# CLIMATE CHANGE AND COCOA PRODUCTION EFFICIENCY LOSSES IN ONDO EAST LOCAL GOVERNMENT, NIGERIA

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**Abstract:** Effect of climate change on cocoa agriculture cannot be underestimated. This study assessed efficiency differentials in cocoa production under with and without climate change scenarios. The data were collected using multi-stage sampling method. Data were analyzed with simple descriptive statistics and stochastic frontier approach. The results show that cocoa farmers are ageing (μ = 54 years) and many owe small farms (μ = 9.15 ha). Also, production input elasticities when under normal climate are all positive, while those for chemical and spraying hour are negative when there is climate change. Return to scale under climate change is higher (2.097075) than without climate change (1.825603), although lower output under the former still implies low productivity. Average production efficiency with climate change is 65.14 percent while it is 83.75 percent without climate change. The study recommended development of viable and cost effective chemicals to curtail increasing incidence of pests and diseases as a result of climate change, among others.

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## 1. Introduction

Cocoa (*Theobroma cacao*) is a low altitude crop that grows from sea level up to an altitude of 700m. It was introduced to Nigeria from the American Continent in 1874. Its rainfall requirement ranges between 1000 to 3000 mm per annum, in absence of which irrigation will be required. Cocoa production is very sensitive to moisture stress and excess soil water portends serious constraint to its optimum performance (Obatolu *et al*, 2003).

Commercial production of cocoa in Nigeria began in the then Western Nigeria between 1889 and 1890. In 1965, cocoa cultivation had gained prominence to the extent that Nigeria became the second largest producer in the world. This production euphoria was however thwarted by discovery of petroleum, after which the agricultural sector was partly neglected.

Among the reasons that have been given for decline in cocoa production are farmers' small land holdings, transportation problem, scarcity of human labour, low capital investment and variability in climatic factors (Adegeye, 1996). Also, while climate change poses serious challenges to Nigerian agriculture, some of the proposed options to address it in the Kyoto Protocol imply some future economic downturn. This is because oil generates more than 90 percent of the country's foreign exchange revenues. Avoidance of impending economic doom requires that the country should diversify her sources of income, and cocoa agriculture easily comes to fore.

Farmers' interest in cocoa production was resuscitated after government implemented the Structural Adjustment Program (SAP) in 1986. The major components of SAP included market-determined exchange rate and interest rates, liberalized financial sector, trade liberalization and commercialization/privatization of a number of public enterprises. With the scrape of the Commodity Marketing Boards that brought a lot of pricing inefficiency in cocoa marketing due to price-giver role it played, cocoa farmers were motivated to grow the crop as well as rehabilitating their old farms.

It should be emphasized that cocoa remains the second largest foreign exchange earner after petroleum (Adegeye, 1996; Izuchukwu). Apart from providing foreign exchange to the exporting countries, cocoa is a means of conserving foreign exchange. This is achieved by locally producing cocoa based products such as cocoa-butter, cocoa cake, cocoa powder and cocoa wine, among others.

However, Nigeria's lost glory in cocoa exports is yet to be restored because the country has slumped to the fifth position in global production, while accounting for just about 5 percent of world's total outputs. Government has taken some initiatives to revive cocoa production through some rebirth processes. However, among the most pressing limiting factors is climate change. This is because every stage of cocoa production requires adequate weather conditions (Nabuurs *et al*., 2007). Also, cocoa is highly susceptible to drought, and the pattern of its cultivation is related to rainfall distribution (Anim-Kwapong and Frimpong, 2005).

Black pod disease accounts for quite a lot of cocoa production losses by attacking the ripened or very young pods (Opoku *et al* 1999). The disease is closely related to the pattern of rainfall distribution. It is more prevalent in damp situations with utmost pod infection in years when the short dry period from July to August is very wet. Ondo state, being the highest cocoa producing state in Nigeria has records of fluctuations in some climatic parameters, especially rainfall, temperature and sunshine hours. Madu (no date) found that among the states in South West Nigeria, Ondo records the highest climate change vulnerability based on indices aggregated from several indicators. Also, Nigerian Meteorological Agency (NIMET) (2011) noted that in August 2010, some places in the South West including Ondo state recorded rainfall values that were 200-300 percent higher than normal.

