**ICCCSDA 2017 Special Issue: Agriculture, Natural Resources and Renewable Energy**
**Vol 1, 29-35, 2018. JENRM**

# Effects of Rainfall and Temperature Variability on Cocoa Production in the Dormaa West District of the Brong-Ahafo Region, Ghana

E. M. Osei[1]* I. S. Egyir[2] C. Gordon[3]

**Abstract**
Climate change and variability are having severe impacts on agriculture production and food security, with yields from rain-fed agriculture in most developing countries projected to half by 2020. One such liable crop is cocoa (Theobroma cacao). This study used a time series statistical approach to measure variability in two weather parameters: temperature and precipitation, with a view to highlighting the effects on cocoa outputs from Dormaa West District. Data used was from the Ghana Meteorological Agency and the Ghana Cocoa Board for a 25-year period (1991 to 2015). The results suggest that there has been a 28.1% and 0.9% variability in average rainfall and temperature trends respectively for the period of 1991 to 2015. The variability in only rainfall accounts for 25.2% of the variations whereas variability in the only temperature accounted for 10.0% of the variations in cocoa outputs. From a general linear regression model, a combined effect of rainfall and temperature was shown to account for 25.3% variations in cocoa outputs for Dormaa West District. If trends in rainfall and temperature are to remain the same the effects of temperature on cocoa production may be limited by the increasing rainfall amount and rainfall months by making up for soil moisture losses. The study, therefore, recommends the need for programs that discourage forest depletion in the district to help boost the local average rainfall amounts to make up for soil moisture losses due to evaporation. A wider geographical spatial spread that will include other climatic variables (sunshine and humidity) should be analysed and modelled. This will help identify cocoa producing areas that are highly vulnerable to harsh weather conditions, for which farmers in those areas must adopt some specific and efficient measures to minimize their vulnerability.

**Keywords**
Cocoa production, climate variability and change, food security, rainfall, temperature

[1]Climate Change & Sustainable Development Program, University of Ghana, Legon, Accra. Email: osei1990@gmail.com
[2]Department of Agricultural Economics, University of Ghana, Legon, Accra. Email: ireneegyir@yahoo.com
[3]Institute of Environmental & Sanitation Studies, IESS, University of Ghana, Legon, Accra. Email: cgordon@staff.ug.edu.gh
***Corresponding author** E. M. Osei. Email: osei1990@gmail.com

## Contents



## 1. Introduction

Agriculture in Africa is one of the sectors most susceptible to climate variability and change, as it is highly rain-fed and dependent on other climatic variables such as temperature, relative humidity, and sunshine [1] [2]. Climate variability directly affects crop development processes [3] and indirectly affect soil properties, as well as thriving pests that attack crops [4]. The temperature in Africa is rising faster than the global average and is likely to persist in the future [2]. These rising temperatures coupled with variable and highly unpredictable rainfall patterns have negative impacts on agricultural activities across Africa and the developing world [3]. In effect, empirical studies suggest that changes in the climate have led to a reduction in crop production [5]. Yields from rain-fed crops in some countries especially Sub-Saharan Africa is projected to halve by 2020 [6] [7] [8].

One crop that is vulnerable to climate variability is Cocoa (Theobroma cacao) of the mallow (Malvaceae) family [9] [10]. Cocoa on the average thrives well within the temperature range of 18ºC to 21ºC mean minimum and 30ºC to 32ºC mean maximum [11], and rainfall averages of 1500 millimetres (mm) to 2000mm annually [12]. This means that any increase or decrease below the mean minimum or beyond the mean maximum would negatively affect cocoa output, as well as, the application of some other determinants of cocoa output such as fertilizer and pesticides. In addition, variations in rainfall pattern often confuse farmers and affect the production process of the cocoa tree [5].

In Ghana, historical climate data recorded by Ghana Meteorological Agency (GMet) across the country between 1960 and 2000 shows a progressive and clear rise in temperature and a decrease in rainfall in all agro-ecological zones of the country [4] [13], which poses threats to Ghana's cocoa industry and cocoa livelihoods as it is highly rain fed. Cocoa production contributes the highest to foreign exchange earnings of approximately 30% [14] [15]. It also contributes significantly to the generation of employment for about 800,000 smallholder farm families [11].

A survey conducted among cocoa farmers in 1991, 1999 and 2005 indicated a reduction in poverty levels among cocoa-producing households from 60.1% in the 1990's to 23.9% in 2005; the reduction was attributed to favourable cocoa prices, higher yields and increased production [16]. In 2010/2011, Ghana's exports of cocoa reached 1,004,000 metric tonnes and, has since been the second largest exporter of cocoa in the world, in terms of quantity [17]. In addition, cocoa plays a significant role in providing a secondary habitat for some forest animals and species [18].

At the beginning of the 2014/2015 growing season, targeted output of cocoa by Ghana Cocoa Board (COCOBOD) was 1,000,000 metric tonnes. Increases in producer prices of cocoa (i.e 62.74% in 2014) were expected to be enough economic incentive for farmers to increase production. However, due to illegal mining activities [19], seasonal bushfires, deforestation, poor farm maintenance, and pest and disease infestations [16], the actual cocoa outputs of the country fell below the targeted 1,000,000 metric tonnes to about 740,000 metric tonnes [20]. The situation was exacerbated by variability in climatic variables (temperature, humidity, sunshine and rainfall) [16]. Most of these factors can be tackled through law enforcement and the provision of extension support. The climate factor, on the other hand, remains a big challenge, as cocoa is noted to react badly to any incidence of harsh weather conditions [21]. The projected climatic variables in areas such as the forest-savannah transitional zone found in and around the Brong-Ahafo Region suggest the area will be unfavourable for cocoa production in the not too distant future [22]. It is therefore critical to assess the level of effect on variability in temperature and rainfall has on cocoa production in the area to help adapt the most effective adaptation measures.

## 2. Literature Review

### 2.1 Evidence of Climate Variability

Climate variability is the way climate of an area fluctuates yearly above or below a long-term average value. That is a yearly shift from the long-term mean climate of an area attributed to events such as EL-Nino, La Nina and volcanic eruption, known as climate teleconnections [3]. The persistence of this variability may eventually lead to a change in the climate of the area.

