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Climate Change and Maize Production: Empirical Evidence from Kaduna State, Nigeria

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Abstract

An estimated 80% of the maize crop suffers periodic yield reduction due to drought stress. Drought at flowering and grain filling period may cause losses of 40-90%. Predicated on the argument that climate change resulted from changes in climatic elements such as rainfall, this study aimed at investigating the relationship between rainfall, among other factors, and maize crop production in Kaduna state over a period of 15 years. Time series data on aggregate maize production, fertilizer use, total area under cultivation with the maize crop and annual rainfall in Kaduna State for the period 1990-2005 were collected and analysed using multiple regression technique. Findings of the study showed that annual rainfall contributes significantly and positively to maize production in the study area inspite of climate change, indicating that climate change has not significantly altered the pattern of rainfall in the study area in such a way as to affect maize production negatively.

Keywords: Climate Change, Maize Production, Kaduna, Nigeria.

Introduction

The importance of the maize crop cannot be over-emphasised. According to Dowswell et al (1996), maize has been put to a wide range of uses than any other cereal: as human food, as a feed grain, a fodder crop, and for hundred of industrial purposes because of it broad global distribution, its low price relative to other cereals, its diverse grain types, and its wide range of biological and industrial properties. However, two factors, one climactic and the other edaphic, were identified as limiting maize crop production in sub-saharan Africa.

First, several studies reported that availability of adequate rainfall is by far the most limiting factor in maize production in sub-saharan Africa (CIMMYT, 1988; Diallo et al 1989). In fact, intermittent drought has been implicated among the major constraints limiting the production of maize in the Guinea Savanna of West

Africa. (Kamara et al, 2005). An estimated 80% of the maize crop suffers periodic yield reduction due to drought stress (Bolonos and Edmeades, 1993). Drought at flowering and grain filling period may cause losses of 40-90% (Grant et al, 1989; Nesmith and Ritchie, 1992; Menkir and Akintunde, 2001).

Second, it has been documented that low soil fertility is among the major constraints limiting the production of maize in the Guinea Savanna of West Africa (Kamara et al, 2005). More fertilizers are used on cereal crops; and that more than 70% of fertilizers devoted to cereals in Nigeria are used for maize crop production (NAERLS, 2002). In fact for sub-Saharan Africa as a whole, fertilizer consumption has shifted to cereals, particularly maize (Desai and Gandhi 1988; Gerner and Harris 1993; Heisey and Mwangi 1996). According to Kelly et al (2005), maize exhibited the best overall response to fertilizer among cereal crops.

The purpose of this study is to investigate the relationship between the aforementioned climactic and edaphic factors on maize crop production in Kaduna state over a period of 15 years.

The following hypotheses were formulated and tested in this study:

(a) There is no significant relationship between aggregate maize production and total area under maize cultivation.

(b) There is no significant relationship between aggregate maize production and quantity of fertilizer use.

(c) There is no significant relationship between aggregate maize production and annual rainfall.

Methodology

Conceptual Framework: The conceptual framework for this study is based on the following argument: (i) that agricultural crop production in Nigeria is essentially rainfed (ii) that climate change results from a change in climactic elements such as rainfall (ii) that any change in climactic elements such as rainfall, will indicate a change in the level of rainfed agricultural crop production.

The study area: Kaduna State is located between latitudes 9 08’ and 11 07’N and longitudes 6 10’ and 8 48’E, with a land mass of about 45,567 square kilometres. It occupies a major position in the agricultural economy of Northern Nigeria (Ado et al, 2005). The state has a suitable climate and environmental conditions favourable for cereal crop production and is becoming notable especially for maize production. According to RMRDC (2004), the State produced more maize than any other maize producing state in Nigeria between 2000 and 2004.

The Data: Time series data on aggregate maize production, fertilizer use, total area under cultivation with the maize crop and annual rainfall in Kaduna State for the period 1990-2005 were collected and used (see Appendix Table A1 for data and sources).

The Model Specification: Consider a typical farm with a production function

$$Y = f(X_1 \ldots X_m; Z_1 \ldots Z_n) \quad (1)$$

Where Y is output, X represent variable inputs and Z represent fixed and other shifter variables of the function.

Based on the production function outlined above, an empirical aggregate model is developed for maize production in Kaduna state, leaving out variables of less interest to this study, as follows

$$Y_t = \beta_1 + \beta_2 X_{1t} + \beta_3 X_{2t} + \beta_4 X_{3t} \quad (2)$$

Where Y_t is maize production in year t (measured in MT), X_{1t} is total area under maize cultivation in year t (measured in hectares), X_{2t} is fertilizer use in year t (measured in MT), and X_{3t} is annual rainfall (measured in mm).

Estimation of model: As noted in various literature, empirical analysis of time series data pose several challenges as empirical work, including causality tests of Granger and Sims based on time series data assumed that the underlying time series is stationary (see Seddighi et al (2000); Enders (1995); Patterson (2000). Mercifully, as Gujarati (2003) noted, by simply establishing stationarity of the residuals from regression equation, the traditional regression methodology is applicable to data involving non stationary time series.

Cointegration was tested on the data collected for this study using the Cointegrating Regression Durbin-Watson (CRDW) Test method as expounded by Gujarati (2003).

Our regression model:

$$Y_t = \beta_1 + \beta_2 X_{1t} + \beta_3 X_{2t} + \beta_4 X_{3t} + \mu_t \quad (3)$$

was estimated and the residuals obtained.

The computed CRDW *d* (1.510) obtained from the cointegrating regression (3) is greater than the critical value of 0.386 at the 5% level, thus it was concluded that the regression residuals are stationary. However, the estimated DW *d* value of 1.510 lies between the critical DW d_L value of 0.897 and DW d_U value of 1.710 indicating that there is inconclusive evidence regarding the presence or absence of positive first order serial correlation. However, for the purpose of this study, our OLS estimators for equation (3) were assumed efficient and the usual t and F tests were applied.