This paper seeks to answer the question: what is the efficiency loss in cocoa production that results from climate change? This is fundamental because climate change is a production shock that subjects farmers to operate below the production frontier. Adaptation is only able to reduce production losses resulting from climate change. In economic sense, the farmer will be technically inefficient. This has some welfare implications for the farmers since their incomes are adversely affected. In the remaining parts of the paper, the materials and methods, the results and discussions and the recommendations have been presented.

## 2. Materials and Methods

### The study area

The study was carried out in Ondo East Local Government Area (LGA), which is one of the 18 Local Government Areas in Ondo state. The 2006 National Population Census put the population of the LGA at 76,092 people (National Bureau of Statistics, 2009). The LGA is characterized by tropical climate with rainy season from April to October, while the dry season is from November to March. The state is predominantly agrarian with about 70 percent of the labour force engaged in agriculture. Cocoa is the primary cash crop with regular intercrops with food crops such as yam, cocoyam, cassava, plantain etc.

### Sources of Data

Primary data that were collected through personal interviews and administration of questionnaires were used. The multi-stage sampling method was used. At the first stage, twelve villages were selected randomly from the list of available villages in the LGA. At the second stage, households were randomly sampled in the selected villages based on their total estimated number of households. Although 120 questionnaires were administered, only 99 contained complete and useful information to be used for the analysis.

### Analytical method

Economic literature suggests several alternative approaches to measuring productive efficiency. These methods can be grouped into non-parametric and parametric frontiers. Nonparametric approach uses linear programming and does not impose any functional form on the production frontiers. The most popular non-parametric approach is the Data Envelopment Analysis (DEA). The parametric approach imposes a functional form on the production function, and makes some assumptions about the data. The most common functional forms include the Cobb–Douglas, Constant Elasticity of Substitution and Translog Production Functions (Coelli *et al*, 2004).

The other distinction is between deterministic and stochastic frontiers. Deterministic frontiers assume that all the deviations from the frontier are as a result of firm's inefficiency, while stochastic frontiers assume that part of the deviations from the frontier is due to random events (reflecting measurement errors and statistical noise) and part is due to firm specific inefficiency. The stochastic frontier production function model has the advantage of allowing simultaneous estimation of individual technical efficiency, as well as the determinants (Coelli *et al.*, 1994).

The stochastic frontier production function that was used in this study can be illustrated with a farm using $n$ inputs $(X_1, X_2, \ldots, X_n)$ to produce output $Q_i$. Efficient transformation of inputs into output is characterized by the production function $f(X_i)$, which shows the maximum output obtainable from various input vectors. The stochastic frontier production function assumes the presence of technical inefficiency of production. Hence, the function is defined as:

$$Q_i = f(X_i, \beta)\exp(v_i - u_i) \qquad .1$$

where $v_i$ is a random error which is associated with random factors not under the control of the farmers. The model is such that the possible production $Q_i$ is bounded above by the stochastic quantity, $f(X_i, \beta)\exp(v_i)$. The random error ($v_i$) is assumed to be normally distributed $N(0, \sigma_v^2)$ random variable that is independent of $u_i$.

Technical efficiency of an individual farmer is defined in terms of the ratio of the observed output to the corresponding frontier output, given the available technology. We specified the farmers' production function by defining the Cobb-Douglas function as:

$$LogQ_i = \alpha_i + \beta_i \sum_{i=1}^{6} LogX_i + (v_i - u_i) \quad .2$$

$Q_i$ represents cocoa output of i-th farmer measured in kg, $X_1$ represents hired labour (man days), $X_2$ represents family labour (man days), $X_3$ represents the land area (hectares), $X_4$ is chemical input (litre), $X_5$ is spraying hours, $X_6$ is cocoa bean processing time (hours), $\beta_i$ are coefficients to be estimated. The $u_i$ is the technical inefficiency effect, which can be defined as:

$$u_i = \theta + \rho_i \sum_{i=1}^{n} Z_i + k_i \quad .3$$

Where $Z_i$ are spraying interval, death of cocoa trees, capsid infection, not drying cocoa beans, repeat spraying, sex, age, marital status, education, income sources, experience, irrigate, market access, losses from capsid, losses from black pod disease, quality reduced.

