

Climate Change and Variability Effects on Cocoa Output in the Western Corridor of Ghana

Romeo Oduro Akrasi[1]* Emmanuel Okyere[2] Rejoice Adarkwah[3] Prince Ntrie Eddico[4]

1. Excise Division, Ghana Revenue Authority, PMB Accra, Ghana.
2. Cocoa Field Operations, Fundamental Resource Corporation, 2 Obenesu Close, Cantonment, Accra, Ghana
3. Department of Agricultural Economics & Agribusiness, Kwame Nkrumah Univ of Science & Technology, PMB Kumasi, Ghana
4. Department of Agricultural Economics and Agribusiness, University of Ghana, PMB Accra, Ghana

* E-mail of the corresponding author: rodewise@yahoo.co.uk

Abstract

Climate change and variability have been impacting most agricultural activities and cocoa, a major cash crop of the Western Regions of Ghana and to the nation at large has not been spared. This study sought to analyse the effects of climate change and variability on cocoa output. The multistage sampling techniques was used to select the respondents (cocoa farmers). The first objective examined evidence of climate change and variability in the study area. The second objective primarily analysed the effect of these climatic variables (rainfall, temperature, bright sunshine duration and relative humidity) on cocoa output. Climate has changed with strong variability over the past 40 years in terms of significant changes in decade temperature, relative humidity and bright sunshine duration. A 1mm increase in extreme rainfall amount resulted in a 0.24MT/ha decrease in cocoa output whilst a unit change in technology resulted in a 0.86 MT/ha increase in cocoa output from the regression results. It is recommended that COCOBOD, MoFA and NGOs should design improved technology such as cocoa seeds/seedlings that can withstand extreme climatic events as well as boost yields, since extreme rainfall and technology (previous years' yield) significantly affected cocoa output.

Keywords: climate change, variability, cocoa, output, Ghana

DOI: 10.7176/JEES/10-9-10
Publication date: September 30th 2020

1. Introduction

Cocoa is a climate sensitive crop, cultivated mainly in Ghana under the mercy of the weather. Irrespective of the level of adoption of output enhancing measures, the climate which is the average weather conditions in a particular area for long period of time, decade and more, still remains an important exogenous variable in the equation which can simply not be overlooked. Weather related events like erratic rainfall, longer drought periods and floods are increasing in terms of both magnitude and frequency in Ghana (FAO, 2008). Such events have been creating natural hazards and adversely impacting on smallholder farmers' livelihoods (Yaro, 2002; Hesselberg & Yaro, 2006; Akudugu, 2012). The negative consequences of natural hazards hamper crop outputs and livelihoods of the rural poor who build their lives on this climate sensitive sector.

Over the years, climate change and variability have been impacting most agricultural activities and cocoa, a major cash crop of the Western Region of Ghana and to the nation at large has not been spared. Even though the region continues to provide the highest output of 51.3% to the national output according to (COCOBOD, 2015), the impact of the climate in the region should be a matter of great concern as climate impacts heavily on cocoa production taking all other things to be constant. While small scale cocoa farmers in the region have and continue to battle with a litany of conventional production and post-harvest challenges confronting the sector, they are now faced with a much bigger issue and the challenges associated with the changes in climatic elements which ultimately affect cocoa production and outputs.

According to Fosu-Mensah *et al.* (2012) the semi-deciduous and evergreen rainforest zone, a major cocoa producing area, of Ghana has experienced varied changes in climate and extreme weather events of which temperature increase and rainfall amount decline are the major climate change and variability challenges. These assertions had been earlier made by Sagoe (2006) and Codjoe and Owusu (2011) in their respective studies. Invariably, the changing climate affects the farmers and the cocoa plants as well. The crop calendar then changes which affect various interventions like spraying, fertilization, post–harvest handling and most importantly output. Farmers become highly distressed as results of the changing climate affecting the establishment, production and post-harvest phases of the crop production as well as increase in pest activity with certain extremes of these climatic variables. The development of cocoa pest and its resistance building are also results of this interaction and an increase in evapotranspiration rate in the tree crop results in plant death (Anim-Kwapong & Frimpong, 2005). Furthermore, the incidence of these pests and diseases destroy cocoa seedlings and fruits, leading to reduction in yields, income and foreign exchange earnings.

The research therefore seeks empirically investigate trends in climate change and variability and its effect on cocoa outputs.

1.1 Concept of Climate Change

Basically, climate is defined as an average weather condition spanning over an extended period of time. Climate is seen as a composite of daily weather conditions that describe the average and variability typically over 30 year (CGIAR, 2009). The major elements of weather are rainfall, solar radiation and ionization, sunshine, humidity, atmospheric pressure, wind direction and wind speed. According to IPCC (2007), "Climate change refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persist for an extended period, typically decades or longer. Further, it can also refer to any change in climate over time, whether due to natural variability or as a result of human activity". There is a contrary view from the position of the United Nations Framework Convention on Climate Change (UNFCCC), which defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" According to (IPCC, 2007), operationally, climate change has been understood and defined from the perspective of any change in the mean and or the variability of the climatic variables for an appreciably long periods, from decades onwards by statistical means.