Rainfall over West Africa is influenced by both the global climate teleconnections such as those associated with El-Nino Southern Oscillation and regional climate systems which include inter-tropical discontinuity, monsoons and sea surface temperature anomalies, as well as human impacts from land use changes (deforestation) [3]. The increasing global temperatures, frequency, and uncertainties in the factors that affect rainfall in West Africa are likely to increase rainfall anomalies within the West African sub-region.

In Ghana, an analysis of a 40-year data from 1960 to 2000 displayed a clear rise in temperature and a simultaneous decline in rainfall across all agro-ecological zones [23]. In addition, climate change scenarios for some agro-ecological zones in Ghana shows a decline in annual rainfall by 2.8%, 10.9% and 18.6% in 2020, 2050 and 2080 respectively and a rise in temperature by 0.6$^o$C, $2.0^oC$ and $3.9^oC$ in 2020, 2050 and 2080 respectively [11]. These changes projected are to decrease soil moisture conditions during the dry seasons and intensify the risk of cocoa production to the adverse impacts of climate change. Within the past 50 years, sea surface temperature (SST) changes in the Western Pacific (El Nino), led to below average rainfall in most West African countries in 1983, leading to a national plea for aid [22].

### 2.2 Cocoa Production in Ghana

The COCOBOD is mandated by the Government of Ghana to manage activities in the cocoa industry, due to its economic importance to the country. Their mandate includes agricultural research into cocoa, export and internal marketing of cocoa beans, hybridization of seeds, the sale of seeds, extension services to farmers and quality control services [15]. The existence of this institution over the years has ensured sustained growth in the cocoa industry in spite of low productivity when compared to other leading cocoa producers in the world.

The country's cocoa production since its establishment in the 1800's has seen four major phases. The introduction and exponential growth period (1888 – 1937), stagnation followed by a brief but rapid growth, after the country's independence (1938 – 1964), a near collapse (1965 – 1982) and finally, the recovery and expansion following the implementation of the Economic Recovery Program (ERP) (1983 – 2008). The last phase became successful with the implementation of the ERP, which involved increases in the price paid to Ghanaian farmers as compared to those paid to neighbouring countries [24]. In addition, farmers were compensated for removing trees infested with swollen shoot virus and planting new ones. This led to a large number of farmers planting higher yielding cocoa tree varieties developed by the Cocoa Research Institute of Ghana, with 1995/1996 growing season having an increase in productivity from 210 to 404 kilograms per hectare (kg/h). From 2001/2002 growing season saw some other interventions by the Government of Ghana through the mass spraying program and HI-TECH subsidy packages to promote the adoption of a higher and more frequent application of fertilizer. In addition, the Cocoa Diseases and Pests Control program coupled with a massive increase in world cocoa prices motivated more farmers to increase their production. These interventions from its start saw a massive increase in national cocoa output from 380,000 metric tonnes to 500,000 metric tonnes in the 2002/2003 growing season [25].

In addition to these interventions by the government that sought to motivate farmers and increases production, cocoa productivity rate in Ghana recently is estimated at around 400kg per hectare (kg/h) [26]. Compared to annual yield rates of countries such as Cote d'Ivoire (600kg/h) and Indonesia (1000kg/h), Ghana's annual yield rate is very low, though most of our agricultural lands are committed to growing cocoa [11] [27] [28]. In addition, the technical efficiency among cocoa producing communities in West Africa was analysed, using the stochastic frontier model and the Meta-stochastic frontier analysis and, Ghana had the least efficiency of 44% with Nigeria having the highest of 74% efficiency [29].

The low productivity has been attributed to several factors such as variable climatic conditions, poor farm practices, seasonal bushfires, illegal mining activities, and pest infestations. Most of which are intensified by climate variability, especially in rainfall and temperature [16]. The highly contagious black pod disease is the most damaging disease that affects the development and riping of the cocoa pod [11]. The high incidences of black pod disease can be attributed to high relative humidity obtained in the morning across the cocoa growing belt in West Africa [10] and also a continuous rainfall for several weeks [30].

The effects of climate variability on cocoa production render the government interventions insufficient. The kind of cocoa variety Ghanaian cocoa farmers are encouraged to grow (the hybrid type), only ensures a continuous higher yield with lots of fertilizer and pesticide application. In most cases the farmers are unable to afford, therefore results in some recurring low yields [28], which require some supporting strategies at the individual farmers' level to boost their yield.

### 2.3 Impacts of Climate Variability on Cocoa Production

A number of climatic factors (temperature, rainfall, humidity and sunshine) are noted to have interrelated impacts on the growth of the cocoa crop [31], but the major determinants of cocoa growth are temperature and rainfall [32]. Research conducted in Ghana indicated that all key informant interviews and farmers revealed that variability in temperature and rainfall are the major challenges being faced [15]. These impacts of climate variability, especially prolonged drought on cocoa makes it difficult to establish new cocoa farms [11] [15]. Marked dry periods result in a reduction in Leaf Area Index leading to a reduction in cocoa yields [23].

Temperature affects crops growth and development in a number of ways. These include alteration of the crop flowering period, leading to a reduction in seed numbers and high evapotranspiration [33]. The moisture loss leads to an increase in Plant Water Demand, causing drought stress on the crop during the dry season [34]. Changing climate can also alter the development of pests and diseases that affect cocoa by modifying the host's resistance to pesticides [30]. A case study conducted at the Cocoa Research Institute Nigeria, Ibadan on the effect of some climatic variables on black pod disease revealed a positive correlation (0.370 and 0.003) for temperature and humidity respectively [10]. That is, as these climatic variables increase the incidence of black pod disease also increases. In addition, the changes in length and intensity of sunshine, that is, exceeding 60% tend to decrease the rate of photosynthesis, with prolonged exposure to higher sunshine damaging the photosynthetic mechanism of the leaf [11].

Rainfall affect cocoa yields more than any other environmental factor [23]. Cocoa is highly sensitive to drought and the pattern of its cultivation is related to rainfall distribution [31], and therefore produces well under minimal but sustained water availability all year [30]. This implies that the year to year variations in cocoa yields are affected more by rainfall regime than any other climate variable, and therefore, the ideal annual rainfall regime suitable for maximum growth and yield is between 1500 and 2500mm [12]. Even though global projection for future rainfall indicates a decline, research suggests an insignificant decline of 12mm in rainfall over Ghana and Cote d'Ivoire by 2030 [18]. In as much as an increased rainfall is needed for high productivity, other researchers argued that increased rains and prolonged wet seasons slow cocoa drying and processing, thereby reducing the value of the bean and increasing the cost of processing [15] [35]. Therefore, an effective cocoa production through harvesting and processing require timely and moderate rainfall distribution, as cocoa is highly sensitive to extreme weather events. In addition, due to the unpredictable rainfall patterns, cocoa farmers tend to confuse regular times of spraying cocoa pods to ensure maximum protection [30].

