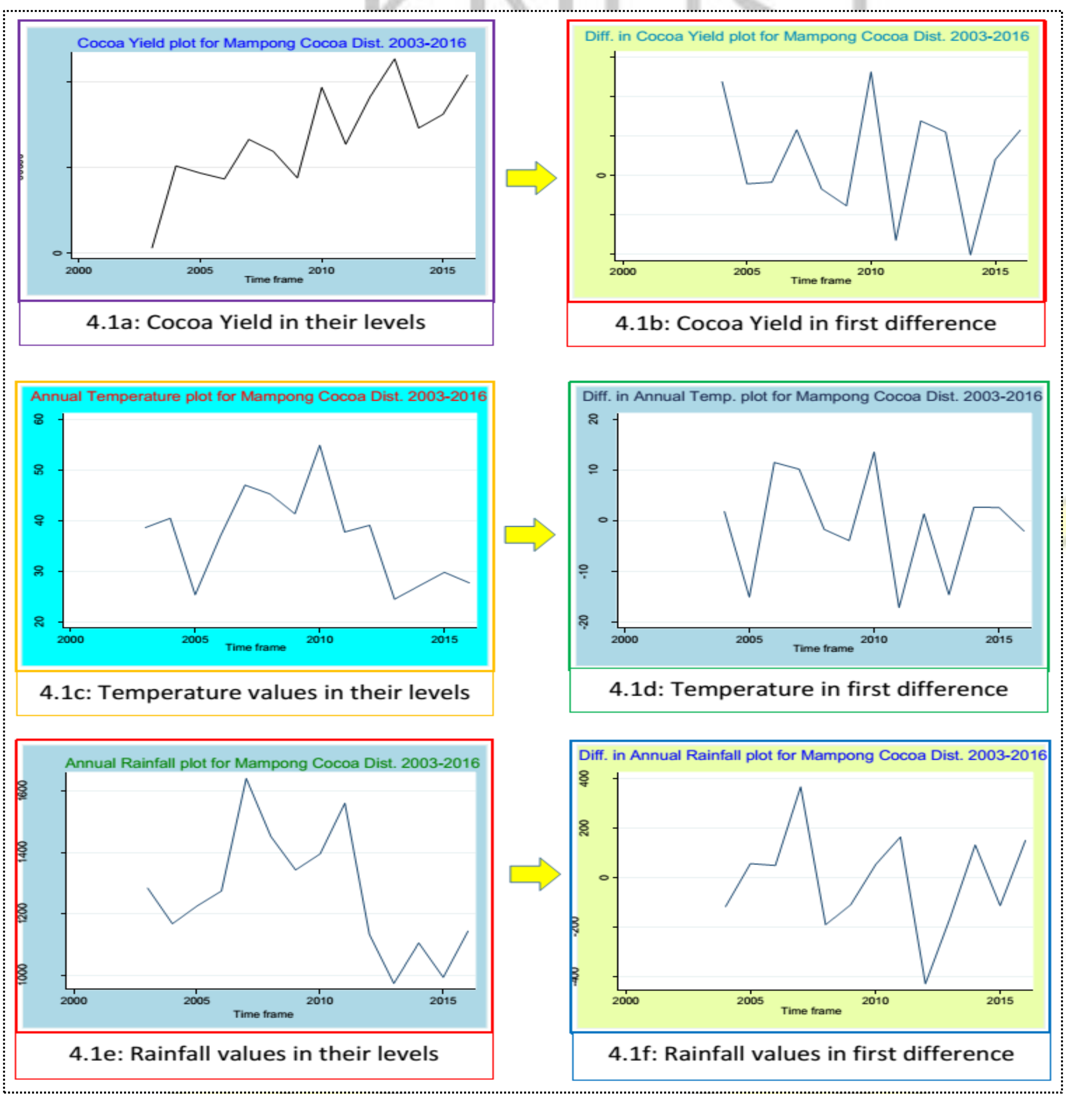

Figure 4.1: Time series line plots for series in their levels and first difference

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

According to Gujarati (2004), prior to one's pursuance of a formal test, it would be highly appropriate to design the time series plot for the adopted data under investigation; such pictorial graph provides an initial clue on how the nature of the adopted time series would be. Take, for instance, the annual cocoa yield, anTmP and anRF time series exhibited in Figure 4.1.

It is observed that over the period of study the annual cocoa yield, anTmP and anRF experienced an increase, which indicates an upward and downward trend, indicating that the averages of the annual cocoa yield, anTmP and anRF have been changing. These imply that the annual cocoa yield, anTmP and anRF series are not stationary. Such an intuitive observation provides a clue that would warrant a more formal test of stationarity.

4.3 Augmented Dickey-Fuller Test for Stationarity

In order to ascertain whether the series are non-stationary, ADF test for stationarity was employed as sufficient condition to assess the stationarity of the series in first difference, and the results are used in the study.

Table 4. 1: Trend of ADF Test (Without drift)

Variable	Test Statistic	1% CV	5% CV	10%CV	Constant Trend	Constant _Trend (P>|t|), 5%	Sig. 5% Z(t)
$\Delta CYLD_t$	-6.653	-4.380	-3.600	-3.240	28718.16	2.00	0.0000
$\Delta anRF_t$	-3.059	-4.380	-3.600	-3.240	128.06	0.72	0.018
$\Delta anTmP_t$	-3.219	-4.380	-3.600	-3.240	8.67	1.24	0.0806
$\Delta MxRF_t$	-3.742	-4.380	-3.600	-3.240	12.98	0.19	0.0197
$\Delta MnRF_t$	-3.038	-4.380	3.600	-3.240	-3.50	-1.08	0.1218
$\Delta MxTmP_t$	-2.933	-4.380	3.600	-3.240	-6.50	-0.58	0.1518
$\Delta MnTmP_t$	-4.766	-4.380	3.600	-3.240	7.22	1.21	0.0005

Table 4. 2: Interpolated Dickey-Fuller (With drift)

Variable	Test Statistic	1% CV	5% CV	10% CV	Constant	Constant _cons (P>|t|), 5%	sig Z(t) 5%
$\Delta CYLD_t$	-6.399	-2.896	-1.860	-1.860	12068.84	2.10	0.0001
$\Delta anRF_t$	-2.990	-2.896	-1.860	-1.397	-16.38	-0.24	0.0087
$\Delta anTmP_t$	-2.807	-2.896	-1.860	-1.397	-0.27	-0.09	0.0115
$\Delta MxRF_t$	-4.022	-2.896	-1.860	-1.397	6.89	0.27	0.0019
$\Delta MnRF_t$	-3.030	-2.896	-1.860	-1.377	-1.19	-0.97	0.0082
$\Delta MxTmP_t$	-3.019	-2.896	-1.860	-1.397	-0.81	-0.19	0.0083
$\Delta MnTmP_t$	-4.553	-2.896	-1.860	-1.397	0.98	0.41	0.0009

$\Delta CYLD_t$: First difference in cocoa yield in period t;
$\Delta anRF_t$: First difference in anRF in period t;
$\Delta anTmP_t$: First difference in anTmP in period t
$\Delta MxRF_t$: First difference in MxRF in period t;
$\Delta MnRF_t$: First difference in MnRF in period t
$\Delta MnTmP_t$: First difference in MnTmP in period t
$\Delta MxTmP_t$: First difference in MxTmP in period t
CV: Critical value

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.1 and Table 4.2 present the results of unit root test using ADF test, which was set to assess the presence of stationarity in all the series used in the study.

As indicated earlier, the variables used were identified to be non-stationary in the levels, when unit root test was performed on them.

However, the differentiation I(0) of the adopted variables were identified to be stationary after the Augmented Dickey-Fuller unit root test was performed. For instance, as observed in Table 4.1 and Table 4.2, there is an evidence of stationarity among all the variables in their first difference –in the trend without the drift, and with the drift. The H_0 is that all the series contain a unit root and that they are not stationary.

