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# The effect of climate change on cocoa production in Ekiti and Ondo States of Nigeria: A co-integration analysis

**THOMPSON, O.A.**
**Department of Agricultural and Resources Economics, The Federal University of Technology, Akure, Ondo State, Nigeria.**

**ABSTRACT: The study examined whether or not there is short run and long run equilibrium relationship between cocoa output and climate change variables (i.e. Rainfall, Temperature and Humidity). This is to ascertain the effect of climate change on cocoa output both in the short run and long run in the study area. The short run was considered to be within the period of 1971-1990 and 1990-2010, while the long run was considered to be within the period of 1971-2010. It was established at the long run that cocoa output and rainfall were non-stationary among the three selected climate change determinants (i.e. Rainfall, Humidity and Temperature.). In the long run, both at 1% and 5% level of significance, their absolute values were greater than the critical values (i.e. for cocoa;-2.855384>-3.610453 & -2.938987 and for rainfall; -1.591781>-3.610453 &-2.938987). Also, the co-integration test was carried out in the long run; the trace statistic test revealed that at both 1% and 5% level of significance 2 and 1 equations were co-integrated. The Max-Eigen values also revealed that at both 1% and 5% levels of significance, that at most 2 and 1 equations were co-integrated, since their absolute values 25.27>15.41 and 20.04; 20.61>14.07 and 18.63. This corroborated the trace statistics, therefore, it was concluded that there is a long run equilibrium relationship between cocoa output and rainfall. The results established the fact that cocoa is highly susceptible to drought and the pattern of cropping of cocoa is related to rainfall distribution in the study area.**

**Key words:** Cocoa, rainfall, humidity, temperature, co-integration

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## INTRODUCTION

Cocoa (*Theobroma cacao)* is an international crop. This crop of Latin American origin had determined both the economic and political fate of many countries of the world of which Trinidad, Ghana, Nigeria, Cote D'Ivoire, Brazil, Costa Rica and Fernando Po are prominent. Cocoa is a major cash crop in the tropical forest, most notably in West Africa, where export earning from its sales account for a major part of the National Income (Mayhew and Perry, 1998). Chocolate, a major product derived from the raw cocoa beans had been a very important beverage in European, American, and Asian countries. While most of the consuming countries are non-producers of the raw cocoa-beans, most of the producing countries consume about 5-10 percent of the commodity (ICCO, 1994).

Nigeria was the second world largest cocoa producer in the 1960s producing between 250,000 to 308,000 metric tons for export yearly and generating about 50 percent of Nigeria's revenue. Cocoa production witnessed a downward trend

*Correspondence to: Thompson, O.A., tonyfav22@gmail.com

after 1970/1971 season, when its export declined to 216,000 metric tones and this reduced Nigeria's market share to about 6 percent to date and fifth world largest cocoa producer, (ICCO, 2008). Currently, cocoa is grown in commercial quantity in nine States of the Federation with Ondo and Ekiti states combined producing about 53.32% of the total Nigeria cocoa production (Folayan, 2005). Also, both the Ekiti and Ondo states governments have been having part of their annual revenue accruing from sales of cocoa beans (Folayan, 2005).

However, crop outputs cocoa inclusive depend relatively on climate and water supply generally (Dennett et al, 1981) and it is agreed that rainfall is an important climatic element for assessing water supply for agriculture in the tropics (Omotosho, 2001). Also, crop outputs are affected biophysically by meteorological variables, including rising temperatures, changing rainfall, precipitation regimes, and increased atmospheric carbon dioxide levels (Parry *et al*, 2004). One persistent problem of water supply to agriculture is manifested by seasonal and variable nature of rainfall (Jonathan *et al*, 2009). Rainfall variability is not only limited to seasonal fluctuation but also includes year to year variability in the onset, cessation and duration of the rains which are also characterized by dry spells of unpredictable magnitude (Mortimore, 1989).