Understanding the effects of temperature and rainfall variability on cocoa production will help stakeholders especially farmers to adopt efficient adaptation measures to minimize their vulnerability. The efficiency of an adaptation must include the level to which the farmers believe that there has been a change in climate and their awareness of the type and form of change [36]. In addition, the research is of importance, especially at a time when the global cocoa industry is investing in productivity gains through sustainable agriculture, as one of the main pipelines for higher income and cocoa sustainability [37].

## 3. Materials and Methods

### 3.1 Study Area

The Dormaa West District is one of the twenty-two (22) political and administrative districts in the Brong-Ahafo Region of Ghana. It is located in the western part of the Region, between Longitude $6^o$ 51'45N and $7^o$ 2'0N and Latitude $2^o$ 50'45W and $3^o$ 1'0W. It is bounded to its southwest by Bia East Districts, the west by La Cote d'Ivoire, the east by Asunafo North Municipality and to the north by Dormaa Central municipality. The district has a total land area of 381 square kilometres and nineteen major towns with Nkrankwanta as its capital [38].

The district falls within the wet semi-equatorial climate region of the country with an average annual rainfall between 125cm and 175cm. The district experiences a double maxima rainfall regime that is May to June and September to October. The area has a pronounced dry season that is from the latter part of November to February. Temperatures are generally high, ranging from $26.1^o$C to $30^o$C with maximum temperatures recorded between March and April, and the Minimum in August. In addition, there is high humidity of 75 to 80% during the rainy seasons and 70 to 72% humidity in the rest of the year. These climatic conditions, therefore, makes it favourable for the cultivation of cash crops such as cocoa, coffee and food crops such as plantain, cocoyam [38]

The major vegetation types in the district are the unused forest, partly broken forest and extensively cultivable forestland and forest reserve that are the Pamu-Mpameso Forest Reserve covering 197.67 square kilometres. The predominant timber species found in the area are Triplochiton scleroxylon (Wawa), Milicia excelsa (Odum), Entandrophragma cylindricum (Sapele) and Swietenia macrophylla (Mahogany). Availability of these timber species has led to the growth of carpentry industry, which is a huge contributing factor to the depletion of the forest cover with its adverse effect on the climate [38].

The district is generally undulating and rises between 180 meters and 375 meters above sea level. The area well drains with a network of rivers spread out within the district. These rivers are mostly perennial due to the double maxima rainfall regime experienced in the area. Notable among these rivers are the Bia, Nkasapim and Pamu rivers and are mostly used as a source of water for the cultivation of vegetables such as okro and tomatoes in the dry seasons [38].

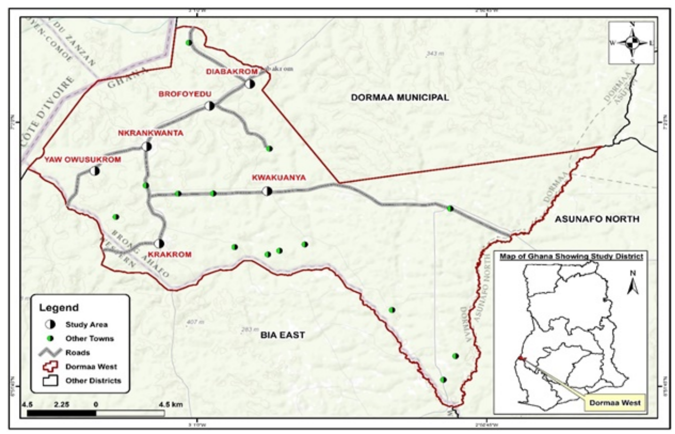


**Figure 1.** Map of Dormaa West District of the Brong-Ahafo Region. **Source:** Author's construct, January 2017. Using ArcGIS 10.4.1

### 3.2 Data Collected

Seasonal variations in the climate in any area are undeniable, and this has proven by several kinds of literature to be affecting agricultural production and for that matter cocoa production, especially in areas that greatly depends on natural conditions for its agricultural activities. Dormaa West District was purposively selected based on its high agrarian economy (81.2%) [38], as the area is predominantly noted for cocoa farming in the Brong-Ahafo Region, with two of the highest producing cocoa districts (Nkrankwanta and Kasapin cocoa districts) fallen within the district [21]. In addition, the increasing deforestation in the district that affects the local climate of the area [38] and its location in the transitional agro-ecological zone of Ghana made it a preferred area for the study. Therefore, these characteristics of the district made it better for the study compared to other districts in the region. For the purpose of this study, secondary data on cocoa yields for the years 1991 to 2015 and for two climatic variables (rainfall and temperature) for the same year period, for the district was obtained from the COCOBOD and GMet respectively. This when analysed, establish the trends and rate of variability in the climate for the district. In addition, how much these variations are affecting the cocoa yields of the area.

The study was limited to only two climatic variables (rainfall and temperature), without some other important climate variables such as sunlight and humidity, which equally affect cocoa development and the spread of pest and diseases. This was because data for such variables for Dormaa West District were unavailable at the Ghana Meteorological Agency.