The rule of thumb indicates that a series is not stationary if the test statistic is less negative than the 5 percent critical value, which implies that the null hypothesis (Ho) cannot be rejected. In other words, we accept the H_0 if the test statistic of ADF is greater than the specified critical value. The ADF results in Table 4.1 and Table 4.2 show that the test statistics of all the variables in their first difference ($\Delta CYLD_t$, $\Delta anRF_t$, $\Delta anTmP_t$, $\Delta MxRF_t$, $\Delta MnRF_t$, $\Delta MxTmP_t$ and $\Delta MnTmP_t$) are far above the one percent, 5 percent, and 10 percent critical values. The corresponding p-values of the variables of interest are also statistically significant. This provides enough grounds to reject the H_0 which states that the series used in the study's models are non-stationary. Thus the p-values of all the series at first difference are far below 0.05, and that the H_0 of stationarity presence is rejected. This observation confirms Gujarati's (2004) postulation that if variables are non-stationary I(1) in their levels, their first difference becomes stationary I(0). It is further observed from Table 4.1 that the trend of change in cocoa yield, change in anRF, and change in MTmP are highly significant ($p<.05$), indicating that the trend of their stationarity has a significant effect in the models' stability (see Appendix I for all the ADF test results).

Table 4. 3: Trend of Rainfall and Temperature Pattern from 2003-2016

YEAR	*AnCYLD*	*AnRF*	*AnTmP*	*MxRF*	*MnRF*	*MxTmP*	*MnTmP*
Yr2003	3113	1284.98	38.66	216.6	13.76	74.36	3.40
Yr2004	50907	1169.10	40.46	277.8	12.74	74.36	22.84
Yr2005	46638	1226.57	25.37	191.72	11.53	74.36	17.63
Yr2006	43190	1275.77	36.84	217.95	13.56	74.36	8.22
Yr2007	66369	1642.32	47.00	412.22	6.33	74.36	25.87
Yr2008	59405	1453.20	45.28	222.03	3.34	74.36	29.31
Yr2009	43914	1343.89	41.35	220.81	6.48	74.36	22.82
Yr2010	96659	1396.66	54.89	243.88	8.77	74.36	35.92
Yr2011	63598	1561.41	37.76	264.52	4.40	50.37	24.87
Yr2012	91330	1133.84	39.11	249.51	6.92	65.09	18.69
Yr2013	113423	974.24	24.51	200.26	3.6	44.54	19.35
Yr2014	72918	1106.79	27.16	206.94	8.88	64.76	18.79
Yr2015	80950	994.47	29.78	193.44	4.15	81.45	21.84
Yr2016	103949	1144.81	27.75	328.27	4.74	63.24	21.42
Average	**66883.07**	**1264.86**	**36.85**	**246.14**	**7.80**	**68.88**	**20.78**

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.3 depicts the trend of actual values for annual cocoa yield (AnCYLD) annual rainfall (AnRF), annual temperature (AnTmP), maximum rainfall (MxRF) minimum rainfall (MnRF), maximum temperature (MxTmP) and minimum temperature (MnTmP) that were used for the data analysis.

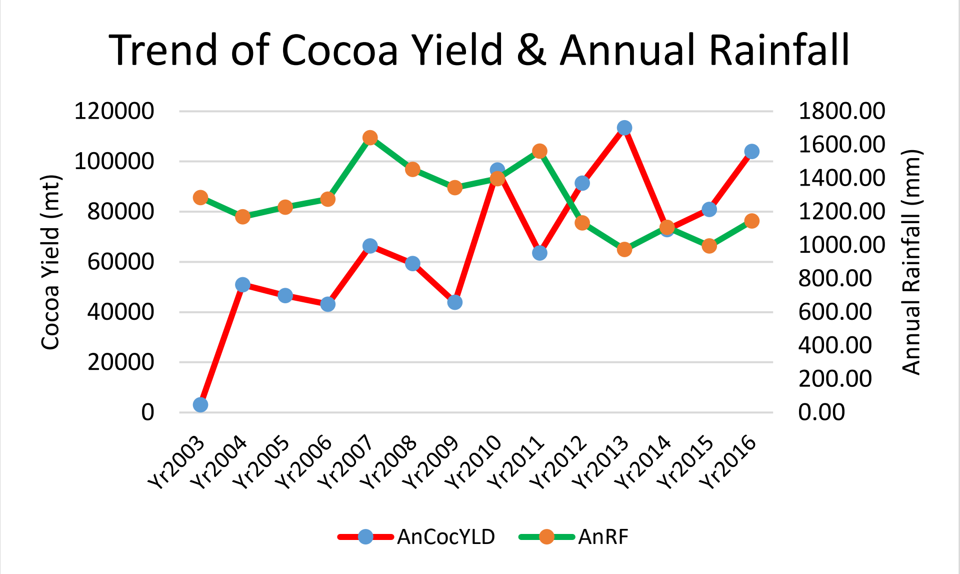

Figure 4. 2: Trend of Cocoa Yield and Annual Rainfall

Source: Secondary Data (2019) from COCOBOD & CHIRPS

Prior study (IITA, 2009) reported that in order to obtain cocoa production naturally needs annual rainfall levels of approximately 1250 mm to 3000 mm, although levels of 1500 mm to 3000 mm are preferred. It is however observed from Figure 4.2 that Cocoa yield in Mampong Cocoa District increased from 3113 MT in 2003 to 50907 MT in 2004 in 2011, while annual temperature also decreased from 1284.98 mm to 1169.10 mm within the same year periods. This shows that there was an inverse (negative) relationship between cocoa yield and annual temperature from the year 2003 to 2004.

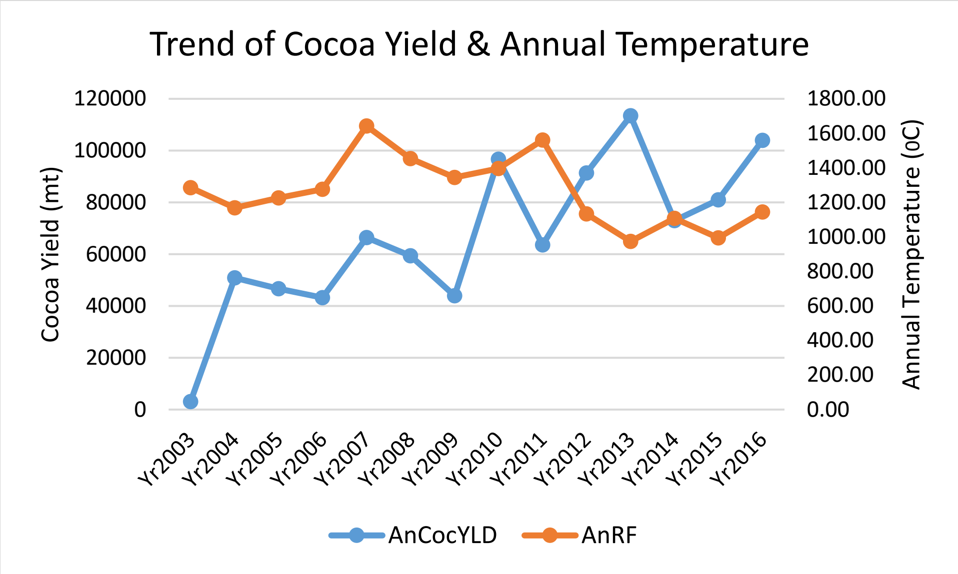

Figure 4.3: Trend of Cocoa Yield and Annual Temperature

Source: Secondary Data (2019) from COCOBOD & Landsat 7 Thermal Band

IITA (2009) maintains that temperature levels that are required to boost cocoa yield range from a minimum of 18 ^{0}C to 21 ^{0}C and a maximum of 30 ^{0}C to 32 ^{0}C. As shown in Figure 4.3 cocoa yield in Mampong Cocoa District increased from 3113 MT in 2003 to 50907 MT in 2004 in 2011, while annual temperature also decreased from 1284.98 mm to 1169.10 mm within the same year periods. This shows that there was an inverse (negative) relationship between cocoa yield and annual temperature from the year 2003 to 2004.

4.4 Interpretation of ARDL-Error Correction Models

Three bounds tests for cointegration were conducted where the first differences of anRF and anTmP were used as independent variables on first difference annual cocoa yield. Additionally, another bounds test for cointegration were conducted where changes in MnRF, MxRF, MnTmP and MxTmP were used as independent variables on change in annual cocoa yield the model in order to examine their [1]L-RN and S-RN effects on each on the variables of interest. The results generated from Stata are presented in Table 4.4.