Therefore, since agricultural output in part of tropic is rain-fed, and recognizing that the constraints of rain-fed agriculture in Nigeria in particular as the erratic rain distribution (Jonathan *et al*, 2009), there is need to determine both the short and long run relationship between cocoa output and climate change determinants ( i.e. rain fall, temperature and humidity) in the study area (i.e. Ondo and Ekiti States). This is with the aim of knowing the extent of the effects of climate change determinants on cocoa output in the study area and make recommendations on how to mitigate such effects on cocoa output in the study area.

**Theoretical Framework**

This study sees cocoa as contributing to the economic welfare of the farmers and the citizen of Ondo State and this is determined by the annual production. Imoudu (1995) reported that "Cocoa is one of the major foreign exchange earners to the country and in particular it has contributed immensely to raising the generated revenue of the producing states in Nigeria". Ondo State Government for example has been having part of their annual revenue accruing from sales of cocoa beans. In Ondo State the revenue accruing to the state increased from N1.04 million in 1980 to about N209.66 million in 2003 (Folayan, 2005) and N298.67 million in 2011 (OSMARD, 2012).

Cocoa production in Ekiti and Ondo States contributes to the economic welfare of the citizens of the two States. However, cocoa production is assumed to be determined by the climate change determinants in the two States. Since agricultural production in parts of tropic is rain-fed, and recognizing that the constraints of rain-fed agriculture in Nigeria in particular is the erratic rain distribution (Jonathan *et al,* 2009). Therefore, water supply determined cocoa production at any point in time (Adejuwon and Odekunle, 2006).

Therefore, it is assumed that rainfall, temperature and humidity which are determinants of climate change will affect cocoa production either positively or negatively. Co-integration method of analysis which basically established both short run and long run equilibrium relationship between two or more variables was used to determine equilibrium relationship between cocoa output and the determinants of climate change in the study area. Since rainfall stability in terms of availability of water which is determined by atmospheric temperature and also determine soil humidity will increase cocoa production. This will invariably affect the economic welfare of the citizens of both States positively, since cocoa production is water dependent (Omotosho, 2007).

## MATERIALS AND METHODOLOGY

### Study area

Ondo and Ekiti State were purposively selected for the study because the two states were the highest producers of cocoa in Nigeria in 2011 (National Bureau of Statistics, (NBS) 2012). The two States are made up of 34 Local Government Areas (i.e. Ekiti state has 16 and Ondo State has 18 Local Government Areas). They are both located in the South-western Zone of Nigeria (Adejuwon and Odekunle, 2006). The two States lie between longitudes 4"30" and 6" East of the Greenwich Meridian, 5" 45" and 8" 15" North of the Equator (Emielu, 2000). The States lie entirely in the tropical rainforest (Salako, 2006).

Since the two States lie in the tropical rainforest, the States have a bimodal rainfall distribution but with less intensity. There is a distinct dry and rainy seasons. The States have an average annual rainfall and temperature of 1489mm and 26.5$^{o}$C respectively (Omotosho, 2007). In Ekiti and Ondo State, there is lower layer vegetation mostly dense with abundance herbs, shrubs and some grasses. While the top layer of the States account for valuable economic trees such as Mahogany, Iroko, Obeche among others (Akeh and Gbuyiro,2006). The States have a high density of human population with agriculture as primary occupation of the people. The States are known for the cultivation of cocoa, maize, cocoyam, cassava, vegetable, yam, oil palm etc (Oyekale, 2009).

### Data collection

Annual cocoa output in both Ekiti and Ondo States were collected from the annual bulletins of Central Bank of Nigeria and from the National Bureau of Statistics. The annual cocoa output data were collected from 1971-2010. The secondary data were used to determine the effect of climate change determinants on cocoa output level in Ekiti and Ondo State. Also, the weather data (i.e. rainfalls, temperature, relative humidity) were obtained from the archive of Nigerian Meteorological Agency (NIMET). Again, the average yearly weather data and cocoa output from 1971-2010 is presented in Table 1. The two States are under the same weather station in Akure, the Capital of Ondo State.