### 3.3 Data Analysis

In determining how climate variability affect cocoa yield, temperature and rainfall data for the district were obtained from the Ghana Meteorological Agency, Accra from1991 to 2015. Preliminary data analysis to obtain yearly averages for the climatic variables (temperature and rainfall) was done using Microsoft Excel version 2016. These averages were used to develop a line graph that gave a pictorial view of the trend of increasing variability in rainfall pattern but at a decreasing rate in rainfall amount and an increasing trend in temperature in the Dormaa West District over the 25-year period under study. A descriptive statistical table (Table 1) was later developed to generate the mean for the years, and other figures, which aided in the calculation of the standard deviation for both rainfall (x) and temperature (k). The formula that was used to calculate the standard deviation was:

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

Where SD = Standard Deviation, $\sum(x-\bar{x})^2$ is the sum of rainfall or temperature measure (x) for each year minus the mean value ($\bar{x}$) for the years, all squared, and finally (n) is the number of years used in the calculation. After calculating the standard deviation (SD) for both temperature and rainfall, the value obtained was used to determine the coefficient of variation (CV) [39] by substituting the mean and standard deviation into the formula:

$$CV = \frac{SD}{\bar{x}} X100 \text{ .......... } (2)$$

Where CV is coefficient of variation, SD is the standard deviation and ($\bar{x}$) is the mean for the rainfall and temperature data used for the calculation. In addition, test was carried out on the three variables (Cocoa output, rainfall and temperature) using Augmented Dickey-Fuller (ADF) stationary test [40] in XLSTAT version 2017. This was to ensure that the linear regression model to establish do not give misleading regression analysis of the effect variations in temperature and rainfall has on cocoa outputs from the district. The results of the ADF test showed that average temperature and cocoa outputs were nonstationary as their absolute observe values were less than the critical value (temperature = -2.117 < -3.536 and cocoa output = -2.857 < -3.536). On the other hand, average rainfall was stationary as its absolute observe value is greater than the critical value (-3.700 > -3.536). Therefore, to make it appropriate to carry out the regression analysis temperature and cocoa outputs for the 25-year period were transformed using integrated by order one I(1) to make them difference stationary [40] (temperature = -4.334 > -3.560 and cocoa output = -3.595 > -3.560).

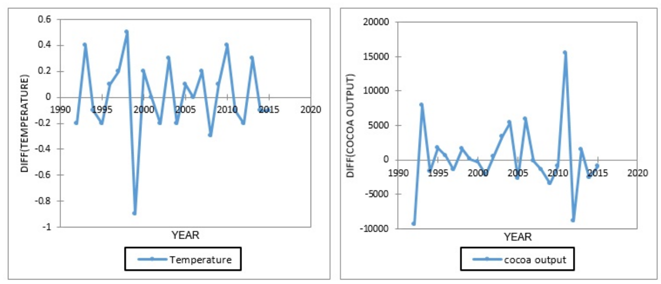


**Figure 2.** Integrated order by one I(1) transformation for temperature and cocoa output values

Annual variations in cocoa outputs from the Dormaa West District for the 25-year period was regressed against average rainfall and temperature for the same period using a multiple linear regression model in SPSS version 21.0 to determine if changes in these climatic variables have significant effects on the annual variations in cocoa yields from the district. Multiple regression is defined by four (4) parameters; Y represents the dependent variable, $\alpha$ represents the model constant, $\beta$ represents the slope and $\chi$ represents the different independent variables.

$$Y = \alpha + \beta_1\chi_1 + \beta_2\chi_2 + \varepsilon \text{ ..................} (3)$$

In this application, Y represents the cocoa outputs, $\alpha$ represents the constant (y-intercept), $\beta$ represents the slope, $\chi_1$ represents average rainfall, $\chi_2$ represents temperature and $\varepsilon$ represents the error term.

## 4. Results and Discussion

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

The trends in annual rainfall and temperature data available for the Dormaa West District from 1991 to 2015 are presented in the following graphs (Fig. 3, 4, 5, 6 and 7). The rainfall distribution for the area indicates an upward trend even though historical climate data by the GMet across the country between 1960 and 2000 shows a progressive and a visible decrease in rainfall in all agro-ecological zones. According to [34], the 19 Global Circulation Models (GCMs) project a little increase in annual rainfall for West Africa in drier areas of forest-savannah transition and the northern parts of the cocoa belt which the Dormaa West District forms a part. This upward trend was explained to be an increased in rainfall intensity for some particular months (Fig. 4) and not necessarily a uniform distribution of rainfall throughout the year for those years under review.

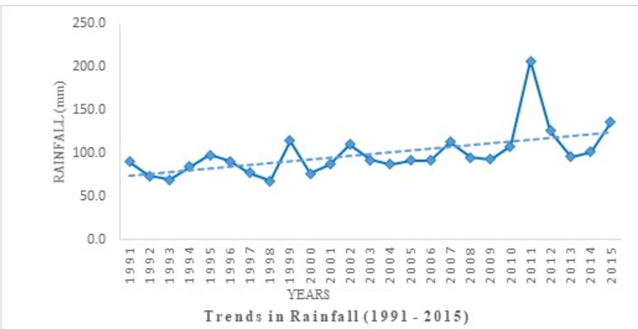


**Figure 3.** Trend of yearly average rainfall (mm) for Dormaa West District (1991 –2015)

In a change detection for the area between the years 1996 – 2000 and 2011 – 2015 (Fig. 4), it was obvious that rainfall has positively changed across almost all the months, with significant upward changes in rainfall observed from the month of October to December. This may be because of the general increasing trends in rainfall for the northern parts of the West African cocoa belt, which is projected to decrease the number of dry months from four to three by 2050 especially toward the northward parts of the Western Region of Ghana [34]. In addition, it can be observed that the area has a double maxima rainfall regime. The major seasons start somewhere in March and ends in July and the minor from September to October. In addition, the more temperature increases, the more crop water use per unit biomass. This water is either directly evaporated from the soil or perspired by plants according to greater demand for water from the atmosphere [41]. Therefore, the increasing rainfall trends in the district indicates that Vapour Pressure Deficit which is the main effect of temperature on cocoa production could be reduced. This will make up for soil moisture losses due to evaporation, and make temperature have an insignificant effect on cocoa production.

On the other hand, temperature trends for the same period for the district (Fig. 5) shows an upward trend confirming historical data of an increasing trend in all agro-ecological zones of the country between 1960 and 2000. This increase in average temperatures has been

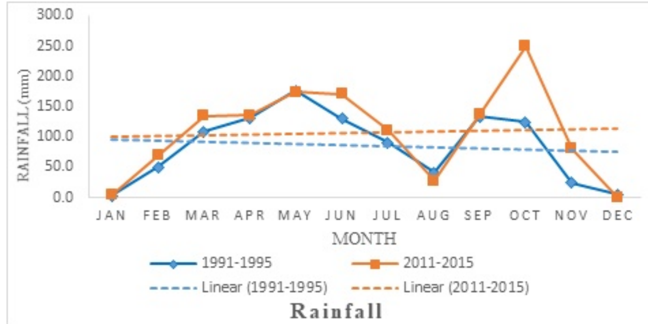


**Figure 4.** Change detection in rainfall patterns (mm) for Dormaa West District between the years 1996 – 2000 and 2011 – 2015

due to the effect of an increasing trend in the minimum temperatures for the district (Fig. 6). Minimum temperature is more probable to increase under climate change [42], and this is causing a decline in the average temperature ranges as the maximum temperatures show a decreasing trend (Fig. 6). The effect of this increase in minimum temperatures would be much significant in affecting all phases of the perennial crop (cocoa) growth and development [43].