1.2 Conceptual Framework for Climate Change and Variability and Cocoa Yield

A conceptual framework on climate change and variability and cocoa yield interactions is adapted from FAO (2008) to highlight the climatic and non-climatic variables affecting cocoa yield. Climate change and variability is fundamentally caused through two mediums. Human induced causes and natural causes. Through the action of man, which in this case is primary by deforestation (cocoa production) and naturally through changes in sea level temperature, changes in solar radiation which then affect climate change indicators like rainfall, temperature, bright sunshine duration and relative humidity. Changes in these climatic variables then results in output changes. The establishment, production and post-harvest phases are all affected through increased cocoa seedlings mortality, increased diseases and pest infestation and even quality of the harvested beans through post-harvest challenges with drying etc. The agro-ecological zones change and land becomes unsuitable for cocoa production. Cocoa crop suffers huge losses from Blackpod diseases caused by Phytophtora megakarya and Phytophtora palmivora when rainfall amounts are high and the increased humidity serves as precursor the fungi attack.

In the event of extreme heat, capsids or mired attack increases as well whereas Bright Sunshine Duration (BSD) affects the photosynthetic apparatus ultimately impacting on output. Climate change variables, such as temperature, rainfall, sunshine duration and relative humidity, can influence biophysical factors, such as land, cocoa plant growth, water quantity and quality as well as cycles, biodiversity and nutrient cycling. These among others results in most farmers adapting to strategies aimed at mitigating the impact of climate change and variability which requires funds for shade tree management, soil fertility management, crop diversification.

More land is therefore required for expansion, labour cost is increased and access to information then becomes a challenge. However, non-climatic variables, such as soil characteristics, technology and management also tend to affect cocoa yield. Chang et al (2005) noted that the type and quality of soils as well as the slope of the land that are used in cocoa cultivation tends to affect its yield. According to Calpe (2002), the type of technology (agricultural machines and inputs) that are used and the agronomic practices that practiced on the cocoa fields has a part to play in affecting it yields.

The climate variables considered in this framework are:

- Increase in global mean temperatures
- Gradual changes in precipitation
- Changes in degree of humidity and extreme weather events

2. Methodology

2.1 Sampling and data collection approach

Multistage sampling approach was employed in this study. The Western Region (now split to include Western North Region) was purposively selected because it is the largest cocoa growing region with the single biggest contribution to the national output. It is the wettest part of Ghana with a double maxima rainfall pattern averaging 1600mm per annum, characterised by moderate temperatures ranging from 22^{O}C at nightfall to 34^{O}C during the day creating an optimum condition for cocoa production. The region is not exempted from the current global change and variability in the climatic variable (rainfall amount, temperature, relative humidity and bright sunshine duration) which invariably affect cocoa crop output. Hence the region was purposively selected. One (1) cocoa district each was then randomly selected, from the Two (2) broad regions, Western North and South Akontombra. Finally, Two (2) communities each from the Two (2) cocoa districts were again randomly selected from each cocoa district for the data collection. The communities where the list of farmers were drawn with the help of COCOBOD's Agricultural Extension Agents (AEAs) were Ashiem and Dansokrom (Sefwi Bekwai Cocoa District); and Bronikrom and Bokaso (Akontombra Cocoa District).

A stratified random sampling method was used to separate female small-scale cocoa farmers from their male counterpart. To give each farmer equal chance of being selected for the study, a simple random sampling method was used identify the respondents using a questionnaire.

In the determination of sample size for the study, the formula was used

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

Where n= sample size, N= population size of cocoa farmers, and e= level of precision (0.05) was used.

Using the above formula, a sample size of 312 was obtained from the population of 1426 cocoa farmers in the Two (2) cocoa districts. However, due to resource constraints (financial and time) 231 smallholder farmers were selected and interviewed. Based on the proportion of farmers in the two (2) cocoa districts, 120 out of 741 farmers were selected from Sefwi Bekwai whilst 111 out of 685 farmers from Akontombra cocoa district were selected for the study.