### Data analysis

Co-integration technique was used to ascertain both the short and the long run equilibrium relationship between cocoa output and weather data in the study area. This is with the aim of ascertaining the effects of climate change on cocoa output in the study area. Therefore, the effects of climate change on cocoa output was considered between 1971-1990 and 1990-2010. These two periods are considered as short run equilibrium relationship (i.e. effect of climate change on cocoa output) between climate change determinants and cocoa output in the study area. Also, the effect of climate change on cocoa output was considered between 1971-2010. This is regarded as long run equilibrium relationship between climate change determinants and cocoa output in the study area. This long run equilibrium relationship depicts the long run effect of climate change on cocoa output.

Therefore, the Augmented Dickey-Fuller (ADF) unit root test estimation was done to test the hypothesis that cocoa output had a unit root for both the two periods (i.e. 1971-1990 and 1990-2010) of the short run and for the period of the long run (i.e. 1971-2010) (i.e. $H_{0:}$ □= 1) using equation 1

**Table 1: Annual cocoa output, rainfall, temperature and humidity between 1971 and 2010**

| Year | Cocoa Production | Rainfall | Temperature | Humidity |
|---|---|---|---|---|
| 1971 | 67,132.01 | 1509.3 | 28.08 | 69 |
| 1972 | 66,670.02 | 1326 | 26.9 | 72 |
| 1973 | 69,003.09 | 1409.05 | 27.85 | 71 |
| 1974 | 71,200.08 | 1234.9 | 28.17 | 70 |
| 1975 | 65,980.12 | 1879.05 | 28.1 | 70 |
| 1976 | 66,187 | 1587.9 | 28.16 | 72 |
| 1977 | 76,139 | 1376.87 | 27.79 | 71 |
| 1978 | 92,800 | 1518.9 | 28.08 | 72 |
| 1979 | 74,595 | 1754.5 | 28.28 | 73 |
| 1980 | 69,595 | 1966.4 | 28.16 | 73 |
| 1981 | 95,193 | 1424.2 | 28.22 | 71 |
| 1982 | 91,790 | 1238.62 | 25.5 | 72 |
| 1983 | 96,941 | 1207.98 | 26.54 | 68 |
| 1984 | 88,748 | 1298.43 | 27.04 | 70 |
| 1985 | 68,347 | 1644.1 | 25.5 | 70 |
| 1986 | 57,705 | 929.92 | 26.25 | 70 |
| 1987 | 72,584 | 1401.4 | 26.42 | 70 |
| 1988 | 110,457 | 1375.62 | 26.67 | 70 |
| 1989 | 71,214 | 1449.9 | 26.46 | 66 |
| 1990 | 72,173 | 1577.9 | 27 | 70 |
| 1991 | 81,276 | 1350.07 | 25.75 | 86 |
| 1992 | 51,620 | 1482.9 | 25.83 | 67 |
| 1993 | 78,649 | 1192.77 | 25.67 | 69 |
| 1994 | 69,525 | 1250.08 | 26.58 | 68 |
| 1995 | 54,749 | 1786.88 | 26.33 | 69 |
| 1996 | 43,898 | 1028.72 | 27.26 | 72 |
| 1997 | 41,181 | 1160.69 | 27.15 | 69 |
| 1998 | 28,817 | 1453.6 | 27.13 | 68 |
| 1999 | 31,154 | 1353.87 | 27.48 | 71 |
| 2000 | 45,875 | 1399.37 | 27.29 | 67 |
| 2001 | 54,218.50 | 722.47 | 27.34 | 69 |
| 2002 | 64,906 | 1549.4 | 27.69 | 69 |
| 2003 | 68,531 | 1473.1 | 27.54 | 70 |
| 2004 | 65,432 | 1437.65 | 27.84 | 69 |
| 2005 | 59,890 | 1315.85 | 27.58 | 70 |
| 2006 | 67,170 | 1249.03 | 27.91 | 69 |
| 2007 | 66,980 | 1248.01 | 28 | 75 |
| 2008 | 62,178 | 1304.2 | 29 | 74 |
| 2009 | 63,235 | 1256.03 | 30 | 70 |
| 2010 | 60,245 | 1157.01 | 30 | 71 |