Table 4. 4: ARDL-Error Correction estimates of ΔanRFt and ΔanTmPt on ΔCYLDt

D.$\Delta CYLD_t$	Coef.[2]	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ÆȿƤĐ						
$\Delta CYLD_t$						
L1	–1.437	0.521	–2.76	0.025	–2.638427	–0.23581
L-RN						
$\Delta anRF_t$	0.300	38.382	0.01	0.994	–83.59842	84.19755
$\Delta anTmP_t$	128.764	1010.032	0.13	0.902	–2200.373	2457.902
S-RN						
_cons	7452.355	8106.028	0.92	0.385	–11240.18	26144.89

Source: Secondary Data (2019) from COCOBOD & Landsat 7 Thermal Band

Table 4.4 depicts the data results obtained from the cointegration models employed in the study. The term ÆȿƤĐ denotes the adjustment speed parameter or reactive effect which is obtained as the stochastic error term from L-RN ARDL models. More specifically, the ÆȿƤĐ indicates how fast the disequilibrium point is fixed to ensure stability.

Thus the ÆȿƤĐ shows the extent to which any disequilibrium in the previous period is being adjusted in the dependent variable in the current period.

[1] The L-RN ARDL models were estimated based on the Akaike Information Criterion (AIC), using a lag of one year interval annual data property in thirteen year period, from 2003 to 2016 [(i.e. lags (1 0 0) aic].

[2] ÆȿƤĐ: Adjustment coefficient or the error correction coefficients.
L-RN: L-RN estimates
S-RN: S-RN estimates
$\Delta CYLD_t = 7452.36 - 0.300\Delta anRF_t + 128.76\Delta anTmP_t$: L-RN estimated model

Using change in annual cocoa yield ($\Delta CYLD_t$) as dependent variable and change in anRF ($\Delta anRF_t$) and change in anTmP ($\Delta anTmP_t$) as independent variables, the error correction coefficient (–1.437) is found to be very high in magnitude in absolute terms, and is significant at 5 percent alpha level. The negative nature of the error correction coefficient was expected because according to Gujarati (2004) the error correction mechanism is expected to be negative to correct the disequilibrium errors in the previous period in order to restore equilibrium in the current period.

As shown in Table 4.4, the error correction value of –1.437 implies that there is a significant L-RN relationship among $\Delta CYLD_t$, $\Delta anRF_t$ and $\Delta anTmP_t$ which implies a very fast fine-tuning process. The speed adjustment coefficient term is more than 100 percent (143.7%) of the disequilibria of the lag fluctuations which bounce back to the L-RN equilibrium point in the present period. The bounds (Pesaran, Shin & Smith, 2001) tests confirm the existence of a L-RN relationship among change in annual cocoa yield, change in anRF and change in anTmP in the Mampong Cocoa District over time.

4.4.1 Bounds Test for Cointegration (L-RN relationship)

Table 4. 5: Kripfganz and Schneider's (2018) bounds test

	10 percent		5 percent		1 percent		p-value	
	I{o}	I{1}	I{o}	I{1}	I{o}	I{1}	I{o}	I{1}
F = 11.296	4.045	5.399	5.399	6.970	9.557	11.950	0.006	0.012
t = -5.520[3]	-2.660	-3.453	-3.137	-3.993	-4.251	-5.265	0.002	0.007

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

[3] **Rule of thumb**
Do not reject H0 if both F and t are closer to zero than critical values for I{o} variables (if p-values > desired level for I{o} variables)
Reject H0 if both F and t are more extreme than critical values for I{1} variables (if p-values < desired level for I{1} variables)

From Table 4.5, it is observed from Pesaran, Shin and Smith's (2001) bounds test with Kripfganz and Schneider's (2018) critical values and approximate p-values that both F and t are more extreme than critical values for the series, and that the null hypothesis that there is no cointegration (L-RN relationship) among change in annual cocoa yield, change in anRF and change in anTmP in the Mampong Cocoa District over time is rejected.

Table 4. 6: Bounds Test for ARDL model

	{I_o} (L_1)	{I_1} (L_1)	{I_o} (L_05)	{I_1} (L_05)	{I_o} (L_025)	{I_1} (L_025)	{I_o} (L_01)	{I_1} (L_01)
F= 11.296	3.17	4.14	3.79	4.85	4.41	5.52	5.15	6.36
t = -5.520[4]	-2.57	-3.21	-2.86	-3.53	-3.13	-3.80	-3.43	-4.10

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

The L-RN relationship is supported by Pesaran, Shin and Smith's (2001) ARDL bounds test. Thus the F-statistic, as shown in Table 4.6, exceeds the upper bounds of the critical value bands. This implies that there is enough evidence to reject the null hypothesis of no cointegration (i.e. L-RN relationship) between change in annual cocoa yield and its determinants (change in anRF and change in anTmP).

More specifically, the results show that in the L-RN, a percentage change (increase) in anRF ($\Delta anRF_t$) is associated with 30 percent change (increase) in the annual cocoa yield ($\Delta CYLD_t$) although such a change is insignificant. The coefficient of anRF was expected to be negative, indicating an inverse relationship between anRF and annual cocoa yield. The L-RN relationship between change in anTmP and change in cocoa

[4] **Rule of thumb**

Accept Ho if F < critical value for I {o} regressors; Reject Ho if F > critical value for I{1} regressors.
Accept Ho if t > critical value for I {o} regressors; Reject Ho if t < critical value for I{1} regressors

yield is very high. Thus a unit change (increase) in the change in anTmP leads to 128.76 change (increase) in the annual cocoa yield ($\Delta CYLD_t$). This observation suggests that $\Delta anRF_t$ and $\Delta anTmP_t$ have a joint significant influent effect on change in annual cocoa yield ($\Delta CYLD_t$) in the L-RN but their individual effects on change in cocoa yield ($\Delta CYLD_t$) are not significant in the L-RN. Table 4.7 presents the S-RN estimate of the effect of change in anTmP and change in anRF on change in annual cocoa yield.

Table 4. 7: S-RN ARDL results: ΔCYLDt ΔanRFt ΔanTmPt, lags (1 0 0) aic

$\Delta CYLD_t$	Coef.[5]	Std. Err	t	P>|t|	[95% Conf.	Interval]
ΔCYLD| L1.	-0.437	0.521	-0.84	0.426	-1.6384	0.7642
ΔanRF	0.437	52.389	0.01	0.994	-120.3788	121.2399
ΔanTmP	185.05	1395.77	0.13	0.898	-3033.61	3403.71
_cons	7452.36	8106.03	0.92	0.385	-11240.18	26144.89

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.7 presents the S-RN ARDL regression outcome for the effect of first lag of change in cocoa yield, change in anRF, and change in anTmP on change in cocoa yield. The results show that a percentage change (increase) in the first lag of change in cocoa yield is associated with 0.437 decrease in the cocoa yield on average in the S-RN, ceteris paribus. However, the effect of the first lag of change in cocoa yield on current cocoa yield is insignificant. On the other hand, both change in anRF and change in anTmP have insignificant effect on change in annual cocoa yield in the S-RN period. The insignificant impacts of the first lag of change in cocoa yield, change in anRF, and change in anTmP on change in cocoa yield in the S-RN, is reflected in the R-square

[5] $\Delta CYLD_t = 7452.36 + 0.24\ \Delta CYLD.L1 + 0.44 \Delta anRF_t + 185.05 \Delta anTmP_t$.: S-RN estimated model dynamics

value of 0.2784, which shows that in the S-RN, only approximately 28 percent of variation in the cocoa yield is jointly explained (influenced) by first lag of change in cocoa yield, change in anRF and change in anTmP.

Based on these findings, inference could be made that although the impact of $\Delta anFR_t$ and $\Delta anTmP_t$ on $\Delta CYLD_t$ is insignificant, they have positive influence on $\Delta CYLD_t$ in the S-RN.

4.4.2 Post estimation test for serial correlation and heteroscedasticity for L-RN and S-RN models

$\Delta CYLD_t = 7452.36 – 0.300\Delta anRF_t + 128.76\Delta anTmP_t$: L-RN estimated model…(4.1)

$\Delta CYLD_t = 7452.36 + 0.24\ \Delta CYLD.L1 + 0.44\Delta anRF_t + 185.05\Delta anTmP_t$. : S-RN estimated model dynamics…………………………………………………….(4.2)

In testing for serial correlation and heteroscedasticity of the error correction models for change in cocoa yield ($\Delta CYLD_t$), Durbin-Watson d-statistic test and Breusch-Godfrey test for autocorrelation were adopted in testing serial correlation in the models, while White test was employed to test for the presence of heteroscedasticity in the model. Durbin-Watson d-statistic test = 2.761 shows no evidence serial correlation. This is supported by Breusch-Godfrey test for autocorrelation [lags(p) = 1; chi2 = 7.098; df = 1; prob>chi2 = 0.0077]. This implies that the null hypothesis (Ho) that the models for ΔCYLDt are affected by the presence of serial correlation is rejected. Based on the White test results [Chi2 (14) = 7.39; Prob> chi2 = 0.5965] there is no heteroskedasticity in the model, and that the null hypothesis that the model for $\Delta CYLD_t$ suffers from heteroskedasticity is rejected.

