

## EFFECT OF CLIMATE CHANGE ON COCOA PRODUCTIVITY IN NIGERIA

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### ABSTRACT

The increasing global consensus built on empirical evidence that the world is facing a threat from climate change has sustained the feeling and belief that many countries in tropical and sub-tropical regions be more vulnerable to the bizarre phenomenon. The situation will be most severe in Africa where information on climate change is the poorest, technological change has been the slowest, and the domestic economies depend the most heavily on agriculture. The study examined the relative effect of climate change on the productivity of cocoa in Nigeria. Data employed were national aggregates of the export crop and climate variables collected from reputable secondary sources covering 1961 – 2010. Overall, rainfall recorded a significant negative coefficient while that of temperature was positive coefficient, implying decreasing rainfall with rising temperature. More so, rainfall and its squared term were the only significant climatic variables influencing the productivity of cocoa. It is therefore suggested that cocoa farmers should adopt new measures to cope with the emerging negative effect of climate change.

**Key Words:** Climate variables, export crop, farmers, time series

### RÉSUMÉ

Le consensus mondial fondé sur une évidence empirique que l'univers est confronté à une menace du changement climatique a nourri le sentiment et la croyance que tant de pays des régions tropicales et subtropicales sont plus vulnérables au phénomène bizarre. La situation sera plus sévère en Afrique où l'information sur le changement climatique est la plus pauvre et le changement technologique a été le plus lent, et les économies domestiques dépendent largement de l'agriculture. Cette étude a examiné l'effet relatif du changement climatique sur la productivité du cacao au Nigeria. Les données employées étaient des agrégats nationaux d'exportations des cultures et des variables climatiques collectées de sources secondaires fiables couvrant la période 1961 – 2010. Dans l'ensemble, les précipitations ont enregistré un coefficient négatif significatif alors que la température a enregistré un coefficient positif, impliquant une réduction des précipitations avec une élévation de la température. En plus, seules la précipitation et ses variables climatiques ont influencé la productivité du cacao. Il est par conséquent recommandé que les producteurs du cacao adoptent de nouvelles mesures pour faire face aux effets négatifs du changement climatique.

**Mots Clés:** Variables climatiques, cultures exportées, fermiers, séries de temps

### INTRODUCTION

There is increasing consensus among actors about a mounting threat due to climate change. Although the degree of the impact and its distribution is still a raging global debate,

available evidence suggests that countries in temperate and polar locations may benefit from small economies because additional warming will advantage their agriculture (Mbanasor *et al.*, 2010). Additional warming will affect water balance and harm agricultural sectors. However,

it is difficult to predict the extent of damage in these regions due to paucity of empirical research information (Mendelsohn *et al.*, 2000).

To date, studies exploring the effects of climate change on the agricultural sector have typically fallen into one of three general categories: agronomic crop models (Jones *et al.*, 1991), computable general equilibrium (CGE studies) (Darwin *et al.*, 1995) and statistical models (Mendelsohn and Dinar, 1999; Schlenker *et al.*, 2006; Shlenker and Roberts, 2006; Lobell *et al.*, 2008). Each of these general approaches is unique and has its own strengths and weaknesses. However, the appropriateness of each approach in a particular context can be evaluated on the basis of data requirements, spatial extent, spatial resolution, user friendliness and process understanding (Ward *et al.*, 2011).

The production of major export crops such as cocoa in countries like Nigeria has declined since the drought of 1972/73 which was the first evidence of climate change in the region. However, the extent to which climate conditions could be held responsible for the changes in agricultural productivity is still an emerging subject of empirical research.

Cocoa is the most prominent export crop in Nigeria in terms of her production and export capacities. Nwajiuba and Onyeneke (2010) attempted to integrate the climate variables in their linear regression model but failed to include a time trend as a factor. Time trend serves as a proxy for the non inclusion of some non climatic variables which are important in agricultural productivity. This is in line with Ajetomobi and Abiodun (2010) who employed a similar methodology in their assessment of climate change impacts on cowpea productivity in Nigeria.

The objective of this study was to analyse the relative effect of climate change on cocoa productivity over the study period so as to understand the growth rate of the climatic elements and their influence on the yield per hectare of cocoa.

## MATERIALS AND METHODS

**Study area.** This study was conducted in Nigeria located at 10° North and 8° East. The country has

a land area of 98.3 million hectares, of which only 71.2 million hectares are cultivable ( FMARD, 2001; NBS, 2007). In 2010, land area under cocoa cultivation rose to 1.34 million hectares (FAO, 2011).

**Data collection and analysis.** Data for the study were national aggregates and climate variables (temperature and rainfall) obtained from secondary sources. Some of the sources included the Production Yearbook published by the Food and Agriculture Organisation (FAO), FAOSTAT website and Nigerian Meteorological Agency as reported in the annual abstract of the Central Bank of Nigeria Statistical Bulletin. The study covered a fifty year period of 1961 to 2010.

