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Impact of Climate Change on Cocoa Agriculture and Technical Efficiency of Cocoa Farmers in South-West Nigeria

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ABSTRACT Climate change poses serious problems to agricultural development in many developing countries. This paper analyzed the impact of climate change (specifically changes in temperature and rainfall) on Nigerian cocoa agriculture. Data collected from randomly selected farmers in three selected states in the cocoa producing zone of the country were used. Results show that observed climate changes are currently affecting cocoa production activities in different ways. Although the farmers are currently technically efficient, future increases in rainfall poses a lot of problem to cocoa production as elasticity with respect to rainfall was the highest (-3.661046). Factors that reduced inefficiency significantly ($p<0.10$) include being male, educational status, household size, number of cocoa farms and age of cocoa trees, while it significantly increased with child dependency ratio and ownership of mobile phone. The study concluded that efforts to mitigate the impact of climate change on cocoa agriculture should include more of media involvements in educating farmers about climate change and its future occurrences, among others.

INTRODUCTION

The major direct effects of climatic change on agricultural production in Nigeria are through changes in temperature, precipitation, length of growing season, and timing of extreme or critical threshold events. Specifically, sensitivity of cocoa production to hours of sunshine, rainfall, soil conditions and temperature makes is vulnerable to climatic change. Changing climate can also alter the development of pests and diseases and modify the host's resistance. Extended drought will cause the newly transplanted young cocoa plants and some cocoa trees to wither, while major pests and diseases of cocoa are promoted by unfavorable climatic situations. More importantly, the black pod disease is a major threat to cocoa production when the relative humidity is very high (Anim-Kwapong and Frimpong 2005).

Cocoa contributes significantly to economic growth and development in Nigeria through its sizeable foreign exchange earnings that are incomparable to any other single agricultural exports commodity, significant farm income to the peasant farmers, direct or indirect employment generation, and a vital source of raw materials for industrial production, among others. UNEP (2002) reported that since the SAP-induced trade liberalization of the late 1980s, cocoa increasingly accounted for the largest percentage of non-oil exports. Preliminary estimates by the Department for International Development (DfID) and World Bank (2008) also indicate that there may be as much as 1,000,000 hectares of cocoa farms in Nigeria with about 30 percent considered to be over 40 years old. Since old cocoa trees have exceeded their productive life, cocoa is now largely a smallholder crop and provides an important source of income for rural households in cocoa growing areas.

It is also worthy to note that over the years, cocoa production in Nigeria has been marked by declining productivity. Boyer (1970) showed that flowering was highly reduced in cocoa when mean monthly temperature drops below 23^{o}C. Obatolu et al. (2003) submitted that a number of factors have an interrelated impact on the growth of cocoa plant. These range from the weather elements of rainfall, temperature, sunlight and humidity to other factors such as soil nutrient status, pest, diseases, farming practices, among others. It was observed that the higher the temperature (Maximum of 32^{0}C), the higher the yield, while the lower the relative humidity, the better the yield. Cocoa is also known to produce well with minimal but sustained water availability throughout the year.

Ojo and Sadiq (2010) noted that another danger to cocoa yield is prolonged dry season which encourages bush burning, while incessant rainfall for several weeks (as it normally occurs in

July and September) easily leads to widespread of black pod disease. This is very contagious and poses some challenges to farmers due to yield losses.

Lawal and Emaku (2007) analyzed the impact of climate change on cocoa production at the Cocoa Research Institute of Nigeria (CRIN) between 1985 to 2004. Their results showed that over the years, standard deviation of cocoa output was 4.69. Instability of weather variables is evident with average rainfall, temperature and relative humidity having standard deviation of 225.13, 1.85 and 1.92 respectively. It was shown that increase in temperature enhances cocoa production, but increase in relative humidity decreases it.

Aigbekaen et al. (2009) analyzed the impact of some climatic factors on cocoa production at the Cocoa Research Institute of Nigeria (CRIN) experimental farm between 1997 and 2008. It was found that climatic change in the form of increased rainfall negatively affects cocoa production due to aggravation of incidences of black pod disease. It was also concluded that adequate temperature, rainfall, relative humidity and soil temperature are very vital to cocoa production. It is worthwhile to have a better understanding of the impact of climate change on cocoa farmers so as to feed such empirical findings directly into current policy discussions (Ludi et al. 2007).

Objectives of the Study

This study seeks to fulfill the following objectives:

i. identify the different forms of climate change related problems that cocoa farmers are facing; and
ii. analyze the impact of some climatic variables on technical efficiency of cocoa production.