## 3. Results

***Socio-economic characteristics of the farmers***

Table 1: Distributions of farmers' socioeconomic characteristics

| Variable | Frequency | % |
|---|---|---|
| *Sex* | | |
| Male | 90 | 90.9 |
| Female | 9 | 9.1 |
| *Marital status* | | |
| Married | 86 | 86.9 |
| Single | 13 | 13.1 |
| *Education* | | |
| None | 15 | 15.1 |
| Primary | 31 | 31.1 |
| Secondary | 18 | 18.2 |
| Adult | 6 | 6.1 |
| Tertiary | 29 | 29.3 |

Source: Field survey Data, 2008.

Table 1 shows that cocoa farmers were predominantly males, making up of about 90.9% of the total respondents. Also, majority of the sampled population were married (86.9%), while the remaining 13.1% were single. About 15.1% of the respondents had no formal education, while just 6.1% had adult education. Primary education was attained by 31.3%, while 18.2% had secondary education. This shows that majority of the respondents were literate with about 94.9% having some form of formal education.

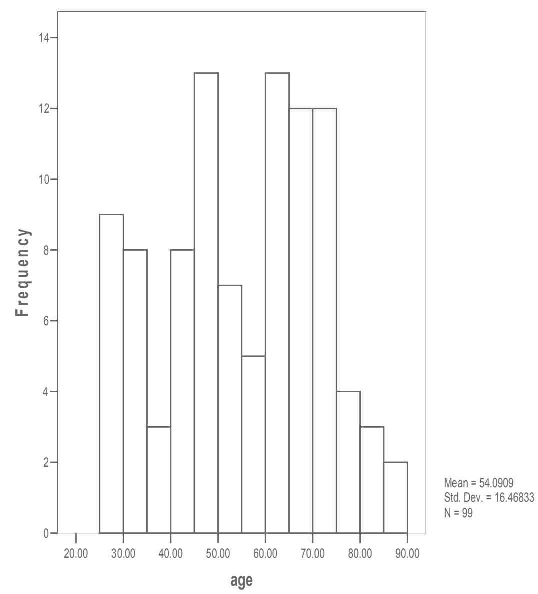


Figure 1: Distribution of cocoa farmers' age

Figure 1 shows the distribution of farmers' age. It reveals that although the average age is 54 years, highest concentration falls within 60-75 years of age. This shows that majority of them are aged. Also, the oldest farmer was 89 years old, while the youngest was 25 years old. The results are pointing to the fact that cocoa farmers' population in Ondo state is ageing.

Figure 2 also shows the distribution of land areas cultivated to cocoa. It reveals that average farm size is about 9 hectares with majority of the farmers having less than 10 hectares of land.

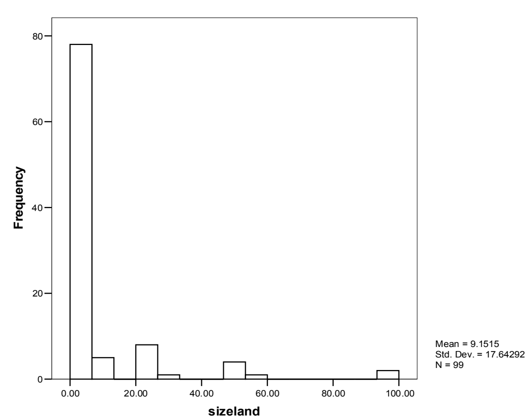


Figure 2: Distribution of farmers' cocoa land areas

**Forms of climate change noticed and their importance for cocoa production**

Table 2 presents the different forms of climatic change that had been noticed by the farmers. It shows that monthly rainfall that was lower than normal average was observed by 58.6% of the farmers, while high monthly rainfall was observed by 21.2%. Similarly, 11.1% of the respondents noticed unfavorable sunlight, while 4.0% noticed high temperature.