Table 4.8: ARDL-Error Correction model (ECM) of ΔMxRFt and ΔMnTmPt on ΔCYLDt

$D.\Delta CYLD_t$	Coef.[6]	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ӕȿƤĐ						
$\Delta CYLD_t$						
L1	–1.352	0.251	–-5.38	0.001	–1.93146	–0.77198
L-RN						
$\Delta MxRF_t$	3.813	56.837	0.07	0.948	–127.2537	134.879
$\Delta MnTmP_t$	1054.553	717.9252	1.47	0.180	–600.9852	2710.092
S-RN						
_cons	6848.563	6850.233	1.00	0.347	–8948.102	22645.23

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.8 exhibits the results of error correction model for change in cocoa yield in the L-RN. In the model, change in cocoa yield ($\Delta CYLD_t$) was used as dependent variable while change in MxRF ($\Delta MxRF_t$) and change in MTmP ($\Delta MnTmP_t$) were considered as independent variables. The adjustment speed (ӕȿƤĐ) of –1.352 is found to be very high in terms of magnitude, and is statistically significant at one percent alpha level. The adjustment coefficient was expected to be negative to correct the disequilibrium errors in the previous period in order to restore equilibrium in the current period. The error correction coefficient of –1.352 indicates that approximately 135 percent of the adjustment takes place within each of the previous periods.

This implies that the rate at which disequilibrium in the previous period was being adjusted in change in cocoa yield in the current period is very fast.

[6] $\Delta CYLD_t$= 6848.56 – 1.35$\Delta CYLD_t$ L1. + 3.81$\Delta MxRF_t$ + 1054.55$\Delta MnTmP_t$: L-RN estimated model
Adjustment error correction coefficient (ӕȿƤĐ) = –1.352; p = 0.001 (Highly significant at 1%)

The error correction coefficient (–1.352) shows that there is a significant L-RN relationship among $\Delta CYLD_t$, $\Delta MxRF_t$, and $\Delta MnTmP_t$ which is established through a very fast adjustment process. The bounds (Pesaran, Shin & Smith, 2001) tests confirm the existence of a L-RN relationship among change in cocoa yield, change in MxRF and change in MTmP in the Mampong Cocoa District over the period under investigation. The F-statistic of Pesaran, Shin and Smith's (2001) ARDL bounds test (see Appendix II Table b) exceeds the upper bounds of the critical value bands. This implies that there is enough evidence to reject the null hypothesis of no cointegration (i.e. L-RN relationship) between change in cocoa yield and its determinants ($\Delta MxRF_t$ and $\Delta MnTmP_t$). This finding is consistent with the study of Ibn-Musah *et al.* (2018) whose study results indicate that extreme MxRF adversely affects cocoa production in the L-RN, all things being equal.

Table 4.9: S-RN ARDL results: ΔCYLDt ΔMxRFt ΔMnTmPt, lags (1 0 0) aic

$\Delta CYLD_t$	Coef.	Std. Err	t	P>|t|	[95% Conf.	Interval]
ΔCYLD| L1.	-0.352	0.251	-1.40	0.199	-0.931	0.228
$\Delta MxRF_t$	5.154	76.655	0.07	0.948	-171.614	181.921
$\Delta MnTmP_t$	1425.459	872.728	1.63	0.141	-587.054	3437.973
_cons	6848.563	6850.233	1.00	0.347	8948.102	22645.230

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.9 exhibits the S-RN ARDL regression results. The results show that a percentage change (increase) in the first lag of change in cocoa yield is associated with 0.352 change (decrease) in the cocoa yield on average in the S-RN, all things being constant. However, the effect of the first lag of change in cocoa yield on current cocoa yield is not significant. Although the individual impacts of change in MxRF and change in MTmP on change in cocoa yield in the S-RN, are not significant, the R-square value of 0.4708 shows that in the S-RN, approximately 47 percent of variation in the cocoa yield is jointly explained (influenced) by first lag of change in cocoa yield, change in MxRF and change in MnTmP.

Comparatively, the results obtained from the S-RN and L-RN ARDL estimation show that whereas the impact of first lag of change in cocoa yield on the current cocoa yield is highly significant in the L-RN, the S-RN impact of first lag of change in cocoa yield on the current cocoa yield is insignificant. However, the impact of change in MxRF (5.154) and change in MTmP (1425.46) on cocoa yield in the S-RN is greater than that of change in MxRF (3.81) and change in MTmP (1054.55) on cocoa yield in the L-RN, although the impact of both $\Delta MxRF_t$ and $\Delta MnTmP_t$ on $\Delta CYLD$ in the L-RN and S-RN periods is positive. These findings suggest that the impact of the change in MxRF and change in MnTmP on cocoa yield in the S-RN is great, and should be given the needed attention.

4.4.3 Post estimation test for serial correlation and heteroscedasticity for L-RN and S-RN models

$\Delta CYLD_t$= 6848.56 – 1.35$\Delta CYLD_t$ L1. + 3.81$\Delta MxRF_t$ + 1054.55$\Delta MnTmP_t$: L-RN estimated model dynamics………………………………………………… (4.3)

$\Delta CYLD_t$ = 6848.56 – 0.352$\Delta CYLD_t$ L1. + 5.15$\Delta MxRF_t$ + 1425.459$\Delta MnTmP_{t:}$ S-RN estimated model dynamics…………………………………………….. (4.4)

Durbin-Watson d-statistic test = 2.091 shows no evidence serial correlation. This is supported by Breusch-Godfrey test for autocorrelation [lags (p) = 1; chi2 = 0.318; df = 1; prob>chi2 = 0.573]. This implies that of null hypothesis (Ho) that the L-RN and S-RN models are affected by the presence of serial correlation is rejected. Based on the White test results [Chi2 (9) = 9.44; Prob> chi2 = 0.398] there is no heteroskedasticity in the model, and that the null hypothesis that the L-RN and S-RN models suffer from heteroskedasticity is rejected.

Table 4.10: ARDL-Error Correction model (ECM) of ΔMxTmPt and ΔMnRFt on ΔCYLDt

D.ΔCYLD$_t$	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ᴁȘƤĐ ΔCYLD$_t$						
L1	–1.770	0.284	–6.23	0.000	–2.42449	–1.11517
L-RN ΔMxTmP$_t$	–564.50	309.40	–1.82	0.106	–1277.98	148.989
ΔMnRF$_t$	–275.62	1078.18	–0.26	0.805	–2761.90	2210.663
S-RN _cons	8162.59	6826.01	1.20	0.266	–7578.21	23903.39

ΔCYLD$_t$= 8162.59– 1.770ΔCYLD$_t$ L1. –564.496ΔMxTmP$_t$ + –275.618ΔMnRF$_t$: L-RN estimated model dynamics
Adjustment error correction coefficient (ᴁȘƤĐ) = –1.770; p = 0.000 (Highly significant)

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

The coefficient of error correction (–1.770), as expected, is negative and is highly statistically significant at one percent alpha level. This shows that there is a L-RN relationship among change in MxTmP and change in MnRF and change in cocoa yield. The bounds tests, as shown in Appendix II Table (c) also confirm the existence of a L-RN relationship change in MxTmP and change in MnRF and change in cocoa yield in the Mampong Cocoa District over the period under investigation. The adjustment error coefficient of –1.770 indicates that more than 100 percent of the adjustment takes place within each of the previous periods. This means that there is an instant and full adjustment error correction in the previous periods, which established equilibrium for difference in cocoa yield in the current period.

The L-RN model results, as shown in Table 10 reveal that the percentage change (increase) in MxTmP will lead to –564.496 change (decrease) in cocoa yield ($\Delta CYLD_t$) in the L-RN. Although the coefficient of $\Delta MxTmP_t$ (–564.496) is not statistically significant, a unit increase in $\Delta MxTmP_t$ will affect cocoa yield to reduce by approximately 564.50 tons in the L-RN, all things being equal. The results further show that in the L-RN, a percentage change (increase) in MnRF is associated with –275.618 percent change (decrease) in $\Delta CYLD_t$. These findings show that there is an inverse relationship between change in MxTmP and change in MnRF and change in cocoa yield in the L-RN. However, there is statistically significant inverse relationship between first lag of change in cocoa yield and the current change in cocoa yield at one percent alpha level. This observation is contrary to Wiah's (2017) model which establishes that there exist a direct relationship between cocoa yield and change in MxTmP.