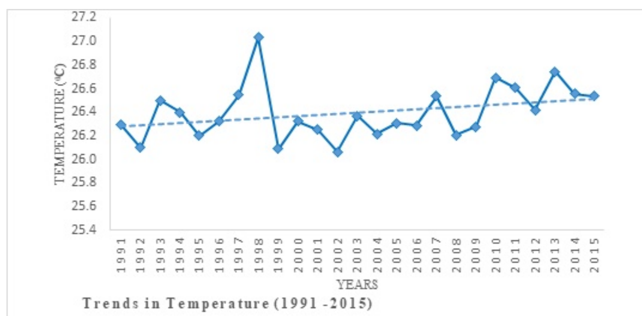


**Figure 5.** Trend of yearly temperature (0C) for Dormaa West District (1991 –2015)

From a change detection record, it is shown that maximum temperature over the years 1996 – 2000 and 2011 – 2015 have not significantly changed for most months (Fig. 7). Slightly increases were recorded in January, September, and October and slight decreases in March. Minimum temperatures, on the other hand, have increased throughout the year with the exception of December and January. In areas where the changing climate is expected to cause an increase in rainfall (Fig. 3), large increases in maximum temperatures are less likely to occur than regions prone to drought [43].

From Fig. 6 and Fig. 7, it is observed that even though the average yearly temperature ranges are gradually decreasing, monthly temperature ranges for January and December (dry season) are seeing an increase. This

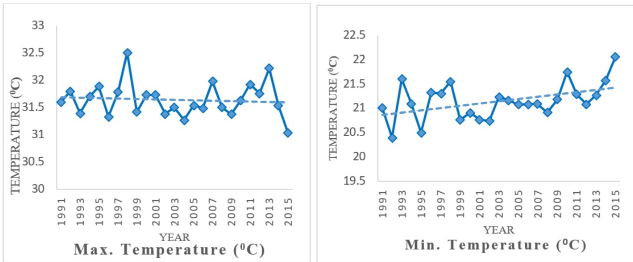


**Figure 6.** Trend of yearly averages in maximum and minimum temperatures (0C) for Dormaa West District(1991–2015).

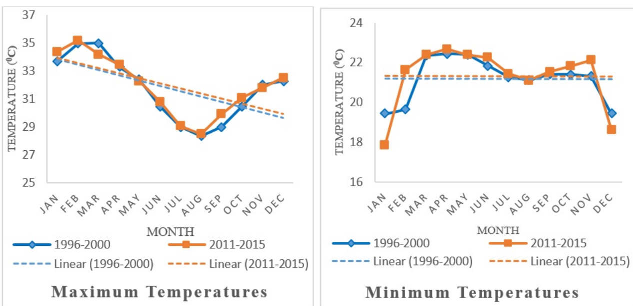


**Figure 7.** Change detection in maximum and minimum temperature (0C) between the years 1996 – 2000 and 2011 – 2015

is due to precipitation deficits that affect cloud cover and soil moisture anomalies, which eventually impact the energy balance [44]. That is, dry conditions that correspond to the higher ratio of sensible heat flux to latent heat flux are responsible for the increased temperatures during the daytime and very low temperatures during night-time in the dry seasons. On the other hand, during the wet season, a large amount of energy for evaporation is used, which is a cooling effect, and supported by increased soil moisture, causing monthly temperature ranges for most land surfaces in the wet seasons (April – July, and September – October) to be a little stable compared to the dry season.

### 4.2 Determining how variations have occurred in Temperature and Rainfall Amount for the District between the years 1991 to 2015.

This variability in the temperature and rainfall patterns for the area as shown in the trend analysis were then proven statistically by finding the coefficient of variation among the temperature and rainfall data. Greater reliability means less variability [39]. Therefore, at 10% confidence level, when the coefficient of variation for a data is more than 10% it means the data is not reliable and shows a significant variability in the data, on the other hand, when the coefficient of variation is less than 10%, it means the data is reliable and therefore shows an insignificant variability in the data.

Therefore, from Table 1, the coefficient of variation for temperature for the district is 0.9% indicating an insignificant variability in temperature over the 25 years (1991 to 2015) under study. While the coefficient of variation (CV) for rainfall for the district is 28.1% indicating a significant variability in rainfall amount over the 25 years under study.

**Table 1.** Annual Temperature and Rainfall variability in the Dormaa Area

| | Temperature ($^oC$) | | | Rainfall (mm) | | |
|---|---|---|---|---|---|---|
| Year | k | $k-\bar{k}$ | $(k-\bar{k})^2$ | x | $(x-\bar{x})^2$ | $(x-\bar{x})^2$ |
| 1991 | 26.3 | -0.1 | 0 | 90.6 | -8.7 | 76.4 |
| 1992 | 26.1 | -0.3 | 0.1 | 74.2 | -25.2 | 635.3 |
| 1993 | 26.5 | 0.1 | 0 | 69.6 | -29.7 | 883.4 |
| 1994 | 26.4 | 0 | 0 | 84.2 | -15.2 | 229.7 |
| 1995 | 26.2 | -0.2 | 0 | 98.5 | -0.8 | 0.7 |
| 1996 | 26.3 | -0.1 | 0 | 91 | -8.4 | 69.9 |
| 1997 | 26.5 | 0.2 | 0 | 77.2 | -22.1 | 489.4 |
| 1998 | 27 | 0.6 | 0.4 | 68.2 | -31.1 | 968.6 |
| 1999 | 26.1 | -0.3 | 0.1 | 114.5 | 15.2 | 230.1 |
| 2000 | 26.3 | -0.1 | 0 | 76.8 | -22.5 | 506.9 |
| 2001 | 26.3 | -0.1 | 0 | 87.6 | -11.8 | 139.4 |
| 2002 | 26.1 | -0.3 | 0.1 | 110.2 | 10.8 | 117.1 |
| 2003 | 26.4 | 0 | 0 | 92.7 | -6.6 | 44 |
| 2004 | 26.2 | -0.2 | 0 | 87.7 | -11.7 | 135.8 |
| 2005 | 26.3 | -0.1 | 0 | 91.4 | -7.9 | 62.6 |
| 2006 | 26.3 | -0.1 | 0 | 91.6 | -7.8 | 60.3 |
| 2007 | 26.5 | 0.1 | 0 | 113.6 | 14.2 | 202.4 |
| 2008 | 26.2 | -0.2 | 0 | 95.4 | -3.9 | 15.5 |
| 2009 | 26.3 | -0.1 | 0 | 93.1 | -6.3 | 39.5 |
| 2010 | 26.7 | 0.3 | 0.1 | 108 | 8.6 | 74.3 |
| 2011 | 26.6 | 0.2 | 0 | 207.4 | 108 | 11668.9 |
| 2012 | 26.4 | 0 | 0 | 126.1 | 26.8 | 717.3 |
| 2013 | 26.7 | 0.4 | 0.1 | 96 | -3.4 | 11.5 |
| 2014 | 26.6 | 0.2 | 0 | 102 | 2.7 | 7 |
| 2015 | 26.5 | 0.1 | 0 | 136.2 | 36.9 | 1358.6 |
| Total | 659.9 | | 1.2 | 2483.9 | | 18744.6 |
| Average | 26.4 | | | 99.4 | | |
| Standard Deviation (SD) | | 0.23 | | | 27.95 | |