Results and Discussion

The maize response model (eqn 3) was estimated using the time series data for the period 1990-2005 with SPSS 16.0. The F value of 4.590 computed for equation (3) is significant, when viewed in relation to the p-value of 0.023. This implies that aggregate total area, fertilizer use and amount of rainfall significantly explain the variation in the aggregate maize output in Kaduna state. The R^2 value obtained from the equation is 0.534. This further indicates that aggregate total area, fertilizer use and amount of rainfall explained about 53% of the variation in aggregate maize output in Kaduna state during the study period. This finding is further supported by the estimated value of the intercept of the model (-742883.513), which indicates that maize production is practically impossible without the variables included in the equation. The unexplained variation, 47%, in the model is attributable to other factors not specified in the model due to difficulties in quantification and for computational ease.

The computed t value of 2.380 calculated for $\beta_{1,}$ the coefficient of total area under cultivation with the maize crop in Kaduna state, is found to be significant when viewed in relation to the computed p-value of 0.035, hence the null hypothesis is rejected and it is thus concluded that there is a significant and positive relationship between the aggregate maize output and total area under cultivation with maize in Kaduna state. This finding indicates that increased in the quantity of maize production results more from increase in land under cultivation with maize crop than intensification of production.

The computed t value of 0.693 calculated for $\beta_{2,}$ the coefficient of aggregate fertilizer use in Kaduna state, is found to be not significant when viewed in relation to the computed p-value of 0.502, hence the null hypothesis is accepted and it is thus concluded that there is no significant relationship between the aggregate maize output and quantity of fertilizer use in Kaduna state. A probable explanation on why fertilizer use has an insignificant effect on aggregate maize production in Kaduna state is that farmers are applying fertilizer below the recommended rates. This explanation is supported by Liverpool-Tasie et al (2010), that low fertilizer use is one of the many reasons for low agricultural productivity in Nigeria; fertilizer use estimated at 13 kg/ha in 2009 by the Federal Ministry of Agriculture and Rural Development (FMARD), is far lower than the 200 kg/ha recommended by the FAO as well as the 104 kg/ha in South Asia and 142 kg/ha in Southeast Asia. This finding further lends credence to our previous finding that increased in the quantity of maize production results more from hectarage expansion in Kaduna state than from intensification of production. Intensive maize production will naturally require the use of more inputs like fertilizer.

The computed t value of 3.467 calculated for $\beta_{3,}$ the coefficient of total annual rainfall in Kaduna state, is found to be highly significant when viewed in relation to the computed p-value of 0.005, hence the null hypothesis is rejected and it is thus concluded that there is a significant and positive relationship between the aggregate maize output and total annual rainfall in Kaduna state. This finding indicates that annual rainfall contributes significantly and positively to maize production in the study area inspite of climate change. Climate change has not significantly altered the pattern of rainfall in the study area in such a way as to affect maize production. This finding did not provide enough evidence to agree with Arnell (1992), that climatic changes would result in changes in rainfall patterns.

TABLE 1

Results of Regression Analysis of aggregate maize output, area under-cultivation, fertilizer use and annual rainfall model (3)

Independent Variables	Coefficients	t-values	p-values
Constant term	-742883.513	-1.572	0.142
Area Cultivated	0.505*	2.380[a]	0.035
Fertilizer Use	0.137*	0.693	0.502
Annual Rainfall	0.736*	3.467[a]	0.005

R^2=0.534; Adjusted R^2=0.418; R=0.731; $F_{(model)}$ =4.590; p-value for $F_{(model)}$=0.023; DW d=1.510.

[a]*Statistically significant statistics at α = 5%*

**Standardized*

Conclusion

This study aimed at investigating the relationship between area under cultivation, fertilizer use and annual rainfall, in maize crop production in Kaduna state over a period of 15 years. Time series data on aggregate maize production, fertilizer use, total area under cultivation with the maize crop and annual rainfall in Kaduna State for the period 1990-2005 were collected and analysed using multiple regression technique. Findings of the study indicates: (i) increased in the quantity of maize production results more from increase in land under cultivation with maize crop than intensification of production (ii) there is no significant relationship between the aggregate maize output and quantity of fertilizer use in Kaduna state (iii) annual rainfall contributes significantly and positively to maize production in the study area inspite of climate change. The study concluded that climate change has not significantly altered the pattern of rainfall in the study area in such a way as to affect maize production.

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Appendix

TABLE A1:

Time series data on aggregate maize production, fertilizer use, total area under cultivation with the maize crop and annual rainfall in Kaduna State for the period

Year	Maize Production (MT)*	Area Under Maize (Ha)*	Quantity of Fertilizer Used (MT)**	Annual Rainfall (mm)***
1990	426120	14182	40000	1022
1991	529561	223443	36470.97	1407
1992	563503	252692	41417.8	1095
1993	484694	255219	29760	987
1994	751752	346337	31050	1061
1995	670520	252264	37000	720
1996	462875	225793	32806.32	1031
1997	953130	320469	33000	1110
1998	1334343	66075	28000	1879
1999	1391048	371938	51689	1286.1
2000	812721	315008	34256.49	980.5
2001	832922	315500	26881.6	992.1
2002	826800	318000	27000	988.7
2003	944671	318072	27652	
2004	635487	316163	28750	
2005	907495	316201	33925	

*Source: *Kaduna ADP, **Authours' estimate, ***CBN (2007).*

Note: *The data from Kaduna ADP was extracted from their records and made available to the authours.*