4.4.4 Post estimation test for serial correlation and heteroscedasticity for L-RN and S-RN model

$\Delta CYLD_t$= 8162.59 – 1.770$\Delta CYLD_t$ L1. –564.496$\Delta MxTmP_t$ – 275.618$\Delta MnRF_t$: L-RN estimated model dynamics…………………………………… (4.5)

$\Delta CYLD_t$ = 8162.59 – 0.770$\Delta CYLD_t$ L1. – 999.060$\Delta MxTmP_t$ – 487.795$\Delta MnRF_{t:}$ S-RN estimated model dynamics……………………………………… (4.6)

Durbin-Watson d-statistic test = 3.062 shows no evidence serial correlation. This is supported by Breusch-Godfrey test for autocorrelation [lags (p) = 1; chi2 = 7.574; df = 1; prob>chi2 = 0.0059]. This implies that of null hypothesis (Ho) that the L-RN and S-RN models are affected by the presence of serial correlation is rejected. Based on the White test results [Chi2 (9) = 8.42; Prob> chi2 = 0.4924] there is no heteroskedasticity in the model, and that the null hypothesis that the L-RN and S-RN models suffer from heteroskedasticity is rejected.

Table 4.11: S-RN ARDL results: ΔCYLDt ΔMxTmPt ΔMnRFt, lags (1 0 0) aic

$\Delta CYLD_t$	Coef.	Std. Err	t	P>|t|	[95% Conf.	Interval]
ΔCYLD| L1.	-0.770	0.284	-2.71	0.027	-1.424	-0115
$\Delta MxTmP_t$	-999.060	620.335	-1.61	0.146	-2429.555	431.435
$\Delta MnRF_t$	-487.795	1902.443	-0.26	0.804	-4874.836	3899.245
_cons	8162.594	6826.006	1.20	0.266	-7578.205	23903.390

Source: Secondary Data (2019) from COCOBOD, CHIRPS & Landsat 7 Thermal Band

Table 4.11 shows S-RN ARDL regression output. The results show that a percentage change (increase) in the first lag of change in cocoa yield is associated with 0.770 change (decrease) in the cocoa yield on average in the S-RN, which is statistically significant at 5 percent alpha level all things being constant. The results further show that both change in MxRF and change in MTmP have negatively insignificant relationship with change in cocoa yield in the S-RN. The R-square value of 0.4971 shows that in the S-RN, approximately 50 percent of variation in the cocoa yield is jointly explained (influenced) by first lag of change in cocoa yield, change in MxTmP and change in MnRF. Comparatively, the results obtained from the S-RN and L-RN ARDL estimation show that although there is negatively insignificant relationship between changes in MxTmP (coeff. = -999.06) and change in MnRF (coeff. = – 487.80) and change in cocoa yield, the S-RN impact on cocoa yield is greater than the L-RN impact of change in MxTmP (coeff. = -564.50) and change in MnRF (coeff. = – 275.618) on cocoa yield. These findings imply that the impact of the change in MxTmP and change in MnRF on cocoa yield in the S-RN is greater than their impact on cocoa yield in the S-RN. Inference can therefore be made that cocoa yield could fall greatly in the S-RN than in the L-RN periods when there is greater change in MxTmP and MnRF.