Table 2: Distributions of respondents by noticed climate changes

| Climate change | Frequency | Percentage |
|---|---|---|
| High rainfall | 21 | 21.2 |
| Low rainfall | 58 | 58.6 |
| High temperature | 4 | 4.0 |
| Unfavorable sunlight | 11 | 11.1 |
| More than one response | 5 | 5.0 |
| Total | 99 | 100.0 |

Source: Field Survey 2008

Table 3 also shows the perception of the farmers about importance of some climatic variables in cocoa production. It reveals that 97 percent of the farmers indicated that rainfall is most important for cocoa growth and development of the pods.

Table 3: Distributions of respondent by degree of importance of climate variables in cocoa production

| Climate variables | Frequency | Percentage |
|---|---|---|
| Rainfall | 96 | 97.0 |
| Temperature | 1 | 1.0 |
| Others | 2 | 2.0 |
| Total | 99 | 100.0 |

Source: Field Survey 2008

**Climate Change and production efficiency losses**

Table 4 shows the Maximum Likelihood Estimates (MLE) of the production function that was estimated. The analyses were conducted for the present situation whereby farmers complained about climate change. Farmers were also asked to estimate their cocoa production losses that are due to farm infections by several diseases that are directly associated with climate change. The addition of farmers' production losses to what they eventually got gives us an idea of what their outputs would have been, if the climate was adequate. This was referred to as "normal climate". The models produced a good fits of the data because the likelihood ratio and the Wald Chi square values are statistically significant ($p<0.01$).

The table shows that under normal climate, the parameter of hired labour is not statistically significant ($P>0.10$), whereas it is significant under abnormal climate ($p<0.01$). The elasticity differential for hired labour is also positive (3.77%). This implies that efforts to increase hired labour by 1% will increase output more under the problematic climate scenario that if things were normal. The parameters of family labour for the two results are statistically significant ($p<0.01$). Under normal climate, increasing family labor by 1% will result in 0.76% increase in cocoa output. However, with climate change, increasing family labour by 1%will lead to 1.38% increase in output. This shows that with climate change, cocoa outputs can increase with the use of more family labour. This can be explained from the fact that the owns the farm and would do everything possible to do an effective and lasting job.

However, although both are statistically significant ($p<0.01$), the elasticity coefficient of land under normal climate (0.5691221) is higher than that with climate change (0.5676654). This shows that land productivity declines with climate change. This is expected because proper interaction of normal climatic parameters with land is needed for output optimization.

The elasticity of chemical input under normal climate is not statistically significant ($p>0.10$), whereas it is significant under climate change ($p<0.01$). The results however show that whereas the parameter is with positive sign without climate change (0.1147638), it has negative sign under climate change (-.1005723). The implication is that without climate change, increase in chemical input by 1% will increase output by 0.11%. Similar increment will lead to reduction in cocoa out by 0.10 percent when climate has changed. Therefore, the result points to the fact that chemicals had been overused under climate change. This is expected because farmers indicated that due to high infection of their farms with black pod disease, they were compelled to spend more money on chemicals.

The elasticity of spraying hour (.0366154) is not statistically significant ($p>0.10$), while that under climate change (.0280924) is significant ($p<0.01$). The results also show that increasing spraying hour by 1% will lead to about 0.03% increase in cocoa output under climate change. Elasticity of processing hour under climate change is statistically significant ($p<0.01$) but with negative sign. Under normal climate, processing hour elasticity is not statistically significant ($p>0.10$) but with positive sign. The results are showing that the bulk of the problem with cocoa output under climate change does not lie in processing, but farm-based challenges in the form of cocoa pods that are being destroyed by pests and diseases.

