Original Research Article

Future Impact of Climate Change on the Yield of Cocoa in Ondo State, Nigeria

Abstract

This study was carried to determine the trend of cocoa yield and climatic variables and assessment of the impact of climate change on the future yield of cocoa in Ondo State, Nigeria. Annual trend statistics for cocoa yield and climatic variables were analyzed for the state using Mann-Kendall test for trend and Sen's slope estimates. Downscaled data from six Global Circulation Models (GCMs) were used to examine the impact of climate change on the future yield of cocoa in the study area. The results of trends analysis in Ondo State showed that yield decreased monotonically at the rate of 492.18 tonnes/yr ($P<0.05$). An increased significant trend was established in annual rainfall trend. While Maximum temperature, minimum temperature, and mean temperature all increased at the rate of 0.02 ℃/yr ($P<0.001$). The ensemble of all the GCMs projected a mid-term future decrease of about 9,334 tonnes/yr by 2050 and a long-term future decrease of 13,504 tonnes/yr of cocoa by 2100. The economic implication of these is that, if the projected change in the yield of cocoa as predicted by the ensemble of all the GCMs should hold for the future, it means that Ondo state may experience a loss of about $22,470,018.22 and $32,308,584.32 by the year 2050 and 2100 respectively according to the present price of the commodity in the world market. Measures are to be taken by the government and farmers to find a way of mitigating the impacts of climate change on the future yield of the cocoa study area. This research should be extended to other cocoa producing areas in Nigeria.

Keyword: Climate change; cocoa yield; climate variable; Mann-Kendall trend; future yield

1. Introduction

One of the most important cash crops contributing to the gross domestic product (GDP) of Nigeria is cocoa (*Theobroma cacao)* (Oyekale *et al*, 2009). It has contributed greatly to the economic development and social wellbeing of the people in the cocoa-producing areas and also boosted their financial status of the farmers after oil. The beans derived from cocoa is used in the production of chocolate products, biscuits, cocoa bread, cream, soap, livestock feeds, cocoa powder amongst others (Hamsat *et al*., 2003; Olubamiwa *et al*., 2000).

In the time past, Nigeria used to be the second largest producer of cocoa in the world and Ondo state was also the largest producing state but the production dwindled and currently the fourth producer in the World and due to some limiting factors, the production of cocoa declined drastically because of change in weather and climate change, management practices, oil exploration, etc (ICCO, 2008). Ayanlaja (2000) reported that cocoa production declined from 310,000 tonnes/yr despite increase insecticide application, land area, and introduction of a high yielding variety of cocoa in the country. Weather and climate change over the years has greatly affected cocoa production which is a major cash crop in Nigeria where Ondo state the worst hit of the menace.

The variation in the two climatic variables: Rainfall and temperature were discovered to have much influence on the sprouting, production, and growth of cocoa trees (Anim-Kwapong and Frimpong, 2005). However, most of the developing countries are already experiencing low yield of the crop, as a result, extreme weather and climate change (Odjugo, 2010). Extreme weather is a situation best described as extreme in terms of historical distribution, severe or unfavorable weather (ICCO, 2003). Climate change was reported to have played a vital role in the alteration, development of cocoa pests and pathogens thereby shifting their interactions (Oyekale et al., 2009). This, in turn, leads to lower yield, which brings about low yield, which brings about reduced income and livelihood for the farmers. Cocoa production is highly sensitive to change in rainfall, the intensity of sunshine, temperature, water supply, soil condition due to evapotranspiration effects (Anim-Kwapong and Frimpong, 2005). Climate change has been reported to be one of the most serious environmental threats affecting humans and their crops in the world today (Enete and Amusa, 2010). It also has a great effect on agricultural production.

Unfortunately, the recent trends pattern of rainfall had either been excess leading to the infestation of black pod disease which also leads to losses in cocoa yield. Insufficient rainfall also leads to seed mortality, drought and bush burning. This gives us the opportunity to examine the trends and impact of climate change on cocoa yield in Ondo state.

Therefore, the aim of this study is to evaluate the trends in historical cocoa yield, climatic variables and determine the impact of climate change on the future yield of cocoa in Ondo state, Nigeria.

2. Methodology

2.1 Study Area

Ondo state is located within the rainforest agro-climatic zone of Southwest Nigeria. It lies between latitudes 5^{o}45’ and 7^{o} 52‘N and longitudes 4^{o} 20’ and 6^{o} 5’ E. The major occupation of the people is agriculture, which provides income and employment for about 70% of the total population. The major arable crops cultivated include: yam, rice, cassava, tomatoes, maize, etc and some tree crops cultivated include: cocoa, coffee, oil palm and timber (OSMARD, 2004). Ondo state consists of 18 local government areas producing about 45 to 65% of the total cocoa production figures in Nigeria. OSMARD (2004) reported that 9 local government areas (LGAs) are producing about 95% of the total cocoa production in the state which include: Akure-North, Akure -South, Ondo- East, Ese Odo, Odigbo, Ile Oluji / Okeigbo, Ondo -West, Owo, and Ilaje.