The growth rate of the climatic elements was analysed using trend analysis. The linear trend equation is specified in line with Ghosh (2010) and Onyenweaku (2004) as:

$$\ln C_t = a + b_t + U_t \dots\dots\dots \text{Equation 1}$$

Where:

$C_t$  = Magnitude of climatic variable (Temperature in degree centigrade or Rainfall in mm);

$b_t$  = Trend variable (1,2.....n);

$U_t$  = Error term; and

$\ln$  = Natural logarithm

Analysis of the effect of climate variables on cocoa productivity followed the statistical model in line with Torvanger *et al.* (2004), Schlenker *et al.* (2006), Lobell *et al.* (2008) and Ajetomobi and Abiodun (2010). The model relates yield per hectare to meteorological data and assumes a quadratic relationship. Only rainfall and temperature were employed as the climate variables because they are considered the most important climatic factors influencing crop production. It is specified thus:

$$Y_t = a + b_j R_{it} + c_j T_{it} + d_i R^2 + e_j T^2_{it} + \tau + w_{it} \dots\dots\dots \text{Equation 2}$$

Where:

Y = Yield of cocoa per hectare (tonnes per hectares);

R = Rainfall (Millimeter);

T = Temperature (°C);

□ = Time index denoting annual observations (1961–2010);

w = Error term; and

a, b, c, d and e are estimated parameters.

## RESULTS AND DISCUSSION

Analytical outputs for the growth rate of climatic elements are presented in Table 1. Rainfall recorded a significant negative coefficient at ≤ 5% that the volume of rainfall was reducing over the study period. On the other hand, temperature posted a significantly positive coefficient implying that this parameter progressively over time. This may be as a result of increasing intensity and duration of sunshine and rainfall variability in the African continent as observed by several researchers (Mendelsohn *et al.*, 2000; Deressa and Hassan, 2009; Ward *et al.*, 2011). The anticipation is that the continent will continue to get warmer to the detriment of plant and animal life which will inexorably affect productivity of cocoa. Both models for rainfall and temperature have appreciable explanatory power as shown by the F-ratios while their goodness – of – fit measures hover around 50%. This suggests that about 50% are attributable to errors and omitted variables. The estimate is not out of place especially among time series data sets when autocorrelation is addressed (Simonoff, 2011).

Data for the effect of climate change on cocoa productivity and the quadratic model of multiple regression analysis are presented in Table 2. The result shows that the coefficient of multiple determination ( $R^2$ ) is 0.560 (56.0%) implying that the independent variables jointly explained 56.0% of variation in cocoa yield per hectare. The intensity of the explanatory power of the model was confirmed by the significance of the F-ratio of 2.483 at 5% level of probability,

Among the test variables, rainfall and its squared term were statistically significant at ( $P \leq 10\%$  and  $P \leq 1\%$  levels, respectively) with opposite signs. With a negative coefficient (- 0.019), it indicates that decreasing rainfall engenders increase in cocoa yield per hectare in the short run while increasing volume of rainfall (coefficient for rainfall - 8.221) enhances cocoa output per hectare in the long run. By implication, any 1% drop in rainfall will bring about a marginal increase in the yield of cocoa per hectare by 0.019% in the short run. On the other hand, any 1% increase in rainfall will engender 8.221% increase in the productivity of cocoa in the long run (Table 3). This relates to the report of Ajewole and Iyanda (2010) who observed that yearly variations in the yield of cocoa was affected more by rainfall than any other climatic factors.

In the light of the observations that there is decreasing rainfall and rising temperature based on the trend analysis, cocoa farmers are anticipated to adopt new measures to cope with the emerging negative effect of climate change. New measures for effective adaptation to the raging menace of the climate change include the planting of early maturing seed, drought resistant varieties and use of irrigation facilities are suggested by the study.

TABLE 1. Trend of climatic elements in Nigeria for 1961-2010

| Variable    | a                     | b <sub>i</sub>       | R <sup>2</sup> | F- Ratio  |
|-------------|-----------------------|----------------------|----------------|-----------|
| Temperature | 2.476***<br>(45.570)  | 0.005**<br>(2.751)   | 0.53           | 67.568*** |
| Rainfall    | 7.264***<br>(192.249) | -0.005**<br>(-3.653) | 0.518          | 13.345**  |

Values in parentheses are t - values. \*\*\* and \*\* represent significance at 1 and 5% level respectively

TABLE 2. Regression analysis of the effect of climate change on cocoa yield per hectare

| Variable                 | Coefficient | Standard error | t-value |
|--------------------------|-------------|----------------|---------|
| Constant                 | 20.475*     | 11.158         | 1.825   |
| Temperature              | 0.029       | 0.081          | 0.351   |
| Rainfall                 | -0.019*     | 0.011          | -1.766  |
| Rainfall <sup>2</sup>    | 8.221***    | 2.281          | 3.604   |
| Temperature <sup>2</sup> | -0.050      | 0.049          | -1.050  |
| Trend                    | 0.015       | 0.023          | 0.639   |
| R <sup>2</sup>           | 0.560       |                |         |
| F-Ratio                  | 2.483**     |                |         |

\*\*\*, \*\*, \* denote significance at 1.0, 5.0 and 10.0% probability respectively.