Sources: CBN, NBS and NIMET

$Ho_{1:}$ cocoa output had a unit root for both periods of 1971-1990 and 1990-2010

$$\Delta C_t = \beta_1 \Delta C_{t-1} + \beta_2 \Delta C_{t-2} + - - - + \beta_p \Delta C_{p-1} + V_t$$
.............. (1)

Where $C_t$ is the exogenous regressor (i.e. cocoa Output) with a constant trend.

□ is the parameter to be estimated

$V_t$ is the error term.

Also, the ADF unit root test estimation was done to test the hypothesis that rainfall had a unit root for both the two periods of the short run and for the period of the long run (i.e. $H_0$: □ = 1) using equation 2

$Ho_{2:}$ rainfall had a unit root for both periods of 1971-1990 and 1990-2010

$$\Delta R_t = \alpha_1 \Delta R_{t-1} + \alpha_2 \Delta R_{t-2} + - - - + \alpha_p \Delta R_{p-1} + \epsilon_t$$
...................(2)

Where $R_t$ is the exogenous regressor (i.e. rainfall) with a constant trend.

□ is the parameter to be estimated

$\epsilon_t$ is the error term.

Furthermore, the ADF unit root test estimation was done to test the hypothesis that temperature had a unit root for both the two periods of the short run and for the period of the long run (i.e. $H_0$: □ = 1) using equation 3

$Ho_{3:}$ temperature had a unit root for both periods of 1971-1990 and 1990-2010

$$\Delta T_t = \rho_1 \Delta T_{t-1} + \rho_2 \Delta T_{t-2} + - - - + \rho_p \Delta T_{p-1} + u_t$$
.........................(3)

Where $T_t$ is the exogenous regressor (i.e. temperature) with a constant trend.

□ is the parameter to be estimated

$u_t$ is the error term.

The ADF unit root test estimation was equally done to test the hypothesis that humidity had a unit root for both the two periods of the short run and for the period of the long run (i.e. $H_4$: □ = 1) using equation 4

$Ho_{4:}$ humidity had a unit root for both periods of 1971-1990 and 1990-2010.

$$\Delta H_t = a_1 \Delta H_{t-1} + a_2 \Delta H_{t-2} + - - - + a_p \Delta H_{p-1} + u_t$$
....................(4)

Where $H_t$ is the exogenous regressor (i.e. Humidity) with a constant trend.

$a_1$ is the parameter to be estimated

$u_t$ is the error term.

The next step was the co-integration test. Equation 5 was used to determine the short run and long term equilibrium relationship between cocoa output in the study area and the climate change determinants (i.e. rainfall, temperature and humidity)

$$\Delta Y_t = \prod Y_{t-1} + \sum_{i=1}^{p-1} i \Delta Y_{t-1} + \theta_i X_t + \varepsilon_t$$
..........................(5)

However, equation 5 was transformed as follows;

$$\prod = \sum_{i=1}^{p} A_1 - I_t - - - \theta_i = \sum_{j=i+1}^{p} A_j$$
.................(6)

where $Y_t$ = (C, R, T, H) is a k-vector of non-stationary I(1) variables;