2.2 Data Source

The climatic data used for this study was (rainfall, Maximum temperature, Minimum temperature and Mean temperature) were extracted between 1976 and 2014. These data were retrieved from the Climate Research Unit (CRU) dataset (www.cru.uea.ac.uk). The cocoa yield data was obtained from Ondo State Ministry of Agriculture and Natural Resources (between 1976 and 2014 and also from the Food and Agricultural Organization Statistics (FAOSTAT, www.faostat.org).

2.3 Data Analysis

To evaluate the trend in cocoa yield and meteorological parameters in the study area, MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), An Excel template which was developed for detecting and estimating trends in the time series was used. The Mann-Kendall test statistic S is given by Salmi *et al*. (2002) as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \qquad (1)$$

Wherein is the length of the time series $x_i \ldots x_n$, and sgn(.) is a sign function, x_j and x_k are valued in years j and k, respectively. The expected value of S equals zero for series without trend and the variance is computed as:

$$\sigma^2(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5) \right] \qquad (2)$$

Where q is the number of tied groups and t_p is the number of data values in p^{th} group. The test statistic Z is then given as:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{\sigma^2(S)}} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \dfrac{S+1}{\sqrt{\sigma^2(S)}} & \text{if} \quad S < 0 \end{cases} \qquad (3)$$

No assumptions as to the underlying distribution of the data are very significant as a non-parametric test, The Z statistic was then used to test the null hypothesis, H_o that the data are randomly ordered in time, against the alternative hypothesis, H_1, where there is an increasing or decreasing monotonic trend. A positive (negative) value of Z indicates an upward (downward) monotone trend. H_o will be rejected at a particular level of significance if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from the standard normal cumulative distribution tables. Hobbins et al. (2001) noted that the Mann-Kendall test is non-dimensional and does not quantify the scale or the magnitude of the trend but the direction of the trend. To estimate the true slope of an existing trend the Sen's non-parametric method will be used (Salmi *et al*., 2002).

3. Results and Discussion

3.1 Descriptive trends in annual cocoa yield and climatic variables

The summary statistics of the Mann-Kendall monotonic trend statistics and nonparametric sen"s slope estimate test for annual trends in cocoa yield and climatic variables in Ondo State is presented in Table 1. The results of the analysis of trends showed that cocoa yield decreased monotonically at the rate of 492.18 tonnes/yr (P<0.05), which agrees with Oguntunde *et al.*(2014), that noticed a decreasing trend in cocoa yield in the study area which was attributed to variations in weather elements. No significant correlation was established in annual rainfall. While there was a positive significant trend in Max. temperature, Min. temperature and mean temperature all at the rate of 0.02 ^oC/yr (P<0.001). Similarly, the statistical trend of annual yields of cocoa and the climatic variable is presented in Figures 1 to 5. Cocoa Yield showed a declining temporal trend while Rainfall, Max. temperature, Min. temperature and mean temperature showed a positive statistical trend. This may be due variations in the amount of rainfall in the study area which is in line with the findings of Thompson, (2013) who carried out a study on the climate change and the cocoa production in Ekiti and Ondo States of Nigeria: A cointegration analysis. He reported that the availability of rainfall will have much effect on cocoa yield over time.

There was also an increasing positive statistical trend for climatic variables during the time under study. This result also confirms the empirical study carried out by Oyekale *et al.* (2009) who reported that the reduction in the cocoa yield was as a result of excessive rainfall which was deduced in the time under study. These also reduce the quality of cocoa as a result of the climatic failure. In terms of correlation, rainfall was not significantly correlated with the yield of cocoa; Tmax, Tmin, and Tmean were the only variables that are significantly correlated with cocoa yield in the study area.

3.2 Development of climate-yield regression Models

The correlation between cocoa and climatic variables has given us an understanding of the time characteristics of each variable. Therefore, to establish a relationship between cocoa yield and climatic variables, the variables which were identified to have a significant relationship with the yield using multiple linear regression analysis were regressed with cocoa yield. The summary of stepwise regression between cocoa yield and climatic variables using multiple linear regression for the four states are presented in Table 2.

In the study area, the model I the correlation coefficient (R) = 0.52 showing that the regressor (TY_{12}) in the model I accounted for 52% in the variability of cocoa yield. Model II also have R = 0.68 which implies that the regressors (TY_{12} and R6) are responsible for 68% variability in cocoa yield in Ondo State. Looking at Model III, where R = 0.74, this implies that the regressors (TY_{12}, R_6, and TX_5) are responsible for 74% of the variability in cocoa yield. Examining Model IV, with R = 0.78, this simply means that the regressors in model IV (TY_{12}, R_6, TX_5, and TZ_3) accounted for 78% in the variability in cocoa yield. Model IV from the stepwise regression analysis was also selected in order to predict the future yield of cocoa by 78% assurance based on RCP 4.5 emission scenario.