Source: Ghana Meteorological Agency, 2017

### 4.3 Trends in Cocoa Production for Dormaa West District (1991 – 2016)

Cocoa production for the Dormaa West District from 1991 has seen a steady increase and decrease until 2004 (18,327 metric tonnes) and 2006 (21,574 metric tonnes) when it shot beyond the normal increases between the 1991 to 2000 yield figures. From 2007 (21,351 metric tonnes) saw a decreasing trend until 2010 (15,482 metric tonnes), but eventually saw an excessive increase in 2011 (31,017 metric tonnes) which could not be maintained and therefore saw a significant decrease and which has continued until 2016 (17,108 metric tonnes), falling below the 2004 production figures. This trend in the cocoa production for the area conforms to the national output trends with an increasing trend up until 2007. This has been attributed to an increase in cultivated lands and partly due to improved practices such as fertilizer application and change in crop variety from the “Amazons” to the “Hybrid” varieties [24]. In addition, the recent decreases in output from 2011 is being attributed to seasonal bushfires, deforestation, poor farm maintenance, illegal mining activities and pest infestations, all of these are exacerbated by variability in climatic variables [16].

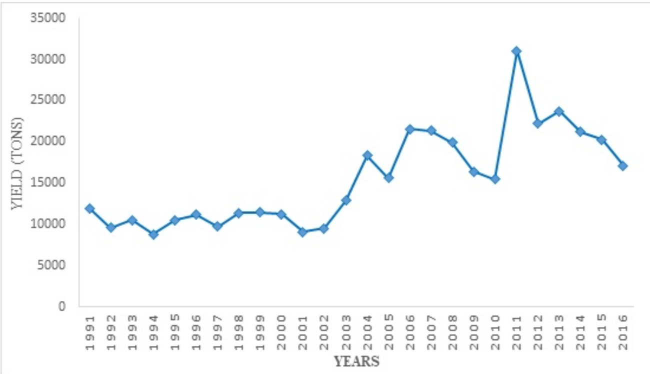


**Figure 8.** Trends in cocoa production for Dormaa West District (1991 – 2016)

From the trend analysis of temperature, rainfall, and cocoa production for Dormaa West District, there has been a significant variation in temperature and rainfall pattern. These variations are observed to be affecting cocoa production for the area, all other things being equal, especially rainfall, as trends in the rainfall pattern for the area shows almost the same as the trends in cocoa output. For instance, 2011 recorded the largest cocoa outputs ever in the district's output trends of 31,017 metric tonnes, and in that same year, total annual rainfall amount saw its peak at 204.7mm. In addition, if trends in rainfall and temperature are to remain the same the effects of temperature on cocoa production could be limited by the increasing rainfall amount and rainfall months by making up for soil moisture losses.

### 4.4 Effect of Temperature and Rainfall Variability on Cocoa Production for Dormaa West District.

A multiple linear regression analysis was used to establish the relationship between Cocoa Output (metric tonnes) and Rainfall (mm), Cocoa Output (metric tonnes) and Temperature (0C), as well as the combined effect of these climatic variables on cocoa production, using SPSS version 21.0. This enabled to conclude on the fact that there have been some effects of variability in rainfall and temperature on cocoa yields for the district.

From Table 2, the annual rainfall pattern for Dormaa ranges from 68.2mm to 207.4mm per annum. The results of the regression model estimation are presented in Table 1. The coefficient of rainfall is positive and statistically significant at 5% significance level. This indicates that rainfall has a positive effect on cocoa yield in the Dormaa West District. The impacts of climate change on cocoa production in Nigeria was estimated, and the results showed that the main climatic element was rainfall and has a significant impact on the growth and development of cocoa [34]. Rainfall failure has the tendency to increase the cost of controlling diseases and pest, and reduce the quantity and quality of the cocoa beans. The regression coefficient of determination shows that variability in rainfall contributes 25.2% to variations in cocoa yields for the district, leaving 74.8% of the variations to other factors such as soil nutrients. This emphasizes the fact that rainfall affects cocoa yield more than any other environmental factor [23] [45], as cocoa is highly sensitive to drought and the pattern of its cultivation is related to rainfall distribution [31].

From Table 1, the annual temperature averages for the Dormaa area ranges from 26.1$^o$C to 27.0$^o$C. From Table 2, Temperature has a positive effect on cocoa output in the area, as the coefficient of temperature is positive but statistically insignificant at 5% probability level. The regression coefficient of determination indicates that temperature variability contributes 10% to variations in cocoa outputs for the district, leaving 90% of the variations to other factors. The effect of temperature on cocoa outputs in the district could be attributed to increases in minimum temperatures, which has exceeded the average minimum temperature threshold (18 to 210C) (Fig. 5) required for effective growth of cocoa [11]. The increase in minimum temperatures is a contributing factor to the increases in average yearly temperatures for the Dormaa West District.