C: Cocoa output in both Ekiti and Ondo state

R: Rainfall value in Ekiti and Ondo State

T: Temperature value in Ekiti and Ondo State

H: Humidity value in Ekiti and Ondo State

t: 1971-1990; 1990-2010 and 1971-2010

Where *k is the* 4 × 4 matrices **A**, for *i* = 1,..., *k* are matrices of coefficients relating the 4 variables in $\mathbf{Y}_t$ to their lagged values. where $\theta_1$ = - ( **I** - **A** -...-$\mathbf{A}_1$ ), *i* = 1,..., *k* -1, and **Π** = - ( **I** - **A** -...-**A** ) are all 4 × 4 matrices. This specification usefully separates the short-run and long-run adjustments to changes in the variables in $Y_t$, capturing these in the matrices $\theta_1$ and **Π** respectively. Also, the trace statistics for the null hypothesis of co-integrating relations were computed as follows:

$$LR_{tr}\left(\frac{r}{k}\right) = T \sum log\,(1-\lambda_i)_{j=r+1}^{k}$$
.................(7)

and

$$LR_{max}\left(\frac{r}{r}+1\right) = T log\,(1-\lambda_{i+r})$$
...................(8)

Equation 7 and 8 can be transformed as:

$$LR_{tr}\left(\frac{r}{k}\right) - LR_{max\,(r+1/k)\; for\; r=0,1,------,k-1} \quad (9)$$

Where $\lambda_i$ is the i-th largest eigenvalue of the □ matrix in equation 6.

## RESULTS AND DISCUSSION

**Table 2: Results of ADF Unit Root Test For Period 1 (i.e. 1971-1990)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -1.824147 | -4.200056 | -3.175352 | Non stationary |
| Humidity | -2.237569 | -2.147721 | -1.945180 | Stationary |
| Temperature | -3.158537 | -2.927317 | -2.371890 | Stationary |
| Rainfall | -2.168260 | -2.837141 | -2.420140 | Non-stationary |

Source: Computed from cocoa and weather series data

**Table 3: Results of ADF Unit Root Test For Period 2 (i.e. 1990-2010)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -1.916105 | -2.494038 | -2.017421 | Non stationary |
| Humidity | -7.147109 | -6.106609 | -5.700214 | Stationary |
| Temperature | -4.173910 | -4.481301 | -4.191404 | Non Stationary |
| Rainfall | -5.929643 | -4.200056 | -3.175352 | Stationary |

Source: Computed from cocoa and weather series data

**Unit root test**

The presence of unit roots was tested and the order of integration for each variable was identified using the Augmented Dickey-Fuller (ADF).The null hypothesis was considered as non-stationary. The test on the variables (i.e. cocoa output, humidity, temperature and rainfall) for both the two periods of the short run and for the period of the long run gave the following results shown in Tables 2.and 3.

From Tables 2 and 3, which are the values of the computed ADF test-statistic for all the variables in the short periods, Cocoa output and rainfall between 1971 and1990 have a unit root since the computed ADF test-statistic for cocoa output and rainfall are greater than the critical values at 1% and 5% significant levels, respectively. It is concluded that cocoa output and rainfall has a unit root (i.e. non-stationary series). Also, from Table 3, temperature and cocoa output between 1990 and 2010 have a unit root, the computed ADF test-statistic for temperature and cocoa output is greater than the critical values at 1% and 5% significant levels. While the computed ADF test-statistic for humidity for the short periods is lesser than the critical values at 1% and 5% significant levels, respectively as shown in Tables 2 and 3. Therefore, Humidity for the short periods has no unit root (i.e. stationary series).

Therefore, to determine the integrated order ( i.e. integrated of order (1) at both 1% and 5% levels) of cocoa output and rainfall in the short period between 1971 and 1990, the Augmented Dickey-Fuller tests was performed on the first difference. The results of the unit root test revealed in Table 4 that the first differences of both series are stationary which are found to reject the null hypothesis of unit root.