The Global Circulation Models (GCMs) for the projection of the future climate data by the IPCC based on the RCP 4.5 emission scenario were used for this study. This includes CCCMA, ICHEC, MIROC, NCC, NPI, and NOAA. The present-day cocoa yield estimation for the study area present daytime series (1976 - 2005) Midterm (2021-2050) and long term (2071-2100) for the six GCMs based on RCP 4.5 are presented in Figures 6 to Figure 8.

3.3 Impact of climate change on the future yield of cocoa in Ondo state

Figure 9 shows the impact of climate change on the yield of cocoa in Ondo state. Looking at CCCMA model, a mid-term decrease of 7,413 tonnes/yr of cocoa was projected for the study area by the year 2050 and for the long term, a decrease of 10,383 tonnes/yr of cocoa was projected for the study area by 2100. A decrease of 7,992 tonnes/yr cocoa was projected by ICHEC model for the study area for the mid-term by the year 2050. For the long-term projection by ICHEC, a decrease of 11,852 tonnes/yr was projected by the year 2100 for the study area. Considering MIROC, also in Figure 9, 15,960 tonnes/yr decrease yield of cocoa was projected by the year 2050 while a decrease of 28,146 tonnes/yr yield of cocoa was projected for the study area by the year 2100.

For NCC and at the same emission scenario, there will a mid-term future decrease of 8,926 tonnes/yr of cocoa by the year 2050 for the study area. For the long-term, a decrease of 8,162 tonnes/yr of cocoa was projected by the year 2100. With reference to MPI, there was a decrease of 6,335 tonnes/yr of cocoa for the mid-term future projection for the study area and decrease of 6,395 tonnes/yr in the long-term future was projected for the study area by the year 2100. For the NOAA model, there was a decrease in both mid-term and long-term future with 9,379 tonnes/yr and 16084 tonnes/yr of cocoa by the year 2050 and 2100 respectively for the study area. The ensemble of all the GCMs projected a mid-term future reduction of 9,334 tonnes/yr by 2050 and a long-term future decrease of 13,504 tonnes/yr of cocoa by 2100.

The study of the impact of climate change on the future yield of cocoa both by the midterm (2050) and long term (2100) in the study area cannot be overemphasized being the highest cocoa producing state. From the study, climate change will have a negative impact experienced in the study area. The variation in the future projected yield of cocoa may be due to variability in rainfall distribution across the study area by the year 2050 and 2100. This agrees with Oluyole (2010); Edet *et al.* (2018); Amos and Thompson (2015) that variability in rainfall has much influence on the cocoa yield. Thompson (2013) established that the yield of cocoa is mostly affected by rainfall variability in the long run, that is, the yield of cocoa is highly susceptible to drought and excess rainfall.

Anim-Kwapong and Frimpong (2005) reported that cocoa is highly sensitive to rainfall and water application. Also, yearly variations in the yield of cocoa were affected by more by rainfall than any other factors in Nigeria (Ajewole and Iyanda, 2010).

3.4 The economic implication of the impact of climate on cocoa yield

The projected change in the future yield of cocoa using RCP 4.5 future climate scenario in the future for all the GCM, showed that a loss of 9,334 tonnes/yr of cocoa was projected by the year 2050 and a loss of 13,504 tonnes/yr of cocoa was also projected by the year 2100 Now, if the projected change in the yield of cocoa as predicted by the ensemble of all the GCMs should hold for the future, it means that Ondo state may experience a loss of about $22,470,018.22 and $32,308,584.32 by the year 2050 and 2100 respectively.

4. Summary and Conclusion

From the trend analysis, the yield decreased monotonically at a rate of 492.18 tonnes/yr (P<0.05). The increasing trend was established in annual rainfall trend. And there was a positive significant trend in maximum temperature, minimum temperature and mean temperature all at the rate of 0.02 ℃/yr (P<0.001). The impact of climate change on the yield of cocoa in the study areas, there was a projected yield decrease of 9,334 and 9,379 tonnes/yr by the year 2050 and 2100 respectively. This may portray grave threats to the farmers and government, hence the need for the government and farmers find a way of mitigating the the effect of climate change on the future yield of cocoa such as planting of high breed cocoa, weather resistance species or by providing chemicals and necessary farm inputs for the prevention of incidence fungus disease which may be as a result of excess rainfall in the study area. Further studies should be carried in order to find adaptive and mitigation strategies to the effects of future climate change on the yield of cocoa in the study area. This research should be extended to other cocoa producing areas in Nigeria for proper assessment of the impact of climate change on the future yield of cocoa in the country.