In general, from the multiple linear regression of temperature and rainfall effect on cocoa outputs, shows a positive effect of variability in climate (temperature and rainfall) on cocoa production for the district, and statistically significant at 5% significance level. The regression coefficient of determination shows that climate variability accounts for 25.3% variation in cocoa outputs in the Dormaa West District, leaving 74.7% of the variations to other factors such as soil nutrients, fertilizer application, pest and disease control, and other climatic variables. This means that the two climatic variables (rainfall and temperature) influence cocoa outputs from the area [32] [21]. The results confirm the influence of climatic variables on cocoa production as a similar study that used multiple regression analysis and was found that 60% of variations in outputs of cocoa beans could be explained by variations in climatic variables such as annual rainfall and total sunshine duration for Tafo cocoa district [11]. From the multiple linear regression where there is an interaction between rainfall and temperature, the effect of temperature further decreases (Table 2) as the increasing rainfall amount makes up for soil moisture losses due to evaporation.

**Table 2.** Results of a multiple linear regression analysis between cocoa production, rainfall, and temperature

| Variable | Estimation coefficients | T | R with interaction | R without interaction |
|---|---|---|---|---|
| Constant | -8601.43 | -2.355 | | |
| Rainfall (mm) | 89.272 | 2.528 | 0.502* | 0.403* |
| Temperature (0C) | 5382.615 | 1.592 | 0.316 | 0.159 |

R = 0.503, R2 = 0.253, Adjusted R2 = 0.181

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

## 5. Conclusion and Recommendations

In conclusion, the variability in temperature and rainfall challenge in the Dormaa West District shows an increasing temperature and rainfall patterns for the period 1991 to 2015. The increase in rainfall patterns when observed across the months of the year is significantly noticed from October to December, while the increase in monthly temperature is generally observed throughout the year for both minimum and maximum temperatures.

The variability in rainfall patterns is highly significant (28.1%) while variability in temperature is insignificant (0.9%) within the period under study. Cocoa output has seen some fluctuations from 1991 until 2012 where it began falling with no indications of an increase in the coming years, and this pattern in output somehow relate to the rainfall patterns in the district.

The significant variation in the rainfall pattern for the Dormaa East District have some effects on the overall cocoa outputs in the district as it accounts for 25.2% of the total variations in cocoa output Ceteris peribus. On the other hand, the insignificant variability in temperature of the area contributes to 10% of the total variations in the overall cocoa outputs Ceteris peribus. If trends in rainfall and temperature are to remain the same the effects of temperature on cocoa production could be limited by the increasing rainfall amount and rainfall months by making up for soil moisture losses. Therefore, climate variability has a significant effect on cocoa yields from the Dormaa East District of the Brong-Ahafo Region.

Based on the above findings, the study makes these recommendations: The Forestry Commission in collaboration with COCOBOD should organize programs that seek to discourage forest depletion in and around the district to help boost the local average rainfall amounts to make up for soil moisture losses due to evaporation. Secondly, a wider geographical spatial spread with other climatic variables (sunshine and humidity) should be analysed and modelled. This will help identify areas where cocoa productions will be highly favourable and areas where farmers must adopt some specific and efficient adaptation measures due to harsh weather conditions. This will make the COCOBOD identify the areas they can channel more resources to ensure sustained cocoa outputs for the country.

## 6. Acknowledgement

The first author expresses his profound gratitude to the Open Society Foundation and the Building Capacity for Climate Change Challenge project, for providing a scholarship that became very instrumental in the successful completion of his thesis and MPhil. Degree in Climate Change and Sustainable Development. I am also very grateful to Prof. Christopher Gordon and Dr. Irene Egyir for their time, guidance, and the insight they provided to successfully complete his thesis.

## References

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

[2] Intergovernmental Panel on Climate Change, Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectorial Aspects. The contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014), 1-32.

[3] B. Sarr, Present and future climate change in the semi-arid region of West Africa: A crucial input for practical adaptation in agriculture. Atmospheric Science Letters, 13(2), 2012, 108–112. https://doi.org/10.1002/asl.368

[4] R. Sagoe, Climate Change and Root Crop Production in Ghana. A Report Prepared for Environmental Protection Agency (EPA), 2006, Accra-Ghana.

[5] D. S. Ehiakpor, G. Danso-Abbeam, J. E. Baah, and F. Yildiz,. Cocoa farmer's perception of climate variability and its effects on adaptation strategies in the Suaman district of the western region, Ghana. Cogent Food & Agriculture, 2(1), 2016, 1-12. https://doi.org/10.1080/23311932.2016.1210557

[6] United Nations Framework Convention on Climate Change, Climate Change Impact, Vulnerability, and Adaptation in Developing Countries. UNFCCC Secretariat, Martin-Luther-King-Street 8, 53175 Bonn, Germany, 2007).

[7] S. Di Falco, M. Yesuf, G. Kohlin, and C. Ringler, Estimating the Impact of Climate Change on Agriculture in Low-Income Countries: Household Level Evidence from the Nile Basin, Ethiopia. Environmental and Resource Economics, 52(4), 2011, 457–478. https://doi.org/10.1007/s10640-011-9538-y

[8] M. Pilo, A. M. Ahamadou, and W. Tobias, Impact Of Adaptation Strategies On Farm Households' Farm Income: A Bio-Economic Analysis, 63(10), 2016, 1–7. Https://doi.org/10.7498/Aps.63.104215

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

[10] J. O. Lawal, and L. A. Emaku, Evaluation of the effect of climatic changes on Cocoa Production in Nigeria: Cocoa research institute of Nigeria (CRIN) as a case study. African Crop Science Conference Proceedings, 8, 2007, 423–426.

[11] G. J. Anim-Kwapong, and E. B. Frimpong, Vulnerability of Agriculture to Climate Change- Impact of Climate Change On Cocoa Production. Vulnerability and Adaptation Assessment Under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2). Cocoa Research Institute of Ghana, 2, 2004, 1–30.

[12] K. P. Nair, Cocoa (Theobroma cacao L.). The agronomy and economy of important tree crops of the developing world, 2010, 131-180.

[13] E. Boon, and A. Ahenkan, Assessing Climate Change Impacts on Ecosystem Services and Livelihoods in Ghana: Case Study of Communities around Sui Forest Reserve. 18th Commonwealth Forestry Conference, 2010

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

[15] A. Hutchins, A. Tamargo, C. Bailey, and Y. Kim, Assessment of Climate Change Impacts on Cocoa Production and Approaches to Adaptation and Mitigation: A Contextual View of Ghana and Costa Rica. International Development Studies, 2015, 1-22.