4.5.Test for ARDL models' stability

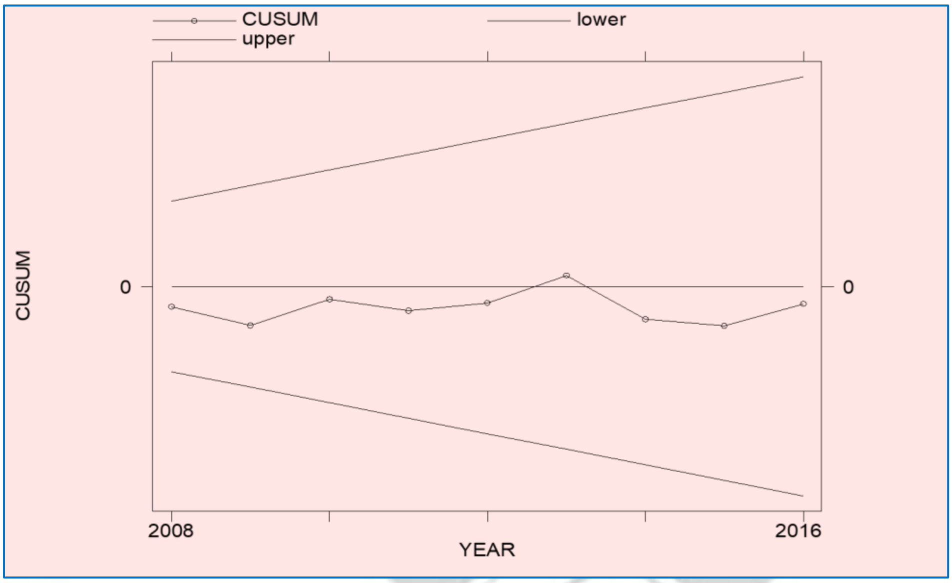

Figure 4. 4: CUSUM for ∆CYLDt ∆anFRt ∆anTmPt, lags (1 0 0) ec

Source: Secondary Data (2019) from COCOBOD & GIS Satellite image

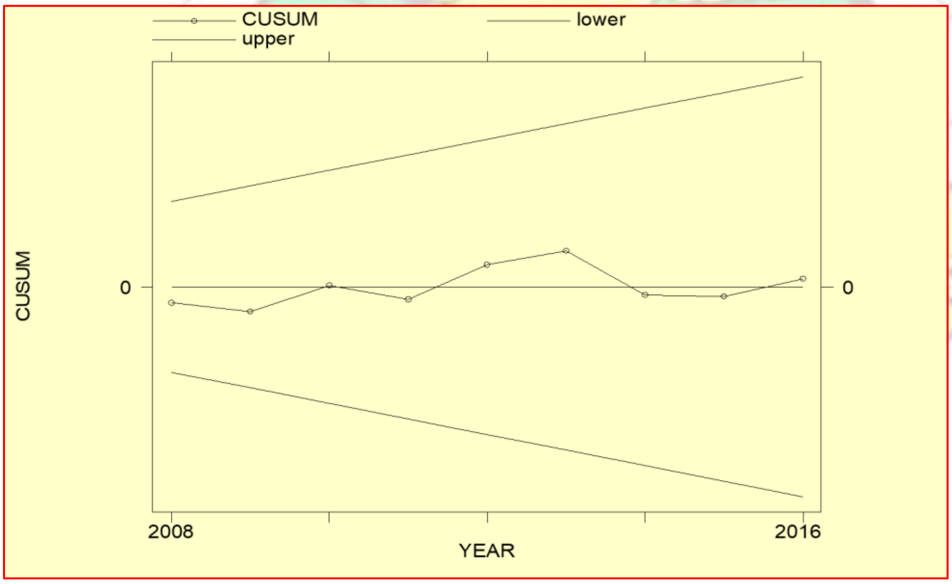

Figure 4. 5: CUSUM for ∆CYLDt ∆MxRFt ∆MnTmPt, lags (1 0 0) ec

Source: Secondary Data (2019) from COCOBOD & GIS Satellite image

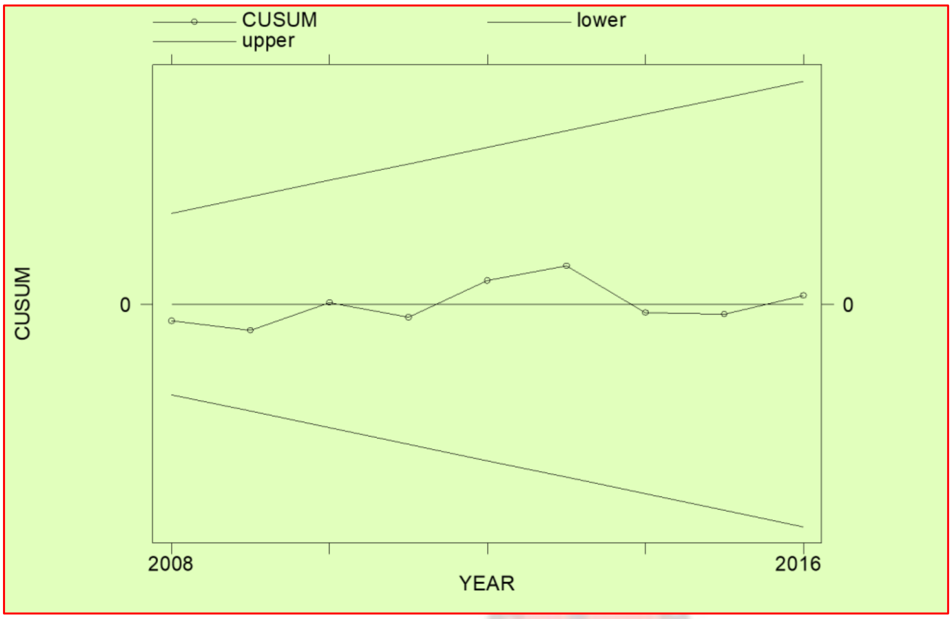

Figure 4. 6: CUSUM for ∆CYLDt ∆MxTmPt ∆MnRFt, lags (1 0 0) ec

Source: Secondary Data (2019) from COCOBOD & GIS Satellite image

Cumulative sum (CUSUM) graph was used to test the stability of the ARDL models adopted for the estimation of the L-RN and S-RN relationship among MnTmP, MxTmP, MnRF, MxRF and cocoa yield. According to Zeileis et al. (2002), CUSUM test allows a more robust estimation which gives more information about ARDL models used to examine L-RN relationship among specified variables. In that regard, Turner (2010) concludes that CUSUM test produces more robust results than cumulative sum squared (CUSUMQ) test. The CUSUM test is based on the recursive residuals of the evaluated model and is plotted against break points. The rule of thumb is that if plot of CUSUM statistics stay outside the critical bounds of 5 percent alpha level, then the null hypothesis of coefficients' instability in the error correction model cannot be rejected. However, there would be enough evidence to reject the null hypothesis if plot of CUSUM statistics stay within the critical bounds of 5 percent alpha level (Turner, 2010; Zeileis *et al*., 2002). As observed from Figure 4.4, Figure 4.5 and Figure 4.6, the plots of CUSUM stay within the critical 5 percent bounds (upper and lower bounds) that confirm the L-RN relationships among anRF, anTmP, MnTmP, MxTmP, MnRF, MxRF and cocoa yield and thus show the stability of the models' coefficients. These show that the null hypothesis of coefficients' instability in the error correction model is rejected.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter concentrates on the summary of the study, the conclusions drawn from the findings and recommendations made for policy implication. The final section of the chapter also focuses on the areas for further research, highlighting the alternative approach that could be employed by future researchers to investigate the problem under investigation in the broader manner. The summary, conclusion and recommendation are based on the study's objective in assessing the impact of rainfall pattern on cocoa yield in the Mampong Cocoa District.

5.1 Summary of the Study

This study was carried to assess the impact of rainfall pattern on cocoa yield in the Mampong Cocoa District in the Ashanti Region. The four specific objectives the study sought to achieve were: (1) to analyze the L-RN and S-RN relationship between cocoa yield and anRF and anTmP in the Mampong Cocoa District; (2) to examine the L-RN and S-RN relationship between cocoa yield and MxRF and MnTmP in the Mampong Cocoa District; (3) to analyze the L-RN and S-RN relationship between cocoa yield and MxTmP and MnRF in the Mampong Cocoa District; and (4) to test models' stability for cocoa yield, anRF, anTmP, MnRF and MxRF and MnTmP and MxTmP.

The various empirical underpinnings reviewed within the scope of the study's objectives showed that Rainfall and temperature are some of the major environmental factors that influence the yields of cash crops such as cocoa. Longitudinal research design was adopted for the study's data collection and analysis procedure. Secondary data were used as the main source of data for the study. The study of this nature required the use of secondary data, and that time series data covering the period of thirteen (13) years, starting from 2003 to 2016 were used for the study. Specifically, data on anRF, anTmP, MxTmP, MnTmP and minimum and MxRF were generated using geographic information system (GIS), while data on cocoa yield and average age of cocoa farms were gathered from Ghana COCOBOD (2018) and Quality Control (2018) official report.

In this regard, quantitative analysis was employed to analyze the collected data. Thus using time series data, quantitative analysis was adopted to provide empirical basis for the problem under investigation. In addition, using empirical models based on past data, Auto Regressive Distributed Lag (ARDL) estimation was adopted to make future predictions. The study however employed Auto Regressive Distributed Lag (ARDL) model considered to be more robust to examine both S-RN and L-RN relationship between some specific independent variables (anRF, anTmP, MnTmP, MxTmP, MnRF and MxRF) and the dependent variable (cocoa yields) employed in the study. In this regard, the study employed inferential research approach where the data analysis was done comparatively. The analysis of data was done using the Microsoft Excel 2013 version and Stata software version 13. Date results were presented using tables and graphs.

5.2 Conclusions

Based on the specific objectives of the study, the following conclusions were made:

Objective 1: *To analyze the L-RN and S-RN relationship between cocoa yield and anRF and anTmP in the Mampong Cocoa District.*

On the basis of the first objective, which was to analyze the L-RN and S-RN relationship between cocoa yield and anRF and anTmP in the Mampong Cocoa District, the study concludes that there is a significant L-RN relationship among change in cocoa yield and change in anRF and change in anTmP in the Mampong Cocoa District over time. This conclusion suggests that there is a L-RN relationship among change in cocoa yield, change in anRF and change in anTmP without any S-RN influence which could cause these variables to deviate from L-RN equilibrium point

Objective 2: *To examine the L-RN and S-RN relationship between cocoa yield and MxRF and MnTmP in the Mampong Cocoa District.*

Based on the second objective, which was to examine the L-RN and S-RN relationship between cocoa yield and MxRF and MnTmP in the Mampong Cocoa District, conclusion can be drawn that impact of first lag of change in cocoa yield on the current cocoa yield is highly significant in the L-RN. On the other hand, the S-RN impact of first lag of change in cocoa yield on the current cocoa yield is insignificant. This implies that previous cocoa yield in the Mampong Cocoa District can be used to predict change in the current cocoa yield.

Objective 3: *To examine the L-RN and S-RN relationship between cocoa yield and MxTmP and MnRF in the Mampong Cocoa District.*

The study further concludes that there is an existence of a L-RN relationship between change in MxTmP and change in MnRF and change in cocoa yield in the Mampong Cocoa District. In addition, there is likelihood that an instant and full adjustment of errors will be corrected in the previous periods, which will invariably establish equilibrium for difference in cocoa yield in the current period. Comparatively, the S-RN impact of changes in MxTmP and change in MnRF and change on cocoa yield is greater than the L-RN impact of change in MxTmP and change in MnRF on cocoa yield.

Objective 4: *To test ARDL models' stability for predicting cocoa yield, using anRF, anTmP, MnRF and MxRF and MnTmP and MxTmP*

The study further concludes that adopting ARDL models as appropriate analytical technique for the estimation of the L-RN and S-RN relationship among MnTmP, MxTmP, MnRF, MxRF and cocoa yield could produce reliable and unbiased result due to the existence of statistical stability in such models. In this regard, making predictions on cocoa yield using stable empirical model like ARDL techniques would have the tendency of ensuring accuracy and precision in quantitative analysis.

5.4 Recommendations

The study proposes the following recommendations to guide future research that would aim at assessing how rainfall and temperature patterns affect cocoa yield in Ghana:

1. Broad operationalization should be made in future studies to incorporate more environmental variables to widen the scope of the studies. Thus the use of only rainfall and temperature values in predicting cocoa yield may limit the scope of the study's analysis.
2. Cross sectional design and primary data analysis should be adopted by future researchers as an alternative approaches in future studies related to possible determinants (environmental factors) of cocoa yield. Although the study acknowledged the fact that there are different types of data, due to time constraints, the study was limited to the use of secondary data in time series form. It is therefore recommended that future researcher should rely on first hand primary data specifically, in doing analysis on impact of rainfall and temperature pattern on cocoa yield in more than one cocoa district.
3. The time frame for future studies should be extended beyond 13 year period to predict long run relationship among environmental variables like rainfall and temperature. Thus issues regarding cocoa production in Ghana have existed for

over sixty year, but due to unavailability of a comprehensive secondary data on the problem under investigation, the study focused on data which cover only thirteen-year period. These limitations may restrict the scope of the study's analysis and discussions.