2.2 Method of data analyses

2.2.1 Determining the trends in climate change and variability

Data on the climate indicators (Rainfall, Temperature, Relative humidity and Bright Sunshine Duration) were obtained from the Ghana Meteorological Agency (GMA) and their mean values computed. Testing the differences between two means can be done by using different methods. Stephens (1996) used analysis of variance to test for significant difference between 60 monthly maximum temperatures of 1931-60 and 1961-90

Table 1. A priori expectation of cocoa yield response model

Variables	**Parameters**	**A priori Expectation**
Previous years cocoa yield	δ_t	Positive
Temperature	δ_1	Negative
Temperature Square/extreme high temperature	δ_2	Negative
Rainfall	δ_3	Positive
Rainfall Square/ extreme high rainfall	δ_4	Negative
Maximum – minimum temperatures (extreme)	δ_5	Negative
Maximum – minimum rainfall (extreme)	δ_6	Negative

A. H_O: Extreme variations in temperature have no effect on cocoa output.
H_A: Extreme variations in temperature have negative effect on cocoa output.

Extreme variations in rainfall amounts, extreme level of temperature and extreme level of rainfall amount follow similar hypotheses stated above

B. H_O: Normal rainfall amount have no effect on cocoa output.
H_A: Normal rainfall amount have positive effect on cocoa output.

2.2.2 Determining the effects of climate change indicators on cocoa yield

According to Lobell et al. (2007), the contribution of climate change to crop yield trends can be estimated by modelling the crop yield data without removing trend factor as a function of both time and climatic variables. Mainardi (2010) assumed that the effect of the previous year's yield on the current year's yield measure the technological changes. The corresponding difference in annual minimum and maximum temperature and rainfall are included in the model in order to measure the influence of departure from normal climatic conditions on cocoa yield (Chang et al, 2005). According to Chang et al. (2005), the actual yield response model is given as:

$$Y_t^R = \delta_0 + \delta_t Y_{t-1}^R + \delta_1 T_t + \delta_2 T_t^2 + \delta_3 R_t + \delta_4 R_t^2 + \delta_5 VarT_t + \delta_6 VarR_t + \varepsilon_t. \quad (2)$$

Where: δ_0 is the intercept of equation, $\delta_2, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5$ and δ_6 are the slope coefficients of the explanatory variables Y_{t-1}^R, T_t, T_t^2, R_t, R_t^2, $VarT_t$ and $VarR_t$ respectively. Y_t^R, Y_{t-1}^R, T_t and R_t denote cocoa yield (metric tonnes per hectare) in year t, previous years cocoa yield (metric tonnes per hectare), average annual temperature (ºC) in year t and total annual rainfall amount (mm) in year, t respectively. $VarT_t$ and $VarR_t$ represent differences between monthly minimum and maximum average temperatures (ºC) and rainfall amount (mm) in year, t respectively. The nonlinear temperature, rainfall and sunshine amount variables are shown by T^2_t and R^2_t, respectively. Lastly, ε_t is the stochastic error term.

Chang et al (2005) used linear log functional form to estimate crop yield response model based on the fact that temperature and rainfall have a non-linear relationship with crop yield. In this research, several functional forms were estimated in equations (3), (4) and the best equation (5) chosen, the log-log functional form. Equation (3), (4) and (5) represent, the log-linear, linear-log and log-log functional forms respectively.

$$\ln(Y_t^R) = \delta_0 + \delta_t Y_{t-1}^R + \delta_1 T_t + \delta_2 T_t^2 + \delta_3 R_t + \delta_4 R_t^2 + \delta_5 VarT_t + \delta_6 VarR_t + \varepsilon_t \quad (3)$$

$$Y_t^R = \delta_0 + \delta_t Y_{t-1}^R + \delta_1 \ln(T_t) + \delta_2 \ln(T_t^2) + \delta_3 \ln(R_t) + \delta_4 \ln(R_t^2) + \delta_5 \ln(VarT_t) + \delta_6 \ln(VarR_t) + \varepsilon_t \quad (4)$$

$$\ln(Y_t^R) = \delta_0 + \delta_t \ln(Y_{t-1}^R) + \delta_1 \ln(T_t) + \delta_2 \ln(T_t^2) + \delta_3 \ln(R_t) + \delta_4 \ln(R_t^2) + \delta_5 \ln(VarT_t) + \delta_6 \ln(VarR_t) + \varepsilon_t \quad (5)$$

3. Results and Discussion

3.1 Socioeconomic Characteristics of Farmers in the Study Area

Demographic Details: Majority of the respondents are aged between 40 and 49 years. This represents about 67% of the total small-scale cocoa farmers. About 17% of respondents were aged 50-59 years. The least percentage (about 0.4%) of the respondents was in the age ranges of 90 years and above. Out of 231 respondents interviewed, majority of them (65%) are males whiles 35% are females. Majority (about 92%) of the small-scale cocoa farmers interviewed were married. About 2% were widowed whiles those divorced and single were 2% and 4% respectively. The modal group of respondents (about 50%) had Middle/Junior High School education.