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

[17] A. Asante-Poku, and F. Angelucci, Analysis of incentives and disincentives for cocoa in Ghana. Technical notes series, 2013, MAFAP, FAO, Rome.

[18] P. Läderach, A. Eitzinger, A. Martinez, and N. Castro, Predicting The Future Climatic Suitability for Cocoa Farming of the World's Leading Producer Countries, Ghana and Cote d'Ivoire. International Centre for Tropical Agriculture (CIAT), Managua, Nicaragua. Climatic Change, 119(3-4), 2013, 841-854.

[19] D. O. Boateng, F. Nana, Y. Codjoe, and J. Ofori, The impact of illegal small-scale mining ( Galamsey ) on cocoa production in Atiwa district of Ghana. International Journal of Advance Agriculture Research, 2, 2014, 89–99.

[20] Ghana Cocoa Board. (2016). Regional Cocoa Purchases. Retrieved from: http//www.cocoaboard.gh/weekly_purchase.php

[21] O. R. Adeniyi, and G. O. Ogunsola, Cocoa Production and Related Social-Economic and Climate Factors: A Case Study of Ayedire Local Government Area of Osun State, Nigeria. Agricultural Science, 2(4), 2014, 1–13. https://doi.org/10.12735/as.v2i4p01

[22] E. Y. Kyere, Farmers Perception on Climate Change, Its Manifestations in Small Holder Cocoa Systems and Shifts in Cropping Pattern in The Forest-Savanna Transitional Zone of Ghana, KNUST, MPhil, 2016.

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

[24] S. Kolavalli, and M. Vigneri, Cocoa in Ghana: Shaping the success of an economy. Yes, Africa can: success stories from a dynamic continent, 2011, 201-218. https://doi.org/10.1596/978-0-8213-8745-0

[25] F. Baah, V. Anchirinah, and F. Amon-Armah, Soil fertility management practices of cocoa farmers in the Eastern Region of Ghana. Agriculture and Biology Journal of North America, 2(1), 2011, 173–181. https://doi.org/10.5251/abjna.2011.2.1.173.181

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

[27] M. R. K, O. Appiah, S. T. Sackey, and A. A. Afrifa, The consequences of cocoa production on soil fertility in Ghana: A review. Ghana Journal of Agricultural Science, 30, 1992, 183–190.

[28] M. Franzen, and B. M. Mulder, Ecological, economic and social perspectives on cocoa production worldwide. Biodiversity and Conservation, 16(13), 2007 3835–3849. https://doi.org/10.1007/s10531-007-9183-5

[29] A. Oguntade, T. Fatunmbi, and C. Okafor, Effects of Farmers' Field School on the Technical Efficiency of Cocoa Farmers in Nigeria. Journal of Biology and Life Science, 4(1), 2012, 135–144. https://doi.org/10.5296/jbls.v4i1.2531

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

[31] R. S. Owoeye, and A. B. Sekumade, Effects Of Climate Change On Cocoa Production In Ondo State, Nigeria. Journal of Social Sciences Research, 10(2), 2016, 2014-2025

[32] J. T. Ngoong, N. G. Forgha, An Analysis of the Socio-Economic Determinants of Cocoa Production in Meme Division, Cameroon. Greener Journal of Business and Management Studies, 3(6), 2013 298–308.

[33] A. J. Challinor, and T. R. Wheeler, Crop yield reduction in the tropics under climate change: Processes and uncertainties. Agricultural and Forest Meteorology, 148(3), 2007, 343–356. https://doi.org/10.1016/j.agrformet.2007.09.015

[34] G. Schroth, P. Läderach, A. I. Martinez-Valle, C. Bunn, and L. Jassogne, Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities, and limits of adaptation. Science of the Total Environment, 556, 2016, 231–241. https://doi.org/10.1016/j.scitotenv.2016.03.02

[35] A. S. Oyekale, M. B. Bolaji, and O. W. Olowa, The effects of climate change on cocoa production and vulnerability assessment in Nigeria. Agricultural Journal, 4(2), 2009, 77-85.

[36] P. Kurukulasuriya, S. Rosenthal, Climate Change and Agriculture: A Review of Impacts and Adaptations, World Bank Climate Change Series (World Bank Environment Department, Washington, DC), 91, 2003, 1-106. https://doi.org/10.1017/CBO9781107415324.004

[37] J. Witjaksono, Cocoa Farming System in Indonesia and Its Sustainability Under Climate Change. Agriculture, Forestry and Fisheries, 5(5), 2016, 170–180. https://doi.org/10.11648/j.aff.20160505.15

[38] Ghana Statistical Service. (2014). 2010 Population and Housing Census: District Analytical Report for Dormaa West District.

[39] J. N. Kimengsi, and J. N. Tosam, Climate Variability and Cocoa Production in Meme Division of Cameroon: Agricultural Development Policy options. Greener Journal of Agricultural Sciences, 3(8), 2013, 606–617.

[40] D. Gujariti, Economics by example (England, Hampshire: Macmillan Publishers Limited, 2012).

[41] I. Fofana, Simulating The Impact Of Climate Change And Adaptation Strategies On Farm Productivity And Income: A Bioeconomic Analysis. IFPRI - Discussion Papers, (1095), 2011, 1-28. Retrieved from http://www.ifpri.org/sites/ default/files/publications/ifpridp01095.pdf

[42] N. Knowles, M. D. Dettinger, and D. R. Cayan, Trends in snowfall versus rainfall in the western United States. Journal of Climate, 19(18), 2006, 4545-4559.

[43] J. L. Hatfield, and J. H. Prueger, Temperature extremes: Effect on plant growth and develop-

ment. Weather and Climate Extremes, 10, 2015, 4–10. https://doi.org/10.1016/j.wace.2015.08.001

[44] B. He, L. Huang, and Q. Wang, Precipitation deficits increase high diurnal temperature range extremes. Scientific Reports, 5, 2015, 12004. https://doi.org/10.1038/srep12004

[45] T. T. Amos, and O. A. Thompson, Climate Change and the Cocoa Production in the Tropical Rain Forest Ecological Zone of Ondo State, Nigeria. Journal of Environment and Earth Science, 5(1), 2015, 36–42.