4. A combination of different analytical tools other than ARDL models should be used by prospective researcher, especially those in the cocoa sector, in conjunction with Ghana Meteorological Department, to triangulate data analysis that would seek to examine the impact of various environmental factors on cocoa yield on both quarterly and annual basis. It is specifically recommended that analytical tools such as Pearson's product moment correlation, Ordinary Least Square (OLS) multiple regression as well as measures of central tendency should be adopted to carry out data analysis in future studies.

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APPENDIX A: ADF test for unit root results

Table (i): ADF test for unit root for change in Cocoa Yield

```
. dfuller DiffCYLD, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -6.653            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
D.DiffCYLD   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffCYLD |
         L1. |  -2.807173   .4219452    -6.65   0.000    -3.804915   -1.809431
         LD. |   .7774877   .2295237     3.39   0.012     .2347505    1.320225
      _trend |  -2251.707   1791.724    -1.26   0.249     -6488.46    1985.046
       _cons |   28718.16   14364.63     2.00   0.086    -5248.797    62685.12
------------------------------------------------------------------------------

. dfuller DiffCYLD, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution -----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -6.399            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0001

------------------------------------------------------------------------------
  D.DiffCYLD |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffCYLD |
         L1. |  -2.624042    .410072    -6.40   0.000     -3.56967   -1.678414
         LD. |   .6703677   .2206915     3.04   0.016     .1614522    1.179283
             |
       _cons |   12068.84   5749.909     2.10   0.069    -1190.474    25328.16
------------------------------------------------------------------------------
```

Table (ii): ADF test for unit root for change in AnRF

```
. dfuller DiffanRF, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.059            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1164

------------------------------------------------------------------------------
D.DiffanRF   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffanRF |
         L1. |  -1.751255   .5725784    -3.06   0.018    -3.105188   -.3973224
         LD. |   .4009975   .3571453     1.12   0.299     -.443517    1.245512
      _trend |  -21.07864   23.95418    -0.88   0.408    -77.72127    35.56399
       _cons |   128.0615   178.4647     0.72   0.496    -293.9405    550.0635
------------------------------------------------------------------------------

. dfuller DiffanRF, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.990            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0087

------------------------------------------------------------------------------
  D.DiffanRF |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffanRF |
         L1. |  -1.556842   .5207325    -2.99   0.017    -2.757653   -.3560306
         LD. |   .3254536   .3417489     0.95   0.369    -.4626209    1.113528
             |
       _cons |  -16.37816   69.05068    -0.24   0.818    -175.6093     142.853
------------------------------------------------------------------------------
```

Table (iii): ADF test for unit root for change in AnTmP

```
. dfuller DiffanTmP, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.219            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0806

------------------------------------------------------------------------------
D.DiffanTmP  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffanTmP |
         L1. |  -1.657839   .5149584    -3.22   0.015    -2.875522    -.440156
         LD. |   .1871397   .3080712     0.61   0.563     -.541333    .9156124
      _trend |  -1.301548    .925538    -1.41   0.202    -3.490098    .8870016
       _cons |   8.674547   6.981827     1.24   0.254    -7.834849    25.18394
------------------------------------------------------------------------------

. dfuller DiffanTmP, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.807            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0115

------------------------------------------------------------------------------
 D.DiffanTmP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffanTmP |
         L1. |  -1.489499   .5305709    -2.81   0.023    -2.712998   -.2660006
         LD. |   .0887773   .3178285     0.28   0.787    -.6441366    .8216912
             |
       _cons |  -.2655137   3.057487    -0.09   0.933    -7.316092    6.785065
------------------------------------------------------------------------------
```

Table (iv): ADF test for unit root for change in MxRF

```
. dfuller DiffMxRF, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.742            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0197

------------------------------------------------------------------------------
D.DiffMxRF   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffMxRF |
         L1. |  -2.222178   .5938603    -3.74   0.007    -3.626435    -.817922
         LD. |   .5636648   .3457173     1.63   0.147    -.2538268    1.381156
      _trend |  -.8726048   8.833167    -0.10   0.924    -21.75972    20.01452
       _cons |   12.97667   67.52068     0.19   0.853    -146.6844    172.6377
------------------------------------------------------------------------------

. dfuller DiffMxRF, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.022            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0019

------------------------------------------------------------------------------
  D.DiffMxRF |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffMxRF |
         L1. |  -2.214056    .550539    -4.02   0.004    -3.483601   -.9445109
         LD. |   .5586007   .3200369     1.75   0.119    -.1794057    1.296607
             |
       _cons |   6.896335   25.98612     0.27   0.797    -53.02776    66.82043
------------------------------------------------------------------------------
```

Table (v): ADF test for unit root for change in MnRF

```
. dfuller DiffMnRF, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.038            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1218

------------------------------------------------------------------------------
D.DiffMnRF   |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffMnRF |
         L1. |  -2.020623   .6651798    -3.04   0.019    -3.593523   -.4477222
         LD. |   .3596729    .399616     0.90   0.398    -.5852687    1.304615
      _trend |   .3157425   .4062284     0.78   0.462     -.644835     1.27632
       _cons |  -3.503176   3.231945    -1.08   0.314    -11.14551     4.13916
------------------------------------------------------------------------------

. dfuller DiffMnRF, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution -----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.030            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0082

------------------------------------------------------------------------------
  D.DiffMnRF |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    DiffMnRF |
         L1. |  -1.837103   .6062825    -3.03   0.016    -3.235193    -.439013
         LD. |   .2470903   .3631091     0.68   0.515    -.5902409    1.084422
             |
       _cons |  -1.187637   1.221703    -0.97   0.359    -4.004889    1.629615
------------------------------------------------------------------------------
```

Table (vi): ADF test for unit root for change in MxTmP

```
. dfuller DiffMxTmP, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -2.933            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1518

------------------------------------------------------------------------------
D.DiffMxTmP  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffMxTmP |
         L1. |  -1.973934   .6730417    -2.93   0.022    -3.565424    -.382443
         LD. |   .2779324   .4073839     0.68   0.517    -.6853774    1.241242
      _trend |   .8130895   1.461285     0.56   0.595      -2.6423    4.268479
       _cons |   -6.49649   11.14134    -0.58   0.578    -32.84158     19.8486
------------------------------------------------------------------------------

. dfuller DiffMxTmP, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution -----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.019            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0083

------------------------------------------------------------------------------
 D.DiffMxTmP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffMxTmP |
         L1. |  -1.879992   .6227749    -3.02   0.017    -3.316114   -.4438709
         LD. |    .243523   .3848961     0.63   0.545     -.644049    1.131095
             |
       _cons |  -.8132049   4.253778    -0.19   0.853    -10.62243    8.996024
------------------------------------------------------------------------------
```

Table (vii): ADF test for unit root for change in MnTmP

```
. dfuller DiffMnTmP, trend regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.766            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0005

------------------------------------------------------------------------------
D.DiffMnTmP  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffMnTmP |
         L1. |  -2.125027   .4458671    -4.77   0.002    -3.179335   -1.070719
         LD. |   .5818988   .2526942     2.30   0.055     -.015628    1.179426
      _trend |   -.873181   .7712257    -1.13   0.295     -2.69684    .9504778
       _cons |   7.221567   5.982321     1.21   0.267    -6.924375    21.36751
------------------------------------------------------------------------------

. dfuller DiffMnTmP, drift regress lags(1)

Augmented Dickey-Fuller test for unit root         Number of obs   =        11

                               ----------- Z(t) has t-distribution ----------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.553            -2.896            -1.860            -1.397
------------------------------------------------------------------------------
p-value for Z(t) = 0.0009

------------------------------------------------------------------------------
 D.DiffMnTmP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   DiffMnTmP |
         L1. |  -1.989347    .436961    -4.55   0.002    -2.996981   -.9817128
         LD. |   .4849506    .241896     2.00   0.080    -.0728626    1.042764
             |
       _cons |   .9771816   2.357787     0.41   0.689    -4.459885    6.414248
------------------------------------------------------------------------------
```

APPENDIX B: Bounds Test for Cointegration (L-RN relationship)