Farming Experience of Respondents: According to Deressa et al. (2008), it is the well-experienced farmers who perceived that climate has changed. Therefore it is convenient for a researcher to look at the perception of farmers on climate change based on the respondents' years of farming experience (Maddison, 2007). The results presented in Table 2 shows that 50 men smallholder farmers representing 54 percent and 42 women smallholder farmers (46 percent) had 11-21 years of farming experience. Similarly, 72 percent of men and 28 percent women smallholder farmers had 1-10 years farming experience. From the study it is evident that men smallholder farmers have more farming experience than their women counterparts. This implies that men smallholder farmers are likely to perceive changes in climate than the women smallholder farmers (Deressa et al., 2008; Maddison, 2007).

Income Sources of Respondents: About 76% of respondents derived their income from agricultural activities such as primary crop production (mainly from cocoa and other crops such as cassava, plantain etc.) and/or animal rearing; working as laborers on people's farm, trading in agricultural commodities; as well as processing of agricultural produce. Aside the agricultural production providing income for some respondents, non- agricultural activities such as petty trading (20%); formal occupation (such as teaching and nursing) (1%) and remittances from family and friends also served as a source of income for the respondents in the study area.

Table 2. Socioeconomic characteristics of respondents

Description	Cocoa Districts				Total Frequency	Total Percentage
	Akontombra		Sefwi Bekwai			
	Frequency	Percent	Frequency	Percent		
Gender						
Male	77	69.4	73	60.8	150	65
Female	34	30.6	47	39.2	81	35
Age						
40-49	79	71.2	76	63.3	155	67.11
50-59	22	19.8	17	14.2	39	16.88
60-69	6	5.4	18	15	24	10.39
70-79	1	0.9	7	5.8	8	3.46
80-89	3	2.7	1	0.8	4	1.73
>90	0	0	1	0.8	1	0.43
Educational Level						
None	17	15.3	14	11.7	31	13.42
Primary	37	33.3	16	13.3	53	22.94
Middle/Junior High	41	36.9	74	61.7	115	49.78
Senior High/ Technical/Vocational	10	9	10	8.3	20	8.66
Tertiary	6	5.4	6	5	12	5.2
Farming Experience (years)						
Min(1-10)	52	46.8	24.2	31	76	35.1
Mean(10-20)	32	28.8	50	60	82	39.8
Max(>20)	27	24.3	25.8	31	53	25.1
Income Sources						
Other farming	84	47.7	91	52.3	176	76.2
Petty Trading	22	47.8	24	52.2	46	19.9
Remittances	3	42.9	4	57.1	7	3.0
Formal Occupation	1	50.0	1	50.0	2	0.9

Source: Author (2016)

3.2. Output, Area Cultivated and Cocoa Yields

Table 3 indicates the percentage of farmers, total cocoa output obtained, total land area of cocoa cultivated and cocoa yields in the Sefwi-Bekwai and Akontombra Districts of the Western Region.

Out of 231 respondents interviewed, 52% from Sefwi-Bekwai Districts obtained 325.97 metric tons of cocoa on 122.07 hectares of land cultivated. Additionally, about 48% of the respondents in the Akontombra Districts cropped 100.27 hectares of land and produced 258.58 metric tons of cocoa.

Table 3. Summary of Output, Cultivate Hecterage and Yields of Cocoa

Study Area	Frequency	Percent	Total Output	Mean Output	Yield (MT/ha)	Total Farm Size	Average Farm Size	Cocoa Yield (MT/ha)
Sefwi Bekwai	120	52	325.97	2.72	2.67	122.1	2.34	0.37
Akontombra	111	48	258.58	2.33	2.58	100.3	2.08	0.38
TOTAL	**231**	**100**	**584.55**	**2.53**	**2.63**	**222.3**	**4.42**	**0.75**

Source: Author (2016)

Farmers from Sefwi-Bekwai District have higher cocoa yield than those in Akontombra District. The small-scale cocoa farmers interviewed in the Sefwi-Bekwai and Akontombra Districts obtained cocoa yields of 0.37 metric tons per hectare and 0.38 metric tons per hectare respectively. On average, farmers interviewed had cocoa yield of 0.375 metric tons per hectare. This yield figure is slightly lower than the national figure of 0.4 metric tons per hectare in 2014. The average farm size of farmers in Sefwi-Bekwai and Akontombra Districts were 2.34 hectares and 2.08 hectares respectively.

3.3 Trend of climate indicators

3.3.1 Total Annual Rainfall

Figure 1 depicts the trend and direction of change of total annual rainfall recorded over the period 1975 to 2015. There were extremely high and low rainfall amounts recorded between 1997 through 1985 but a much more greater than average rainfall occurring in the 1990 through 2010.The linear trend line shows an upward climb meaning on the average, there has been increase in the level of rainfall over the long run for the period 1975-2015.