Therefore, cocoa output and rainfall series involved in the estimation procedure were regarded as (1) and it is suitable to make co-integration test

Also, the order of integration of the short period between 1990 and 2010 was determined at both 1% and 5% level of cocoa output and temperature The Augmented Dickey-Fuller tests was performed on the first difference. The results of the unit root test in Table 5 showed that the first differences of both series are stationary which are found to reject the null hypothesis of unit root.

**Table 4: Results of ADF on first difference of cocoa and rainfall (1971-1990)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -3.960387 | -2.700549 | -2.403978 | Stationary |
| Rainfall | -6.308428 | -4.884130 | -3.980652 | Stationary |

Source: Computed from cocoa and weather series data

**Table 5: Results of ADF on first difference of cocoa, temperature and rainfall (1990-2010)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -5.194028 | -4.956301 | -4.084184 | Stationary |
| Temperature | -3.580124 | -3.291307 | -2.908563 | Stationary |

Source: Computed from cocoa and weather series data

From the above, cocoa output and temperature series involved in the estimation procedure were regarded as (1) and it is suitable to make co-integration test

Again, from Table 6, the computed ADF test-statistic for cocoa output ( i.e. -2.855384) in the long run is greater than the critical values (i.e. -3.610453 and -2.938987) at 1% and 5% significant levels, respectively. Thus it is concluded that cocoa output has a unit root that is non-stationary series, while the computed ADF test-statistic for humidity (-6.452821) is less than the critical values (i.e. -3.610453 and -2.938987) at 1% and 5% significant levels, respectively. Therefore, humidity has no unit root (i.e. stationary series). Also, the computed ADF test-statistics for temperature (-5.934024) is less than the critical values (i.e. -3.610453 and -2.938987) at 1 and 5% significant level, respectively. Therefore, it is concluded that temperature has no unit root (i.e. stationary series). However, the computed ADF test-statistic for rainfall (-1.591781) is greater than the critical values (-3.610453 and -2.938987) at 1 and 5% significant level, respectively). Rainfall has a unit root that is non-stationary series.

As shown in Table 6, for the variables of cocoa output and rainfall, the results showed that it is evident that the presence of a unit root at conventional levels of statistical significance found at both 1 and 5% for the variables of cocoa output and rainfall. To see whether they are integrated of order one (1) at both 1% and 5% level, the Augmented Dickey-Fuller tests were performed on the first difference. The results of the unit root test as shown in Table 7 that the first differences of both series are stationary which are found to reject the null hypothesis of unit root.

It is thus concluded that only cocoa output and

**Table 6: Results of ADF unit root test for long period (i.e. 1971-2010)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -2.855384 | -3.610453 | -2.938987 | Non stationary |
| Humidity | -6.452821 | -3.610453 | -2.938987 | Stationary |
| Temperature | -5.934024 | -3.610453 | -2.938987 | Stationary |
| Rainfall | -1.591781 | -3.610453 | -2.938987 | Non-stationary |

Source: Computed from cocoa and weather series data

**Table 7: Results of ADF on first difference of cocoa and rainfall period (i.e. 1971-2010)**

| Variable | ADF-statistic | Critical value (1%) | Critical value (5%) | Result |
|---|---|---|---|---|
| Cocoa | -7.525729 | -3.615588 | -2.941145 | Stationary |
| Rainfall | -8.540910 | -3.615588 | -2.941145 | Stationary |

Source: Computed from cocoa and weather series data rainfall series involved in the estimation procedure were regarded as (1) and suitable to make co-integration test.

**Johasen co-integration test**

As shown in Table 4 and 5 by previous test of the two variables (i.e. cocoa output and rainfall) in the short period between 1971 and 1990 and two variables (i.e. cocoa output and temperature) in the short period between 1990 and 2010 are integrated of order 1 (namely (1) hence the co-integration test was performed. The proper way to test the relationship between cocoa output and rainfall (i.e.1971-1990) and cocoa output and temperature ( i.e. 1990-2010) is certainly to test for a co-integrating equation. In testing co-integration relationships, the Johansen and Juselius method of testing was used. For selecting optimal lag length for the co-integration test, the Schwartz Information Criterion (SIC) and Schwarz criterion (SC) Criterion was adopted. The co-integration tests results performed on both the cocoa output and rainfall variables (i.e.1971-1990) gave the following results shown in Table 8.