TABLE 3. Summary statistics of rainfall, temperature and cocoa yield

| Period      | Mean          |                  | Values               |
|-------------|---------------|------------------|----------------------|
|             | Rainfall (mm) | Temperature (°C) | Cocoa yield (tonnes) |
| 1961 - 1970 | 1368.00       | 11.70            | 230750.00            |
| 1971 - 1980 | 1408.10       | 14.02            | 198370.00            |
| 1981 - 1990 | 1246.00       | 14.19            | 184180.00            |
| 1991 - 2000 | 1182.70       | 14.31            | 296600.00            |
| 2001 - 2010 | 1193.80       | 14.55            | 388845.30            |

## REFERENCES

- Ajetomobi, J. and Abiodun, A. 2010. Climate Change Impacts on Cowpea Productivity in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development* 10(3): 2258 - 2271.
- Ajewole, D.O. and Iyanda, S. 2010. Effect of climate change on cocoa yield: A case of Cocoa Research Institute (CRIN) Farm, Oluoye Local Government Ibadan, Oyo State, Nigeria. *Journal of Sustainable Development in Africa* 12(1):350 - 358.
- Darwin, R., Tsigas, M., Lewandrowski, J. and Ranases, A. 1995. World agriculture and climate change: Economic adaptations. *Agricultural Economics Reports*.
- Deressa, T. T. and Hassan, R.M. 2009. Economic Impact of climate change on crop production in Ethiopia: Evidence from cross - section measures. *Journal of African Economies* 18(4): 529 - 554.
- FMARD 2001. National Fadama Infrastructure Survey Report, Sheda-Abuja: World Bank/ Projects Coordinating Unit, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.
- Ghosh, B.K. 2010. Growth and variability in the Production of crops in West Bengal agriculture. *Trends in Agricultural Economics* 3(3):135 - 146.
- Jones, C., Dyke, P., Williams, J., Kiniry, J., Benson, V. and Griggs, R. 1991. Epic: An operational model for evaluation of agricultural sustainability. *Agricultural Systems* 37(4): 341- 350.
- Lobell, D., Burke, M., Tobaldi, C., Mastrandrea, M., Falcon, W. and Naylor, R. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science* 319 (5863): 307 - 315.
- Mbanasor, J.A., Nwachukwu, I.N., Agwu, N.M., Osuala, A., Nzegbule, E. and Muoneke, C. 2010. Impact of climate change on the

- productivity of cassava in Southeastern Nigeria. A research proposal submitted to the Directorate of Research and Development of Michael Okpara University of Agriculture Umudike, Abia State, Nigeria for ETF Research grant.
- Mendelsohn, R. and Dinar, A. 1999. Climate change, agriculture and developing countries: Does adaptation matter? *The World Bank Research Observer* 14(2): 227 - 235.
- Mendelsohn, R., Dinar, A. and Dalfelt, A. 2000. Climate change impacts on African agriculture. Preliminary analysis prepared for the World Bank, Washington, District of Columbia. 25pp.
- NBS (National Bureau of Statistics) 2007. Details of the breakdown of the National and State Provincial Population Totals 2006 Census. National Bureau of Statistics, Federal Republic of Nigeria Official Gazette 24(94):1 - 26
- Nwajiuba, C.U. and Onyeneke, R. 2010. Effects of climate on the agriculture of sub – Saharan Africa: Lessons from southeast rainforest zone of Nigeria. A paper presented at 2010 Oxford Business and Economics Conference Program , St. Hugh's College, Oxford University, U.K.
- Onyenweaku, C.E. 2004. Stagnation, acceleration and deceleration in agricultural production in Nigeria, 1970 – 2000. *Journal of Agriculture and Food Science* 2(2):131 – 140.
- Schlenker, W. and Roberts, M. 2006. Nonlinear effects of weather on corn yields. *Applied Economic Perspectives and Policy* 28(3): 391 - 399.
- Schlenker, W., Hanemann, W. and Firsher, A. 2006. The impact of global warming on U.S. agriculture: An Econometric Analysis of Optimal Growing Conditions. *Review of Economics and Statistics* 88 (1):113 - 125.
- Simonoff, J.S. 2011. Ordinary least squares estimation and time series data. No. 2301, Working paper Series, Stern School of Business, New York University, USA.
- Torvanger, A., Twena, M. and Romstad, B. 2004. Climate change impacts on agricultural productivity in Norway, CICERO Working Paper, 10.
- Ward, P.S., Florax, R.J.G.M. and Flore -Lagunes, A. 2011. Climate change and agricultural productivity in Sub Saharan Africa: A spatial sample selection model. Working Paper No. 11 – 4, Department of Agricultural Economics, Purdue University, USA.