MATERIAL AND METHODS

Data Sources and Sampling Procedures

Data used for the study were derived from both primary and secondary sources. Employing a multi-stage sampling procedure, primary data were collected from households in a survey that was conducted in three (3) cocoa producing states in Southwest Nigeria between October and November 2011. In the first stage, three cocoa growing states namely; Ondo, Osun and Ekiti were randomly selected from the six states that make up the Southwest zone of Nigeria. The second stage involved the random selection of some major cocoa producing Local Government Areas (LGAs). In Ondo state, Ile-Oluji/Oke Igbo, Owo and Idanre LGAs were selected. In Osun state, Aiyedaade, Irewole, Isokan and Atakumosa West LGAs were selected. Finally, in Ekiti state, Ise Orun, Gbonyin, Ekiti East and Ikole LGAs were selected. At the 3rd stage a list of cocoa growing villages from each of the LGAs were compiled from where specific numbers of cocoa farm households were sampled in proportion to the estimated number of cocoa farmers that existed in those villages. Being the highest cocoa growing state, a total of 282 questionnaires were administered in Ondo state while 106 and 125 were administered in Ekiti and Osun states respectively. In all 515 cocoa farmers were sampled for the study. Also, secondary data on weather variables available from the Nigerian Meteorological Agencies were used to complement the primary data.

Climatic Change and Technical Efficiency of Cocoa Production

To determine the impact of climatic change on technical efficiency of cocoa production, the stochastic frontier model which was estimated using FRONTIER 4.1 statistical software developed by Coelli (1994) was employed. The stochastic production function is of the form:

$$C_i = \alpha_0 + \sum_{i=1}^{n} \alpha_i LnP_i + u_i + v_i \qquad 1$$

The subscript *i* refers to the ith farmers while C_i is total farm output of cocoa (kg), P are the input variables (land area, fungicide, pesticide, herbicide, labour, relative humidity, rainfall and minimum temperature), and v_i is a random error term with normal distribution $N(0, \delta^2)$, u is a non-negative random variables called technical inefficiency effects associated with the technical inefficiency of production of farmers involved. *Ln* is the natural logarithm (i.e. to base e). The $\alpha_0 - \alpha_n$ are the parameters to be estimated.

The technical inefficiency model to be estimated is specified as:

$$u_i = \delta_o + \sum_{i=1}^{n} \delta_i Z_i + d_i \qquad 2$$

Where the Z_is are sex (male =1, 0 otherwise), years of schooling, household size, dependency ratio, primary occupation (farming) (yes = 1, 0 otherwise), number of cocoa farms, age of cocoa trees, distance of farm, ownership of mobile phone (yes = 1, 0 otherwise), Ondo state (yes = 1, 0 otherwise), television (yes = 1, 0 otherwise), scarcity of drinking water (yes = 1, 0 otherwise), scarcity of cooking water (yes = 1, 0 otherwise), proportion of land areas with cocoa trees (%), ownership of radio (yes = 1, 0 otherwise), age of farmer (years) and other members sick (yes = 1, 0 otherwise)

RESULTS AND DISCUSSION

Table 1 shows the different climatic change related problems among cocoa farmers in southwest Nigeria. While most cases of cocoa tree death were reported in Ondo and Ekiti states, in the combined data, 28.27 percent, 40.55 percent and 50.88 percent of the farmers reported death of cocoa trees in 2009, 2010 and 2011, respectively. Anim-Kwapong and Frimpong (2005) noted that death of cocoa tree could result from invasion by Mirids (capsids) which are usually most active and destructive from September to March particularly when there is higher intensity and extension of dry season. Similarly, problem of falling cocoa trees was more reported in Ekiti state.

Another vital impact that climate change has on cocoa agriculture is drastic reduction in yield. This was most reported in Ekiti state. The farmers also reported higher incidence of black pod disease. In the combined data, the proportion of the farmers that noted this increased from 25.15 percent in 2009 to 40.16 percent in 2010 and 61.99 percent in 2011. Cocoa farmers in Ekiti state also reported the highest cases of pest infestation. This is another way climate change can affect cocoa production. Anim-Kwapong and Frimpong (2005), Aigbekaen et al. (2009), Apata et al. (2009) among several others have also documented higher pest infestation resulting from climate change.

Cocoa farmers from Ondo state are more affected by inability to spray cocoa pods effectively due to too much rainfall. Some farmers also reported lack of enough sunshine to dry cocoa beans. In the combined data, 15.98 percent, 35.28 percent and 50.49 percent reported this for 2009, 2010 and 2011, respectively. Wildfire in cocoa farms was also reported by 3.51 percent, 2.34 percent and 5.07 percent of the combined farmers in 2009, 2010 and 2011, respectively.