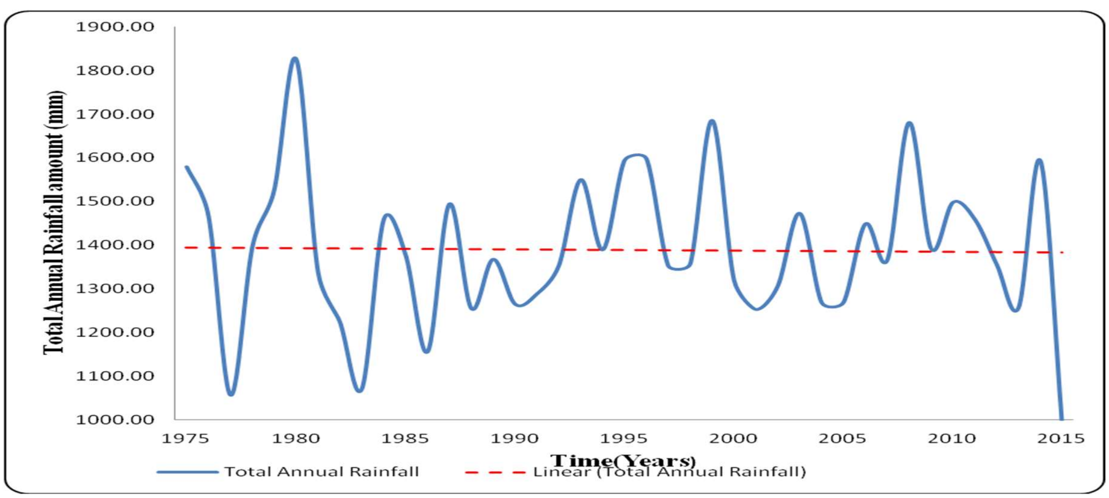

Figure 1. Trend of Annual Total Rainfall from 1975-2015
Source: Authors computation based on GMA data (2016)

3.3.2 Average Annual Temperature

Figure 2 illustrates how the trend in average annual temperature fluctuates over the period 1975 to 2015. The variation in average annual temperature is not constant but rather fluctuates mildly each year about the mean. In the long run, there is a sturdy rise in temperature in the region. There were not too much departure from the mean generally; however the maximum temperature experienced stronger variation than the minimum temperature over the past 40 years. A sharp drop in temperature readings were recorded at two data point, 1976 and 2003 but on the average there was a much stable temperature. There was decrease in temperature towards the end of the study period which could be partly attributed to the effect of the policies such as Reducing Emissions from Deforestations and Forest Degradation (REDD) and Afforestation/tree planting programs being carried out in the region for some years.

It was evidenced that in the case of the average maximum temperature (tmax), the rate of variation showed a much higher fluctuation than the minimum temperature (Tmin) over the same period. The departure from the mean was much positive representing upward trend implying there is greater than average temperature variation in the maximum temperature readings than the case of the minimum. The average maximum and minimum temperature readings were 33.19°C and 23.41 °C. This results further indicates that the region is becoming warmer which confirms the assertion of the farmers that temperature in the study area has been rising. This further shows that but for the forest policies such as Reducing Emissions from Deforestations and Forest Degradation (REDD) and Afforestation/tree planting programs being carried out in the region for some years, there would have been a much warmer.

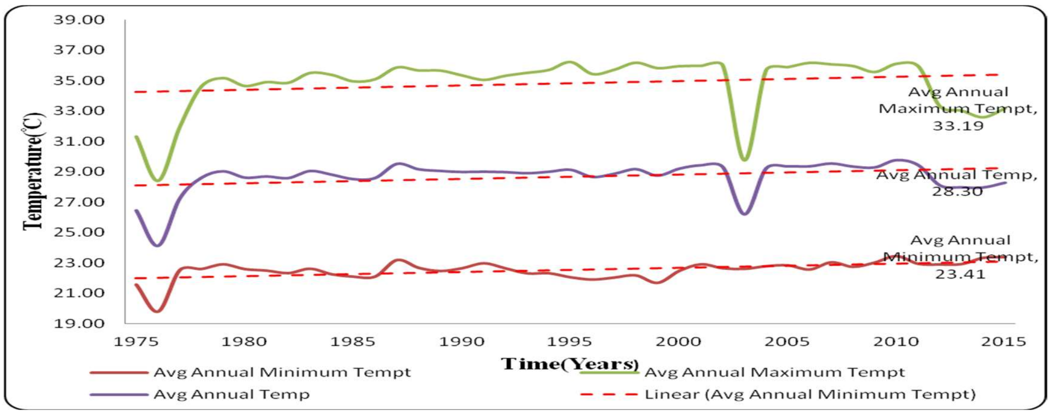

Figure 2. Trend of Average Annual Temperature
Source: Authors computation based on GMA data (2016)