The above result revealed that there is a short run equilibrium relationship between cocoa output and rainfall between 1971 and 1990. This revealed that between this period, cocoa output was immensely influenced by availability of rainfall. This is in line with the findings of Tunde (2011) who carried out a study on how men and women farmers perceive climatic variability in Idanre Local Government Area of Ondo State. In his findings, rainfall was highly correlated with cocoa. The above result showed that cocoa output is highly influenced by rainfall during this period. Therefore, any dwindling in rainfall within this period surely influenced cocoa output.

**Table 8: Results of co-integration rank test between rainfall and cocoa for the period of 1971-1990**

| Hypothesized No. of CE(s) | Eigen Value | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value |
|---|---|---|---|---|
| None ** | 0.370241 | 13.93216 | 10.23 | 12.91 |
| At most 1 * | 0.293610 | 6.731071 | 5.95 | 7.08 |
| **Hypothesized No. of CE(s)** | **Eigen Value** | **Max-Eigen Statistics** | **5 Percent Critical Value** | **1 Percent Critical Value** |
| None ** | 0.370241 | 18.83810 | 10.23 | 16.63 |
| At most 1 * | 0.293610 | 6.731071 | 5.95 | 7.08 |

Source: Computed from cocoa and weather series data
*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 2 co-integrating equation(s) at the 5% level
Trace test indicates 1 co-integrating equation(s) at the 1% level
Max-eigen value test indicates 2 co-integrating equation(s) at the 5% level
Max-eigen value test indicates 1 co-integrating equation(s) at the 1% level

Also, within the short period of 1990 and 2010, cocoa output was majorly influenced by the temperature as shown by the co-integration result in Table 9.

From the above result, the short run equilibrium relationship between cocoa output and temperature within this period ( i.e. 1990-2010) is very high. Since Trace test and Max-eigen value test indicates 2 co-integrating equation(s) at the 5% and 1% level. This actually reflects the findings of Intergovernmental Panel on Climate Change, (IPCC) 2010 that increased atmospheric carbon dioxide concentrations can be harmful to crop productivity. Furthermore, according to Molua and Lambi, (2006) changes in temperature will definitely affect the precipitation and will

**Table 9: Results of co-integration rank test between temperature and cocoa for the period of 1990-2010**

| Hypothesized No. of CE(s) | Eigen Value | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value |
|---|---|---|---|---|
| None ** | 0.918032 | 10.21024 | 7.18 | 9.23 |
| At most 1 * | 0.838031 | 8.639128 | 4.07 | 8.21 |
| **Hypothesized No. of CE(s)** | **Eigen Value** | **Max-Eigen Statistics** | **5 Percent Critical Value** | **1 Percent Critical Value** |
| None ** | 0.918032 | 26.25219 | 16.19 | 21.98 |
| At most 1 * | 0.838031 | 8.639128 | 4.07 | 8.21 |

Source: Computed from cocoa and weather series data
*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 2 co-integrating equation(s) at the 5% level
Trace test indicates 1 co-integrating equation(s) at the 1% level
Max-eigen value test indicates 2 co-integrating equation(s) at the 5% level
Max-eigen value test indicates 1 co-integrating equation(s) at the 1% level

affect humidity negatively which will have adverse results on crop productivity. Again, during this period ( i.e. 1990-2010), the world generally experienced serious green house emission which is due to industrialization (Zha and Byambadorj, 2011). This has led to increase in atmospheric temperature all over the world and which greatly affects crops output especially in Sub-Sahara Africa (SSA) where adaptation strategies are yet to be comprehended by rural farmers (Tologbonse *et al*, 2010). Therefore, increase in temperature will have an adverse effect on the cocoa output, since it is established that there is short run equilibrium relationship between temperature and cocoa output. .