Higher intensity of weed growth and difficulties in controlling it were also reported. Ziska (undated) submitted that weeds have greater genetic diversity than crops and as such changes in light, water, nutrients or carbon dioxide within the environment will more likely result in greater growth and reproductive response. The results in Table 2 show that in the combined data, 21.64 percent, 44.25 percent and 71.73 percent of the cocoa farmers have some difficulties controlling weeds on their farms in 2009, 2010 and 2011, respectively.

Table 1: Climatic change related problems among cocoa farmers in southwest Nigeria

Observed problem	*2009*			*2010*			*2011*		
	Ondo	*Osun*	*Ekiti*	*Ondo*	*Osun*	*Ekiti*	*Ondo*	*Osun*	*Ekiti*
Death of cocoa trees	102	3	40	148	8	52	166	39	56
Cocoa trees falling off	74	1	30	104	3	57	131	34	81
Reduction in cocoa yield	84	7	78	123	12	76	182	71	76
Higher incidence of black pod disease	71	5	53	126	11	69	178	69	71
Higher incidence of wildfire	8	5	5	9	1	2	18	8	0
Inability to spay cocoa pods effectively	78	3	18	116	6	30	165	47	39
Inability to dry cocoa pods effectively	68	5	9	102	4	75	142	36	81
Increase in the number of pests	76	4	49	134	4	72	172	78	79
Difficulties in weed control	83	0	28	142	5	80	185	96	87
Increase in malaria incidences	20	2	61	65	2	35	99	34	42
Scarcity of drinking water	61	2	81	61	4	1	62	2	3
Scarcity of cooking water	53	2	54	51	3	1	54	2	5
Higher incidence of pneumonia	8	0	18	6	1	68	0	0	1
Higher incidence of cholera	2	0	27	3	2	23	8	7	20
Total	282	125	106	282	125	106	282	125	106

Source: Field survey 2011

Malaria is among the diseases that climate change promotes due to favourable breeding grounds for mosquitoes, which are the major transmission media for the vector parasites (Hoshen and Morse 2004). This was most reported in Ekiti state. Morbidity from pneumonia can also be promoted by climate change. In 2010, 64.15 percent of the cocoa farmers from Ekiti state reported this. Scarcity of drinking and cooking water was also reported. This is able to promote water-borne diseases like cholera which was most reported in Ekiti state. Wandiga (2006) reported resurgence cholera incidence due to climate change in the Lake Victoria Region of Kenya, while Abdussalam et al. (2011) found that precipitation shows a clear association with reported cases of cholera in north- west Nigeria.

Table 2: Effect of climate change on cocoa production and efficiency analysis

Variable name	*Parameter*	*Standard error*
Land area	.0875988**	.0454214
Fungicide	.1201645***	.0319607
Pesticide	.1008865***	.0296437
Herbicide	.0514016	.0355711
Labour	.5832862***	.0449099
Relative humidity	-2.20868	1.454423
Rainfall	-3.661046 ***	.7099193
Minimum temperature	3.286195**	1.366724
Constant	-4.609811	9.709316
Sigma square	0.111144	0.012467
Inefficiency model		
Sex	-5.288332**	2.606812
Year of schooling	-.3110376**	.1516164
Household size	-.6824516**	.3454669
Dependency ratio	1.141547**	.5522881
Primary occupation (farming)	-2.972964*	1.7249
Number of cocoa farms	-1.648804**	.7140375
Age of cocoa trees	-.1040253**	.0434846
Distance of farm	-1.147304*	.6191951
Ownership of mobile phone	3.442007**	1.692794
Ondo farmers	-11.24259**	4.87416
Television	-1.743287	1.290335
Scarcity of drinking water	4.168569	4.160634
Scarcity of cooking water	2.533544	3.300139
Proportion of land areas with cocoa trees	-.0237665	.0400068
Ownership of radio	-3.211265**	1.509833
Age of farmer	.0770214	.0550849
Other members sick	1.365976	1.46233
Constant	13.80911**	6.448958
sigma	0.315962	.0100152
Wald Chi-square	377.08***	
Log likelihood function	-146.53058***	
LR test of the one-sided error	19.602143***	
Number of observations	513	

Source: Field survey 2011

Climate Change, Cocoa Production and Technical Efficiency

Table 2 shows the MLE results. The generalized likelihood ratio test is highly significant and suggests the presence of one sided error component. It also implies that the effect of technical inefficiency is significant and a classical regression model of production will be inadequate for the model.