Table 4: Maximum Likelihood Estimate (MLE) Parameters for Cocoa Production Function and Determinants of Inefficiency

| Variables | Parameters | Standard error | t-value | Parameters | Standard error | t-value |
|---|---|---|---|---|---|---|
| | | Normal climate | | | Climate change | |
| Hired labour | .2550139 | .1932953 | 1.32 | .2927343 | 9.39e-06 | 31160.54 |
| Family labour | .7580476 | .2150934 | 3.52 | 1.376696 | 4.87e-06 | 2.8e+05 |
| Land area | .5691221 | .101428 | 5.61 | .5676654 | 5.03e-06 | 1.1e+05 |
| Chemicals | .1147638 | .13892 | 0.83 | -.1005723 | 4.70e-06 | -2.1e+04 |
| Respraying Hours | .0366154 | .1588064 | 0.23 | .0280924 | 4.89e-06 | 5742.30 |
| Processing Hour | .0920401 | .1211774 | 0.76 | -.0675404 | 3.29e-06 | -2.1e+04 |
| Constant | 2.893974 | .1263398 | 22.91 | 3.16226 | 4.76e-06 | 6.7e+05 |
| lnsig2v | -2.397072 | .2068219 | -11.59 | -38.93253 | 437.1132 | -0.09 |
| Wald Chi Square | 96.90*** | | | 6.25e+11 | | |
| LR | -34.111608 | | | | -16.311394 | |
| Returns to scale | 1.825603 | | | 2.097075 | | |
| *Inefficiency model* | | | | | | |
| Spraying interval | .0371973 | .1243895 | 0.30 | -.0163461 | .0561049 | -0.29 |
| Death of cocoa tress | -1.517047 | 1.282399 | -1.18 | -.5203255 | .4015736 | -1.30 |
| Capsid infection | -2.289707 | 1.289083 | -1.78 | -1.192085 | .4508137 | -2.64 |
| Not processing pods | -.070646 | 1.58159 | -0.04 | 1.22256 | .6473814 | 1.89 |
| Repeat spraying | 2.118531 | 1.429468 | 1.48 | .3112483 | .4348759 | 0.72 |
| Sex | -1.276063 | 1.131265 | -1.13 | -.768567 | .7126002 | -1.08 |
| Age | .071356 | .0508786 | 1.40 | .0316 | .0235493 | 1.34 |
| Marital status | .4740244 | 1.743386 | 0.27 | .0282211 | .5978307 | 0.05 |
| Education | -1.562247 | 1.324355 | -1.18 | -.5957948 | .628162 | -0.95 |
| Income sources | -1.233598 | 1.126063 | -1.10 | -1.047092 | .5344456 | -1.96 |
| Experience | .0374346 | .0425419 | 0.88 | .0119882 | .0231066 | 0.52 |
| Irrigate | -1.503439 | 1.226152 | -1.23 | -.987425 | .5657554 | -1.75 |
| Market access | 3.106482 | 2.403053 | 1.29 | 1.761802 | .6750647 | 2.61 |
| Losses from casid | 8.97e-07 | .0000132 | 0.07 | 1.16e-06 | 3.09e-06 | 0.38 |
| Losses from other diseases | -8.50e-06 | .0000149 | -0.57 | -4.97e-06 | 8.80e-06 | -0.56 |
| Quality reduced | -.0769583 | 1.406055 | -0.05 | -1.079921 | .6145109 | -1.76 |
| Constant | -8.61158 | 4.234511 | -2.03 | -1.460272 | 1.423423 | -1.03 |
| Sigma | .3016355 | .0311924 | | 3.51e-09 | 7.68e-07 | |

The results further show that returns to scale under normal climate is 1.825603, while it is 2.097075 with climate change. This show that if all inputs are increased by 1% under normal climate, cocoa output will increase by 1.83%. However, it will increase by 2.1 percent with climate change. The implications of these findings should be critically examined because farmers' outputs are generally low under climate change. Therefore, though returns to scale is higher, in absolute form, returns to cocoa investment under climate change is still low.