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Table 1: Trends results of Annual Yield and climatic variables for Ondo State

Time series	Test Z	Significance	Slope
Yield	-2.03	*	-492.18
Rainfall	0.53		1.88
Max. Temperature	4.15	***	0.02
Min. Temperature	4.09	***	0.02
Mean Temperature	4.61	***	0.02

*** Significant at 0.001, **significant at 0.01, * significant at 0.05, + significant at 0.1

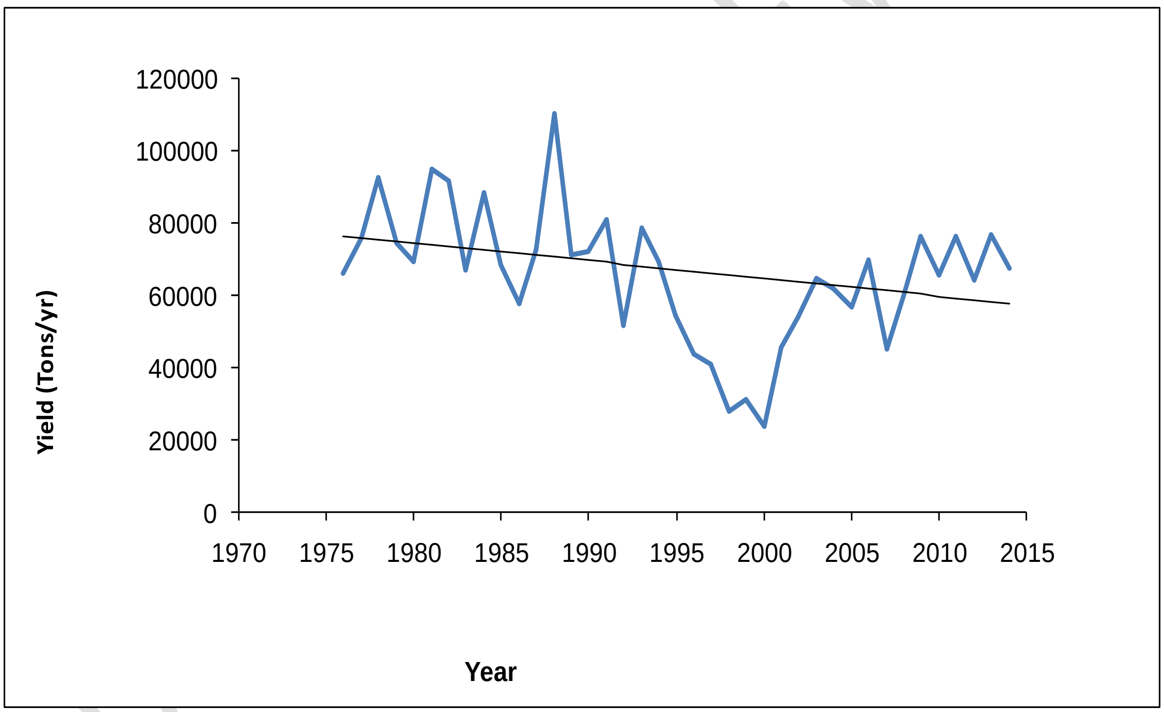

Figure 1: Annual trends in yield of cocoa between 1976 and 2014 in Ondo State

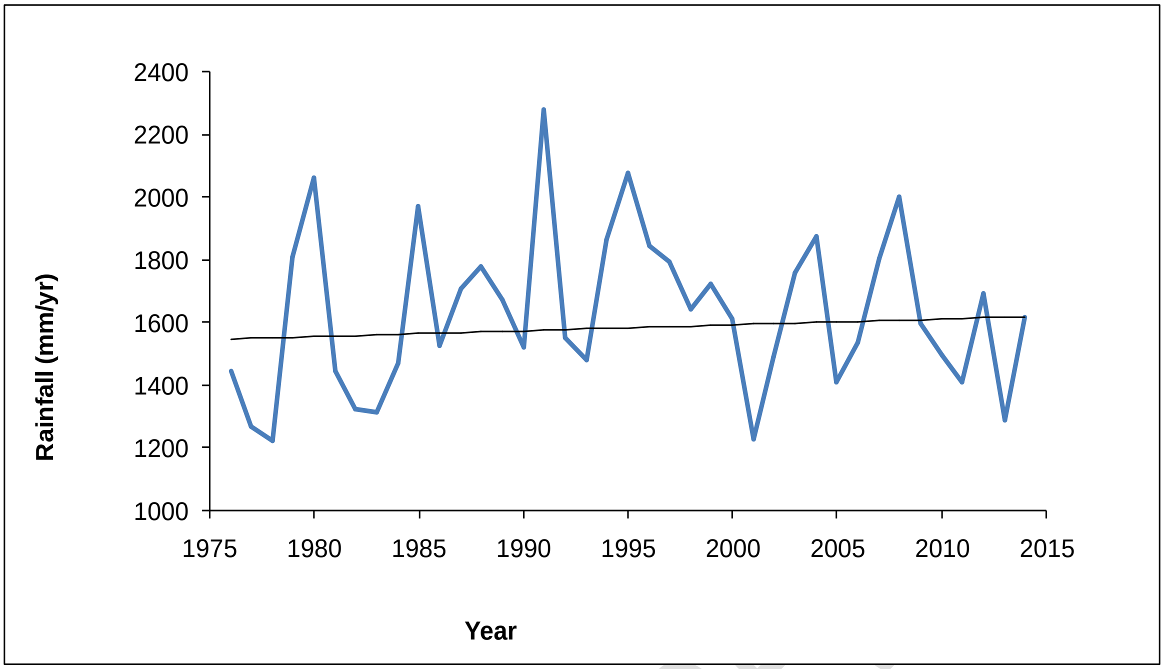

Figure 2: Annual trends in rainfall between 1976 and 2014 in Ondo State