The results show that as land area increases by one percent, cocoa output will increase by 0.088 percent ($p<0.05$). The low elasticity is a reflection of low land productivity. However, the estimated parameter for fungicide (ridomil) implies that a one percent increase in the number of ridomil used by farmer will increase cocoa output by 0.12 percent ($p<0.01$). The coefficient of pesticide also shows that a one percent increase in the liters used will increase output by 0.10 percent ($p<0.01$). Though having positive sign, herbicide parameter (0.051) does not show statistical significance ($p>0.10$). Some farmers complained about the tendency of destroying other vital crops on cocoa farms when herbicide is used to control weeds. The parameter of labour (man day) shows that a one percent increase in man day will increase cocoa output by 0.583 percent ($p<0.01$).

Out of the environmental variables that were included in the model, relative humidity parameter is not statistically significant ($p>0.10$) and also has a negative sign. However, rainfall has negative sign and statistically significant ($p<0.01$). This parameter implies that a one percent increase in rainfall will reduce cocoa output by 3.66 percent. This is expected because as the situation is, the farmers complained about too much rainfall which affected effectiveness of spraying cocoa pods. Also, if minimum temperature increases by one percent, cocoa output will increase by 3.29 percent ($p<0.05$). Favourably high minimum temperature will reduce the relative humidity and discourage multiplication and development of pathogens that are responsible for cocoa pod disease multiplication.

The determinants of technical inefficiency are contained in the lower segment of Table 2. The results show that male farmers have significantly lower technical inefficiency than their male counterparts ($p<0.05$). This is expected because cocoa agriculture is full of drudgery laden activities like pod and tree spraying, weed clearing, pod harvesting which are too strenuous for women. Also, as the years of formal education increases, technical inefficiency significantly decreases ($p<0.05$). This is also expected because education will impact knowledge that can be applied to farming activities for enhancing efficiency.

If household size increases, technical inefficiency significantly decreases ($p<0.05$). This may result from the fact that family members constitute a bulk of labours that are often discharged in carrying out several activities. However, increasing child dependency ratio increases technical inefficiency. Those farmers that indicated farming as primary occupation have significantly lower technical inefficiency ($p<0.10$). This implies that because they are primarily engaged in cocoa agriculture, they are able to devote enough time in taking care of their cocoa farms for increased technical efficiency. Also, increase in the number of cocoa farms reduces technical inefficiency significantly ($p<0.05$). This may result from ability to utilize resources across the different farms more judiciously and wider spreading of production risks. However, as the age of cocoa trees increases, technical inefficiency in cocoa production significantly reduces ($p<0.05$). This can be explained from the fact that many of the cocoa trees, though still producing pods, are aged (average age of cocoa tree is about 33 years). In many instances, the owners of the farms have died and the farms have been transferred to children as inheritance.

Also, as the distances of the villages to cocoa farms increase, technical inefficiency decreases significantly ($p<0.10$). This may result from conscientious allocation of time when the farm is far. The parameter for state dummy (Ondo state) reveals that farmers from the state have significantly lower technical inefficiency ($p<0.05$). Also, ownership mobile phone increases technical inefficiency, while radio decreases it ($p<0.05$). These findings can be explained from the fact that radio constitutes sources of vital production information, while mobile phones can constitute some form of distraction.

Table 3 shows the means of cocoa production technical efficiencies. It shows that majority of the farmers have production efficiency that is greater than 80 percent. This shows that despite being affected by climate change, the farmers are thriving to maintain a production system that is technically efficient.

Table 3: Distribution of efficiency across climate change vulnerability indices in southwest Nigeria

Efficiency groups	*Frequency*	*Average efficiency*
<70	8	0.6828
70<75	23	0.7296
75<80	68	0.7766
80<85	106	0.8266
85<90	148	0.8763
90<95	149	0.9223
> 95	11	0.9659
Total	513	0.8585

Source: Field survey 2011

CONCLUSION

Climate change poses serious problem to cocoa agriculture in Nigeria. Adequate efforts by the government to address this issue are required in order to address present and future income losses from the problem. The findings from this study provide some specific policy directions that include: ensuring that fungicides (ridomil) for spraying cocoa tree against cocoa black pod disease are made available to farmers at affordable prices; promoting research into low cost cocoa driers that can be used when excessive rainfalls hinder sun-drying of cocoa beans; facilitate research efforts to mechanize many of the activities of peasant cocoa farmers in order to reduce their demand for large family sizes; providing adequate education on climate issues through media houses and setting up a “Special Climate Change Initiative” to address farmers’ problems and assist them since their economic activities are seriously affected by climate change. Such initiative should address climate change gender sensitivity, with specific interventions targeted at women farmers.

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