***Determinants of cocoa production inefficiency***

The determinants of inefficiency in cocoa production are shown in lower segment of table 4. The results reveal that many of variables under normal climate are not statistically significant ($p>0.10$). However, form those that are statistically significant, those farmers that indicated capsid infection have significantly lower inefficiency ($p<0.10$) with and without climate change. This not expected but the use of chemicals could have neutralized the expected impact of capsid infection on inefficiency. Also, those that were not processing (drying) their cocoa pods due to inadequate climate have significantly higher inefficiency ($p<0.10$). This is expected because selling the cocoa pods while wet will make the produce buyers to underestimate what it would have weighed if dried. Therefore, output of such farmer will be underestimated.

Farmers with other sources of income have significantly lower inefficiency ($p<0.05$) when there is climate change. This is expected because their time will be allocated to other sources of income if the climate is not adequate to carry out farm operations on their cocoa farms. Also, having other sources of income may imply being able to pay for necessary inputs that are required on cocoa farms. The farmers that irrigated their farms under climate change have significantly lower inefficiency ($p<0.10$). Irrigation would reduce death of cocoa trees, especially the young trees. However, market access significantly increases inefficiency with climate change ($p<0.10$). This shows that cocoa farmers are not able to explore opportunities afforded by market access because majority of them are already indebted to produce buyers that must buy their cocoa beans at regulated prices.

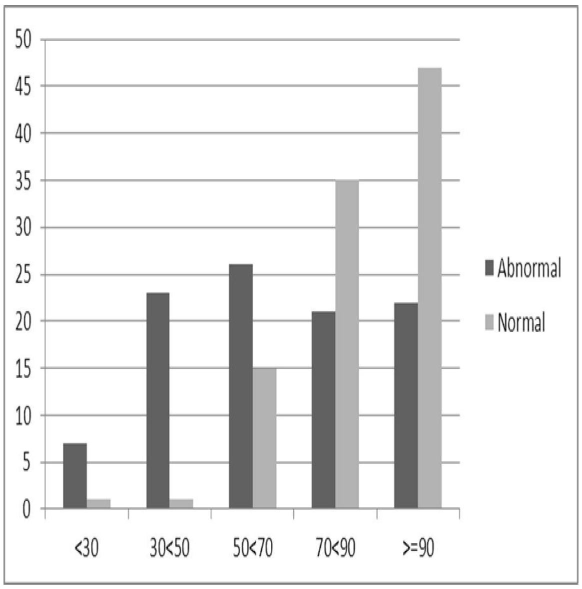


Figure 3: Distribution of technical efficiency in cocoa production under normal and abnormal climate

Figure 3 shows the distribution of cocoa production efficiency with and without climate change. It shows that while majority of the farmers have efficiency levels that are above 70 percent without climate change, the distribution is more towards less than 70 percent with climate change. Average efficiency with climate change is 65.14 percent, while it is 83.75 percent without climate change. This implies an efficiency loss of 18.61 percent.

**4. Recommendations**

Climate change poses serious challenge to agricultural production, and cocoa is among the crops that are extremely vulnerable. The findings of this study have highlighted some policy issues which are discussed below. First, there is need to inject younger blood into agricultural population in Nigeria. This can be done by providing incentives in the form of input provision and opening up of some forest reserves for cocoa production.

It was also found that adapting to climate change to sustain cocoa production requires more of family and hired labour. Given recent migration of youths from rural areas to urban areas in search for greener pasture, it is not sure whether such requirements can be met. Already, the use of child labour to carry our some menial operations in cocoa production had been frowned at by the International Labour Organization (ILO). The implication is that with shortage of labour in rural areas, the effects of climate change may not be easily rectified.

Also, chemical input had been over used by farmers in order to meet curtail the impact of diseases and pests on cocoa farms. Therefore, there is need for more research into developing more vibrant chemicals that will be more effective. Research should also focus on developing low cost dryers because it was found that some farmers were selling wet cocoa beans due to difficulties in having sufficient sunlight for drying the cocoa beans. Cocoa farmers should also be trained in alternative skills that can generate income. Therefore, introduction of cocoa farmers to other farm-based operations that can generate income will go a long way in curtailing the impacts of climate change.

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