Furthermore, Table 10 showed the co-integration result of the long run ( i.e. 1971-2010) equilibrium relationship between cocoa output and rainfall. From table 10 above, the Trace Statistic test reveals that at both 5% and 1% level of significance that at most 2 and 1 equations are co-integrated, since their absolute values are greater than the critical values of 5% and 1% level of significant i.e.25.27>15.41 and 20.04, 4.65>3.76.

Also, from the same Table, the Max-Eigen values reveal that at both 5% and 1% level of significance that at most 2 and 1 equations are co-integrated. The absolute values are greater than the critical values of 5% and 1% level of significant i.e. 20.61>14.07 and 18.63, 4.65>3.76. This corroborated the Trace Statistics. Therefore, it was concluded that there is a long run equilibrium relationship between cocoa output and rainfall in the study area. With all these tests, there is a long run equilibrium relationship between the dependable (cocoa output) and one of the explanatory variables (rainfall) in the model. The results established the fact that cocoa output in the study area is mostly affected by rainfall variability in the long run.

In view of the above, it is established that cocoa output is highly susceptible to drought and the pattern of cropping of cocoa is related to rainfall distribution. It is well established that cocoa is highly sensitive to rainfall and application of water which corroborate the findings of Adu-Ampomah and Frimpong (2002). Since rainfall alter stages and rates of development of cocoa pests and pathogens, modify host resistance and result in changes in the physiology of host-pathogen/pests interaction (Appiah, 2004). The most likely consequences are shifts in the geographical distribution of host and pathogen/ pests, altered crop productions and crop loses which will impact socio-economic variables such as farm income, livelihood and farm-level decision making.

**Table 10: Results of co-integration rank test between rainfall and cocoa for the period of 1971-2010**

| Hypothesized No. of CE(s) | Eigen Value | Trace Statistic | 5 Percent Critical Value | 1 Percent Critical Value |
|---|---|---|---|---|
| None ** | 0.418657 | 25.26546 | 15.41 | 20.04 |
| At most 1 * | 0.115264 | 4.653703 | 3.76 | 6.65 |
| **Hypothesized No. of CE(s)** | **Eigen Value** | **Max-Eigen Statistics** | **5 Percent Critical Value** | **1 Percent Critical Value** |
| None ** | 0.418657 | 20.61175 | 14.07 | 18.63 |
| At most 1 * | 0.115264 | 4.653703 | 3.76 | 6.65 |

Source: Computed from cocoa and weather series data
*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 2 co-integrating equation(s) at the 5% level
Trace test indicates 1 co-integrating equation(s) at the 1% level
Max-eigen value test indicates 2 co-integrating equation(s) at the 5% level
Max-eigen value test indicates 1 co-integrating equation(s) at the 1% level

## CONCLUSION

The implication of the statistical analysis is that rainfall affected cocoa output in the study area within the period of 1971 and 1990. Therefore, this established a short run equilibrium relationship between cocoa output and rainfall in the study area. Also, between 1990 and 2010, short run equilibrium relationship was established between cocoa output and temperature in the study area, which may be connected to high emission of carbon dioxide as a result of industrialization within this period. Therefore, it is possible that this will impact negatively on crop outputs ( cocoa inclusive.) Furthermore, it was established that there is long run equilibrium relationship between cocoa output and rainfall. So, rainfall variability in the long run will affect cocoa production over time. In view of the above, it is recommended that drought management policy through information systems about changing climate conditions and patterns, preparatory practices and options to deal with eventuality of drought must be set in place. Also, irrigation is traditionally not part of the cocoa farming system in the study area, therefore, policies to promote the establishment of irrigation system in farms through the provision of infrastructure, education and training should be considered.

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