3.3.3 Annual Bright Sunshine Duration

Figure 3 illustrates growth in bright sunshine duration (BSD) against time in years. The trends in bright sunshine duration fluctuated over the past 40 year with stronger variation above the mean observed between 1992 through 1995, 1996-1998 and somewhere around 2005 and 2006. Generally, there had been an increasing trend in the annual bright sunshine duration over the period 1975 to 2015. The steepest fluctuation was recorded in 2014, and peaking strongly in 2015. This notwithstanding, BSD has the most extreme variations in both directions but on the long run there is more upward trending with positive departure from the mean implying that over the 40 year period, there has been more greater than average BSD recorded over the time span. Long Bright Sunshine Duration promotes photosynthetic activity for the crop. In other words, the longer the BSD, the more synthesis of chlorophyll which is the energy source for plant growth and also the higher the flower production (Giraldo et al., 2014).

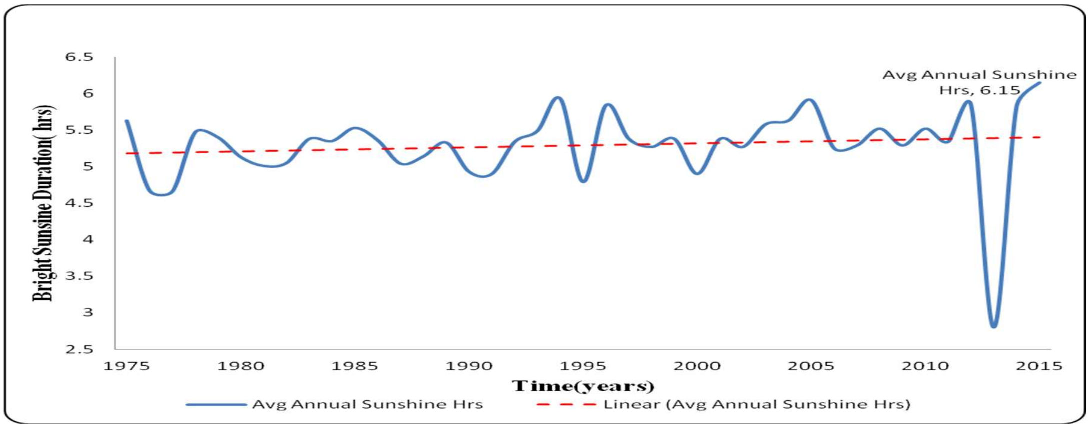

Figure 3. Trend of Average Annual Bright Sunshine Duration
Source: Authors computation based on GMA data (2016)

3.3.4 Average Annual Relative Humidity

Growth rate in average annual relative humidity (RH) is illustrated in Figure 4. The pattern of average annual relative humidity changes yearly with variation that does not depart too much from the mean. The pattern of the growth in average annual relative humidity fluctuates steadily each year. However over the period 1982-1989 and 1996-2013, there has been downward departure, representing growth rates. This means this period experienced lower than average relative humidity for those protracted periods. There were sharp decline and rise in the annual growth rates in 2013-2014 and this period record the highest single negative departure for the period. The slope coefficient value for the equation is 0.0001. This value signifies that the percentage change in annual relative humidity is 0.01%. This implies that the average relative humidity decreases by 0.01% each year. The t-value of 1.02 however implies that the growth rate is not statistically significant. When the following years 1984 and 2014 were controlled, the direction of the change and variation remained the same as seen in the second graph. The decreasing relative humidity recorded in the Western Region over the period is good for the crop. This is because high humidity promotes pests and disease infestation in general and specifically blackpod as reported by Jacobi et al. (2015).

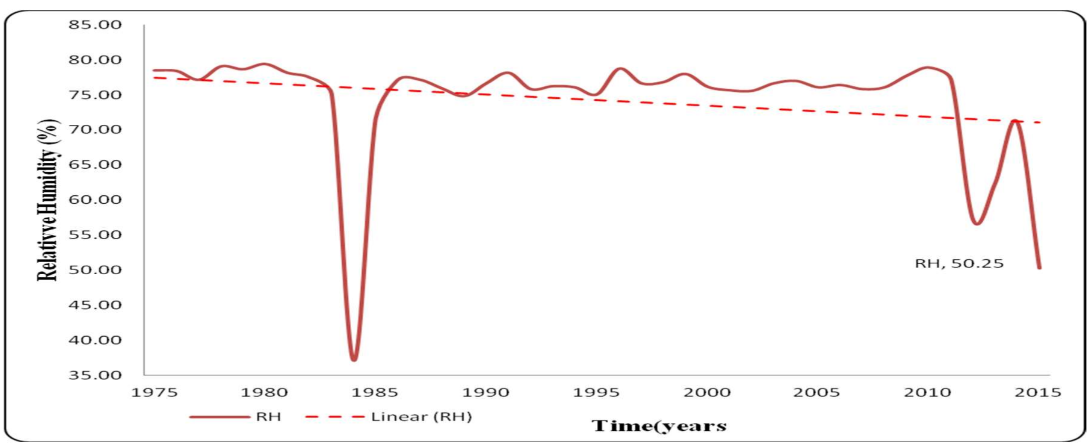

Figure 4. Trend of Average Annual Relative Humidity
Source: Authors computation based on GMA data (2016)