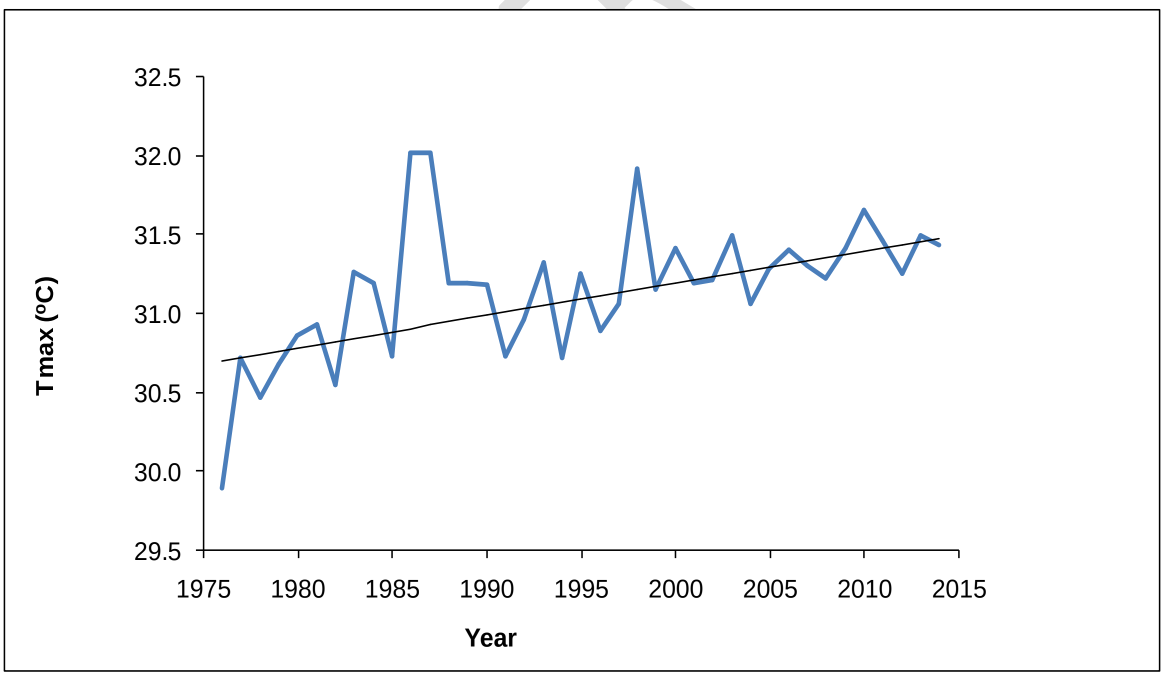

Figure 3: Annual Trends in Max. Temperature between 1976 and 2014 in Ondo State

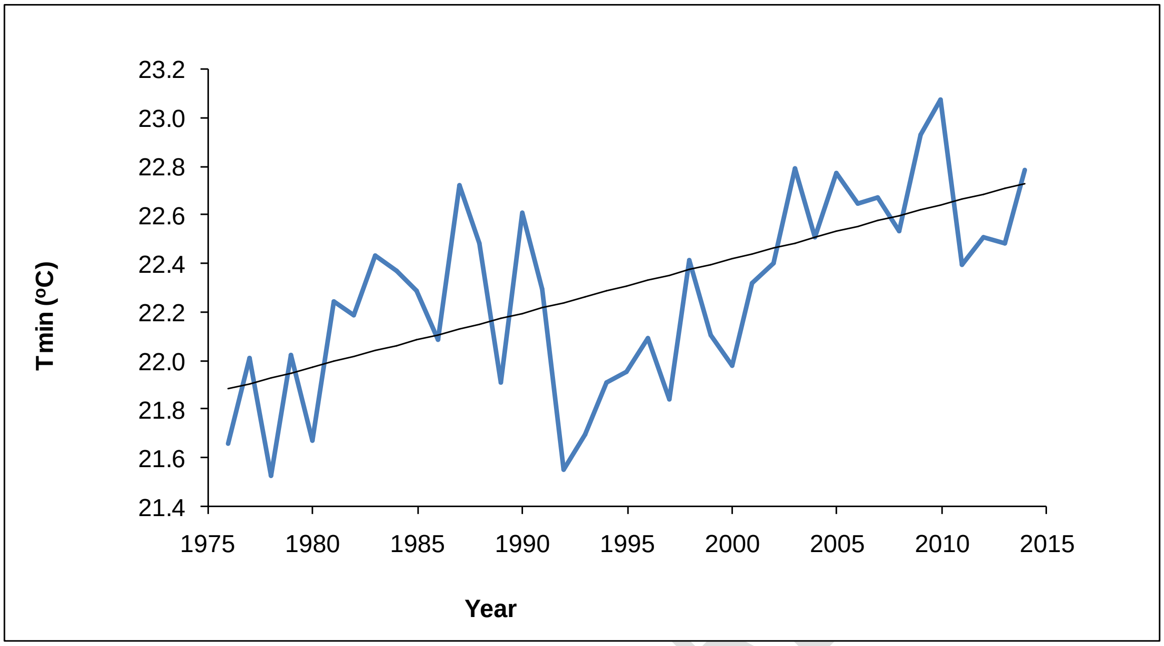

Figure 4: Annual trends in Min. temperature between 1976 and 2014 in Ondo State

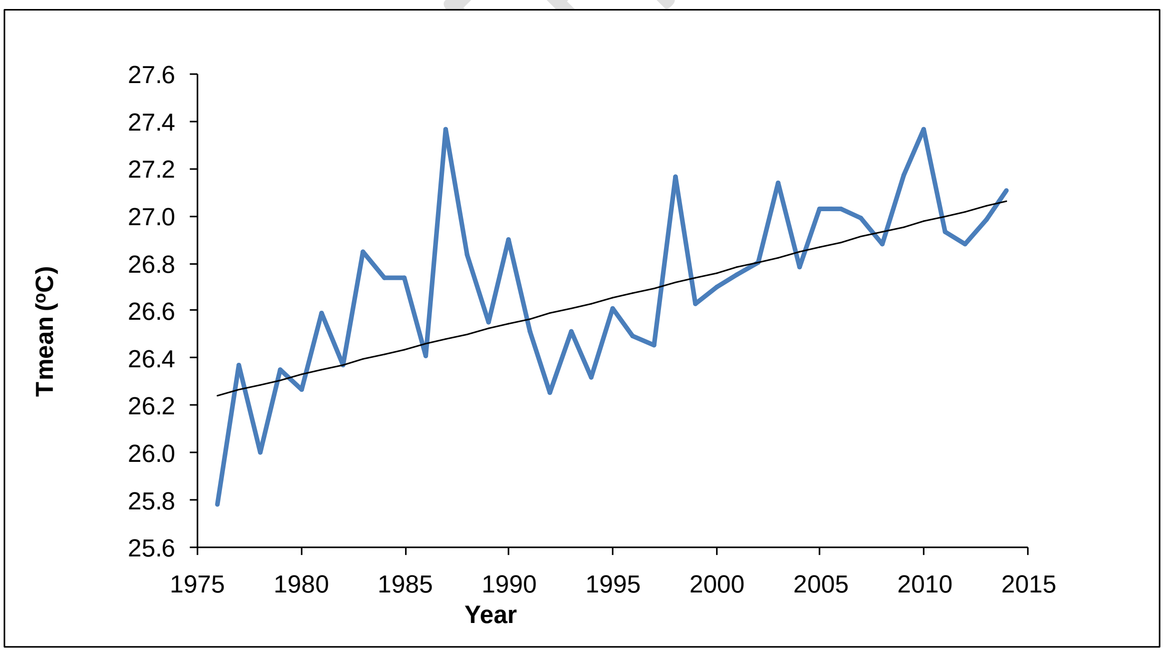

Figure 5: Annual trends in mean temperature between 1976 and 2014 in Ondo State

Table 2: Summary of the stepwise regression between cocoa yield and the climatic variables

Models	States	Regression Model	R
i.	Ondo	$Y_c = \beta_0 + \beta_1 TY_{12} + e_i$	0.52
ii.	Ondo	$Y_c = \beta_0 + \beta_1 TY_{12} + \beta_2 R_6 + e_i$	0.68
iii.	Ondo	$Y_c = \beta_0 + \beta_1 TY_{12} + \beta_2 R_6 + \beta_3 TX_5 + e_i$	0.74
iv.	Ondo	$Y_c = \beta_0 + \beta_1 TY_{12} + \beta_2 R_6 + \beta_3 TX_5 + \beta_3 TZ_3 + e_i$	0.78

Where R = Correlation coefficient, Yc = Yield, e_i = error term, $\beta_0 - \beta_3$ are constant. R_1-R_{12} (Rainfall of January – December), R13 (Annual Rainfall); TY_1-TY_{12} (Max Temperature of January – December), TY_{13} (Annual max temperature); TX_1-TX_{12} (Min. Temperature of January – December), TX_{13} (Annual max temperature); TZ_1-TZ_{12} (Mean Temperature of January – December), TZ_{13} (Annual mean temperature).