Table (a): Test of Cointegration for $\Delta anFR_t$ $\Delta anTmP_t$ on $\Delta CYLD_t$

```
Pesaran/Shin/Smith (2001) ARDL Bounds Test
H0: no levels relationship            F =  11.296
                                      t = -5.520

Critical Values (0.1-0.01), F-statistic, Case 3

      | [I_0]   [I_1] | [I_0]   [I_1] | [I_0]   [I_1] | [I_0]   [I_1]
      |   L_1     L_1 |  L_05    L_05 | L_025   L_025 |  L_01    L_01
------+---------------+---------------+---------------+--------------
  k_2 |  3.17    4.14 |  3.79    4.85 |  4.41    5.52 |  5.15    6.36
accept if F < critical value for I(0) regressors
reject if F > critical value for I(1) regressors

Critical Values (0.1-0.01), t-statistic, Case 3

      | [I_0]   [I_1] | [I_0]   [I_1] | [I_0]   [I_1] | [I_0]   [I_1]
      |   L_1     L_1 |  L_05    L_05 | L_025   L_025 |  L_01    L_01
------+---------------+---------------+---------------+--------------
  k_2 | -2.57   -3.21 | -2.86   -3.53 | -3.13   -3.80 | -3.43   -4.10
accept if t > critical value for I(0) regressors
reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship
Critical values from Pesaran/Shin/Smith (2001)

.
end of do-file

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship                                   F =    11.296
Case 3                                                      t =    -5.520

Finite sample (2 variables, 12 observations, 0 short-run coefficients)

Kripfganz and Schneider (2018) critical values and approximate p-values

   | 10%                | 5%                 | 1%                 | p-value
   |     I(0)      I(1) |     I(0)      I(1) |     I(0)      I(1) |     I(0)      I(1)
---+--------------------+--------------------+--------------------+-------------------
 F |    4.045     5.317 |    5.399     6.970 |    9.557    11.950 |    0.006     0.012
 t |   -2.660    -3.453 |   -3.137    -3.993 |   -4.251    -5.265 |    0.002     0.007

do not reject H0 if
    both F and t are closer to zero than critical values for I(0) variables
      (if p-values > desired level for I(0) variables)
reject H0 if
    both F and t are more extreme than critical values for I(1) variables
      (if p-values < desired level for I(1) variables)
```

Table (b): Test of Cointegration for $\Delta MxRF_t$ and $\Delta MnTmP_t$ on $\Delta CYLD_t$

```
Pesaran/Shin/Smith (2001) ARDL Bounds Test
H0: no levels relationship            F =  14.111
                                      t = -5.377

Critical Values (0.1-0.01), F-statistic, Case 3

      | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
      |   L_1     L_1  |  L_05    L_05  | L_025   L_025  |  L_01    L_01
------+----------------+----------------+----------------+---------------
  k_2 |  3.17    4.14  |  3.79    4.85  |  4.41    5.52  |  5.15    6.36
accept if F < critical value for I(0) regressors
reject if F > critical value for I(1) regressors

Critical Values (0.1-0.01), t-statistic, Case 3

      | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]  | [I_0]   [I_1]
      |   L_1     L_1  |  L_05    L_05  | L_025   L_025  |  L_01    L_01
------+----------------+----------------+----------------+---------------
  k_2 | -2.57   -3.21  | -2.86   -3.53  | -3.13   -3.80  | -3.43   -4.10
accept if t > critical value for I(0) regressors
reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship
Critical values from Pesaran/Shin/Smith (2001)

.
end of do-file

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship                                  F =    14.111
Case 3                                                     t =    -5.377

Finite sample (2 variables, 12 observations, 0 short-run coefficients)

Kripfganz and Schneider (2018) critical values and approximate p-values

   | 10%                | 5%                 | 1%                 | p-value
   |    I(0)      I(1)  |    I(0)      I(1)  |    I(0)      I(1)  |    I(0)      I(1)
---+--------------------+--------------------+--------------------+-------------------
 F |   4.045     5.317  |   5.399     6.970  |   9.557    11.950  |   0.003     0.006
 t |  -2.660    -3.453  |  -3.137    -3.993  |  -4.251    -5.265  |   0.002     0.009

do not reject H0 if
    both F and t are closer to zero than critical values for I(0) variables
      (if p-values > desired level for I(0) variables)
reject H0 if
    both F and t are more extreme than critical values for I(1) variables
      (if p-values < desired level for I(1) variables)
```

Table (c): Test of Cointegration for $\Delta MxTmp_t$ and $\Delta MnRF_t$ on $\Delta CYLD_t$

Pesaran/Shin/Smith (2001) ARDL Bounds Test

H0: no levels relationship F = 14.643
t = -6.234

Critical Values (0.1-0.01), **F-statistic**, Case 3

	[I_0] L_1	[I_1] L_1	[I_0] L_05	[I_1] L_05	[I_0] L_025	[I_1] L_025	[I_0] L_01	[I_1] L_01
k_2	3.17	4.14	3.79	4.85	4.41	5.52	5.15	6.36

accept if F < critical value for I(0) regressors
reject if F > critical value for I(1) regressors

Critical Values (0.1-0.01), **t-statistic**, Case 3

	[I_0] L_1	[I_1] L_1	[I_0] L_05	[I_1] L_05	[I_0] L_025	[I_1] L_025	[I_0] L_01	[I_1] L_01
k_2	-2.57	-3.21	-2.86	-3.53	-3.13	-3.80	-3.43	-4.10

accept if t > critical value for I(0) regressors
reject if t < critical value for I(1) regressors

k: # of non-deterministic regressors in long-run relationship
Critical values from Pesaran/Shin/Smith (2001)

.
end of do-file

. estat ectest

Pesaran, Shin, and Smith (2001) bounds test

H0: no level relationship F = 14.643
Case 3 t = -6.234

Finite sample (2 variables, 12 observations, 0 short-run coefficients)

Kripfganz and Schneider (2018) critical values and approximate p-values

	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1% I(0)	1% I(1)	p-value I(0)	p-value I(1)
F	4.045	5.317	5.399	6.970	9.557	11.950	0.003	0.005
t	-2.660	-3.453	-3.137	-3.993	-4.251	-5.265	0.001	0.003

do not reject H0 if
both F and t are closer to zero than critical values for I(0) variables
(if p-values > desired level for I(0) variables)
reject H0 if
both F and t are more extreme than critical values for I(1) variables
(if p-values < desired level for I(1) variables)

APPENDIX C: Serial correlation and Heteroscedasticity Test

Table (i): Serial correlation and Heteroscedasticity Test for $\Delta anFR_t$ $\Delta anTmP_t$ on $\Delta CYLD_t$

```
. estat dwatson

Durbin-Watson d-statistic(  4,    12) =  2.760692

. estat bgodfrey, lags(1)

Breusch-Godfrey LM test for autocorrelation
```

lags(p)	chi2	df	Prob > chi2
1	7.098	1	0.0077

```
                        H0: no serial correlation

. estat imtest,white

White's test for Ho: homoskedasticity
         against Ha: unrestricted heteroskedasticity

         chi2(9)      =      7.39
         Prob > chi2  =    0.5965
```

Table (ii): Serial correlation and Heteroscedasticity Test for $\Delta MxRF_t$ and $\Delta MnTmP_t$ on $\Delta CYLD_t$

```
. estat dwatson

Durbin-Watson d-statistic(  4,    12) =  2.090861

. estat bgodfrey, lags(1)

Breusch-Godfrey LM test for autocorrelation
```

lags(p)	chi2	df	Prob > chi2
1	0.318	1	0.5728

```
                        H0: no serial correlation

. estat imtest,white

White's test for Ho: homoskedasticity
         against Ha: unrestricted heteroskedasticity

         chi2(9)      =      9.44
         Prob > chi2  =    0.3977
```

Table (iii): Serial correlation and Heteroscedasticity Test for $\Delta MxTmp_t$ and $\Delta MnRF_t$ on $\Delta CYLD_t$

```
. estat dwatson

Durbin-Watson d-statistic(  4,    12) =  3.062009

. estat bgodfrey, lags(1)

Breusch-Godfrey LM test for autocorrelation
```

lags(p)	chi2	df	Prob > chi2
1	7.574	1	0.0059

```
                        H0: no serial correlation

. estat imtest,white

White's test for Ho: homoskedasticity
         against Ha: unrestricted heteroskedasticity

         chi2(9)      =      8.42
         Prob > chi2  =    0.4924
```