3.4 Effects of climate change indicators on cocoa output

Table 4 represents regression results on the effects of climate change indicators on cocoa output in the study area. The log-log model was used because it gave better estimators and goodness of fit than the other models. The coefficient of determination (R^2) shown in the table indicates that 94% of the variations in cocoa output is explained by the variation in the previous years' cocoa output *(Y_{t-1}^{R})*, temperature *(T_t)*, rainfall *(R_T)*, variations between maximum and minimum temperatures *($VarT_t$)* and rainfall *($VarR_t$)*. The F-statistics also shows that the explanatory variables jointly and significantly affect cocoa output. The Durbin-Watson value of 2.2 implies that there is no linear relationship between any of the explanatory variables (no multicolinearity)

Table 4. Cocoa output response to climate change variable

Dependent Variable: Cocoa Output (YR) Method: Least Square Sample: 1975-2015 R-squared = 0.9414 F-statistics = 98.91 Prob > F = 0.0000*** Durbin-Watson Stat=2.1630				
Variable	**Coefficient**	**Robust Std Error**	**T stat**	**P value**
LnEducation	0.1312**	0.0672	1.9500	0.0510
LnAge	-0.4019***	0.0830	-4.8400	0.0000
Extension	0.0073	0.0071	1.0200	0.3060
In(YR_{t-1})	0.8559***	0.0615	13.9100	0.0000
In(Tt)	0.6101	1.0567	0.5800	0.5680
In(Rt)	0.0880	0.4491	0.2000	0.8460
In(VarTt)	0.1100	0.1986	0.5500	0.5830
In(VarRt)	-0.2380***	0.0836	-0.2850	0.0070
Constant	0.3594	4.2866	0.0800	0.9340

** and *** represent 5% and 1% levels of significance respectively.

The coefficient of previous years' cocoa output *(Y_{t-1}^{R})* which measures effects of technological changes and management practices on cocoa output is consistent with the *a priori* expectation. It is also significant at 1% indicating that technological changes and management practices significantly affects cocoa output. This means that a unit advancement in technology will result in an increase in cocoa output by 0.86mt/ha.

Worth noting in the findings is the consistency of the variation in rainfall amount (VarRt) with the a priori expectation. It is significant at 10% meaning that variation in rainfall (extreme rainfall) has significant effects on cocoa outputs in the study area. It can be concluded that a 1mm extreme increase in rainfall amount will result in a 0.24mt/ha decrease in cocoa output. In this study, temperature, rainfall amount and extreme temperatures do not have significant effects on cocoa output. These results are inconsistent with the finding of the work of Oyekale et al. (2009) and Anim-Kwapong and Frimpong (2005) whose studies concluded that total rainfall, average annual temperature and extreme temperatures significantly influence the output of crops.

For every additional year increase in a cocoa farmer's education will lead to a corresponding 13.12% increase in cocoa yield. Education of the cocoa farmer (lnEducation) was found to be significantly associated with yield because more educated farmers can make more prudent decisions with respect to appropriate production technologies and input use which will translate into higher yields. Aneani and Ofori-Frimpong (2013) found this to be the case for cocoa farmers in 6 different districts in Ghana.

Age of cocoa farm (lnAge) had a significantly inverse relationship with the yield of cocoa because older cocoa farms have old trees which have likely outgrown their economic lifespan and therefore have begun to decline in yield. The higher yields associated with younger cocoa farms could also possibly be due to the fact that these younger farms have younger plants that are newly improved varieties and therefore have better yields. Edwin and Masters (2005) also held similar views in their study on genetic improvement and cocoa yields in Ghana.

4. Conclusions and Recommendation

From the results of the study, the following conclusions can be drawn:
Climate has changed with strong variability over the past 40 years in the Western Region in terms temperature, relative humidity and bright sunshine duration. Temperature, rainfall, and extreme temperature had no significant effect on cocoa output. Whereas previous year's output and extreme rainfall had significant effect on the output of the small-scale cocoa farmers.