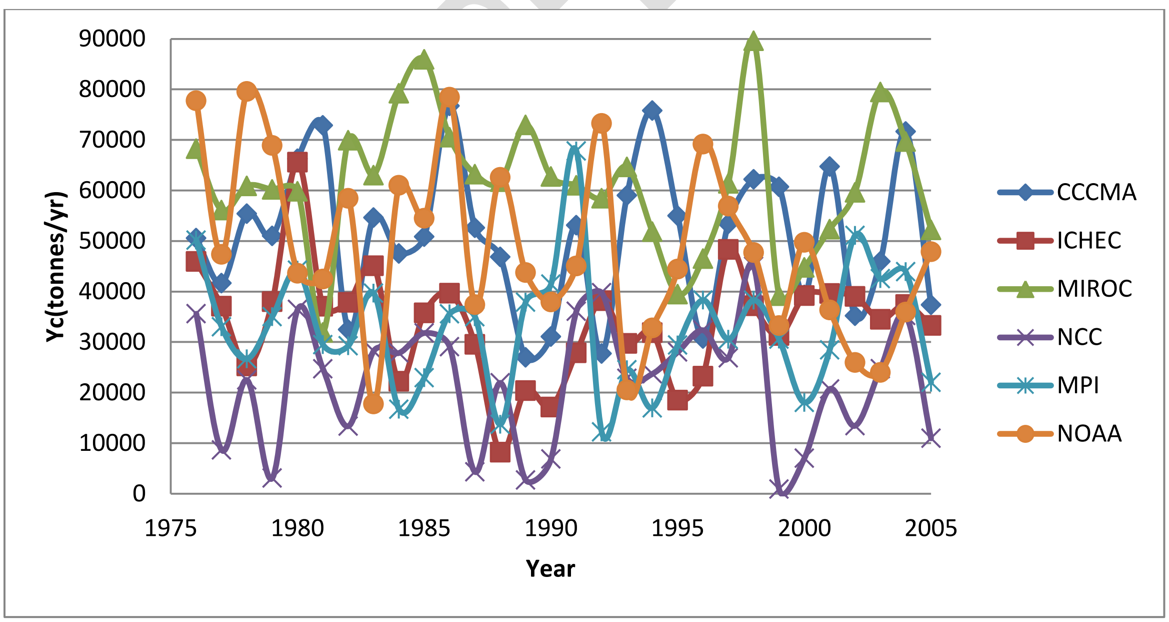

Figure 6: Present Day (1976 – 2005) cocoa yield in Ondo State

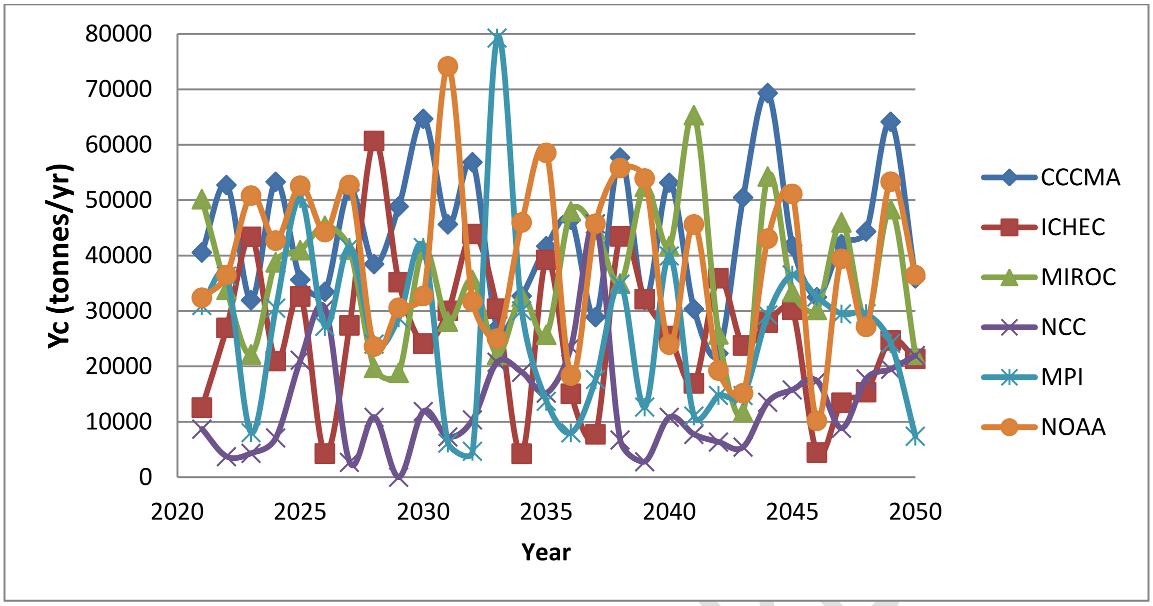

Figure 7: Projected Midterm (2021 – 2050) for different GCMs output based on RCP 4.5 in Ondo State