From the key findings of this study, a number of policy intervention and recommendations are identified. These are:

Since extreme rainfall and technology (previous years' yield) significantly affect cocoa output, it is recommended that COCOBOD, MoFA and NGOs should design improved technology such as cocoa seeds/seedlings that can withstand extreme climatic events and boost yields

Policy makers should design policies to train the farmers on the use of the identified on farm adaptation methods to help them adapt well to the changing climatic conditions. When this is done output would be boost output and cocoa farmers would not diverse to other sources of livelihood.

References

Akudugu, M. A., Dittoh, S. & Mahama, E. S. (2012). The implication of climate change on food security and rural livelihoods. *Journal of Environment and Earth Science*, 2 (3):21-29.

Aneani, F., & Ofori-Frimpong, K. (2013). An analysis of yield Gap and some factors of cocoa (*Theobroma cacao*) yields in Ghana. *Sustainable Agriculture Research*, 2(4), 117.

Anim-Kwapong, G. J. & Frimpong, E. B. (2005). Vulnerability of agriculture to climate change-impact of climate change on cocoa production. Final Report submitted to the Netherlands climate change studies assistance Programme: NCAP, 2.

Calpe, C. (2002). Rice in world trade, Part II. Status of the world rice market, In: Proceedings of the 20th Session of the International Rice Commission, Bangkok, Thailand, 23-26 July 2002. pp. 225.

CGIAR. (2009). Climate, Agriculture and Food security: A strategy for change. www.ccafs.cgiar.org. (Accessed 23 December 2015)

Chang, K. W., Shen, Y., & Lo, J. C. (2005). Predicting rice yield using canopy reflectance measured at booting stage. *Agronomy Journal*, 97(3), 872-878.

Codjoe, S.N.A & Owusu, G. (2011). Climate change/variability and food systems: Evidence from Afram Plains, Ghana. *Regional Environmental Change*, 11(4): pp. 753-765

Deressa, T., Hassan, R. M., Alemu, T., Yesuf, M., & Ringler, C. (2008). Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. IFPRI.

Edwin, J., & Masters, W. A. (2005). Genetic improvement and cocoa yields in Ghana. *Experimental Agriculture*, 41(04), 491-503.

FAO (2008). Climate change adaptation and mitigation in the food and agriculture sector.

Fosu-Mensah, B., Vlek, P., & Manschadi, M. (2012). Farmers' perceptions and adaptations to climate change: A case study of Sekyedumase district in Ghana. A contributed paper presented at World Food Systems Conference in Tropentag, Zurich: 14th -16 september2010.Francisco: Jossey-Bass

Ghana Cocoa Board (COCOBOD) (2015). Socio-economic study. Final report [MASDAR].Ghana Cocoa Board.

Giraldo, J. P., Landry, M. P., Faltermeier, S. M., McNicholas, T. P., Iverson, N. M., Boghossian, A. A., ... & Strano, M. S. (2014). Plant nanobionics approach to augment photosynthesis and biochemical sensing. *Nature Materials,* 13(4), 400- 408.

Hesselberg, J., & Yaro, A. (2006). An assessment of the extent and causes of food insecurity in northern Ghana using a livelihood vulnerability framework. *GeoJournal* 67, 45-55.

Intergovernmental Panel on Climate Change (IPCC) (2007). Mitigation of Climate Change 2007: Contribution to Working Group III to the 4TH Assessment Report of the IPCC

Jacobi, J., Schneider, M., Bottazzi, P., Pillco, M., Calizaya, P., & Rist, S. (2015). Agroecosystem resilience and farmers' perceptions of climate change impacts on cocoa farms in Alto Beni, Bolivia. *Renewable Agriculture and Food Systems*, 30(02), 170-183.

Lobell, D. B., Chil, N. K. & Field, B. C. (2007). Historical Effect of Temperature and Precipitation on California Crop Yield. Springer Science. *Business Media*, 81, 187-203

Maddison, D. (2007). The Perception of and adaptation to climate change in Africa. CEEPA. Discussion Paper No. 10. Centre for Economics and Policy in Africa, Pretoria, South Africa: University of Pretoria, Pretoria.

Mainardi, S. (2010). Cropland use, yields and droughts: Spatial data modelling for Burkina Faso and Niger. Department of Informatics and Econometrics, UKSW-Card. S. Wyszy'nski University, Warsaw, Poland

Oyekale A., Bolaji M. & Olowa O.W. (2009): The effects of climate change on cocoa production and vulnerability assessment in Nigeria, Medwell Publishers, *Agricultural Journal*, 4, 92.

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

Stephens, C. S. (1996). Some empirical evidence of global warming in Ghana. *Ghana Journal of Science*, 36(1).

Yaro, J. (2002). The poor peasant: One label, different lives. The dynamics of rural livelihood strategies in the Gia-Kajelo community, northern Ghana. *Norwegian Journal of Geography*, 1, 10-20.