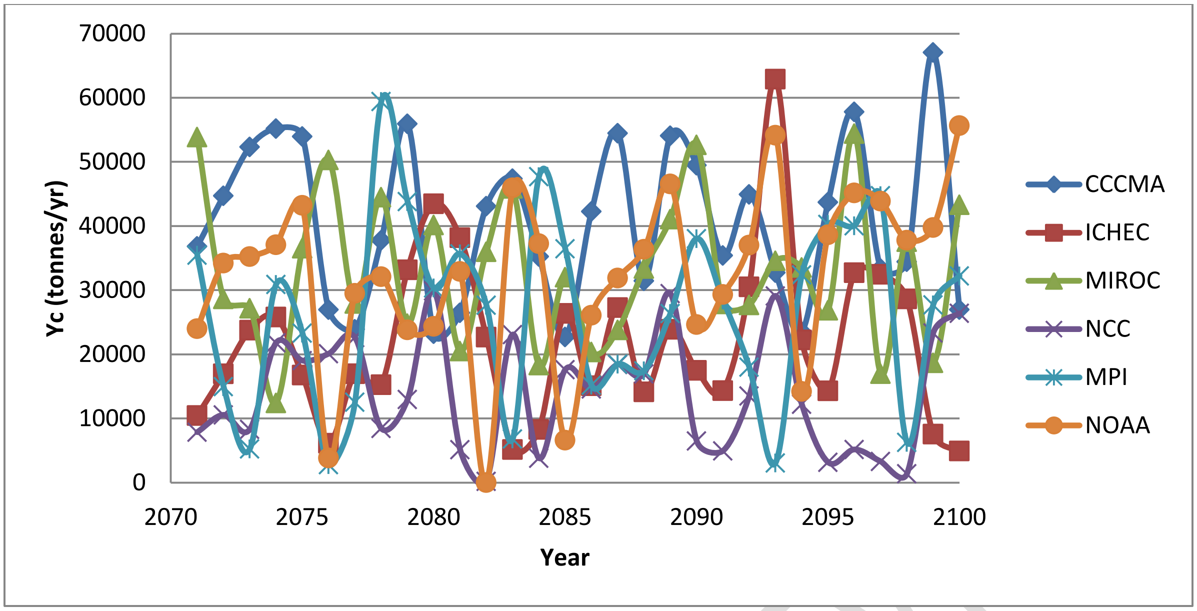

Figure 8: Projected Long term future (2071-2100) yield for Six GCMs output based on RCP 4.5

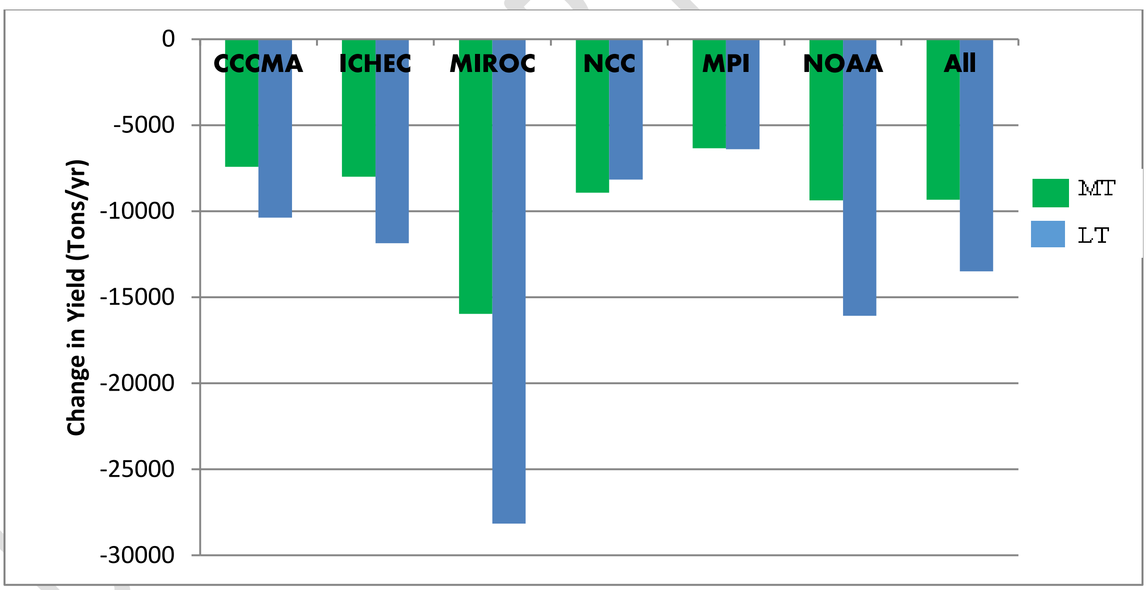

Figure 9: Change in yield of cocoa for the mid-term (MT; 2021-2050 in green) and long-term (LT; 2071 -2100) in blue under RCP 4.5 emission scenario

Table 3: Descriptions of acronyms used for the study

Acronyms	Meaning of the Acronyms
GCM	General Climate model / Global circulation model
RCP	Representative Concentration Pathways
IPCC	Intergovernmental Panel on Climate Change
IITA	International Institute of Tropical Agriculture
CRIN	Cocoa Research Institute
FAO	Food and Agricultural Organization
R	Correlation Coefficient
GHG	Green House Gases
CO_2	Carbon dioxide
NPC	National Population Commission
CRU	Climate Research Unit
Tmax	Maximum Temperature
Tmin	Min Temperature
Tmean	Mean Temperature