THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE IN NIGERIA, FOCUSING ON MAIZE: IMPLICATIONS FOR ACTUARIES

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Abstract

In recent times, climate change has become one of the most complicated challenges facing human society. This study is aimed at establishing how the actuary is affected by the impact of climate change on agriculture. In this study, maize is the major agricultural product considered. Time series analysis (unit root test, cointegration and error correction model) via Eviews 9.0 was utilized to analyze the data obtained from the World Bank groups database and Food and Agricultural Organisation Statistical division 1961-2020, which contained a set of time series data on rainfall, temperature and yield of maize in Nigeria. The results showed climatic elements (rainfall, temperature) has no significant effect on the yield of maize in Nigeria. It is recommended that climate change through a natural occurrence should not be an added input to models for the calculation of premiums in Nigeria. Another agricultural risks such as institutional risk, production risk, human risk, price risk, and financial risk could be considered.

Keywords: Climate change, rainfall, temperature, maize, premium, actuary.

1. Introduction

Climate change, as defined by the Inter-governmental Panel on Climate Change (IPCC), is the significant variations in weather conditions that persist for an extended period of time, typically decades or longer. It is the slow change in the composition of the global atmosphere, which is caused directly or indirectly by various human activities in addition to natural climate variability over time (Koehler-Munro & Goddard, 2010). The manifestations of climate change are seen in increased temperature, increased carbon dioxide, increased pests and diseases, and increased water demand, change invariability of crops, vertical shifts in ecosystems, change in seasonal timings, sea level rise and saltwater intrusions (Johnston, Hoanh, Lacombe, Noble, Smakhtin & Suhardiman, 2009).

Climatic variations will have consequences for the availability of water resources, pests and diseases and soils, leading to significant changes in the conditions for agriculture. In extreme cases, the degradation of agricultural ecosystems could mean desertification, resulting in a total loss of the productive capacity of the land in question. (CEC, 2009). Low rainfall in arid and semi-aridntot regions dictates the formation of shallow soils, which are poor in organic matter and nutrients. Inter- and intra-annual rainfall variability is a key climatic element determining the success of agriculture in many countries (Sivakumar et al., 2005). High temperature can reduce critical growth periods of crops; promote crop disease; and increase the sensitivity of crops to insect pests, thereby affecting crop development and potential yield (CCSP, 2008; Yosef, Jones, Chakraborty & Gillespie, 2015).

Maize is a very important crop in Nigeria, as it provides an inexpensive nutritious food that helps to sustain rapidly increasing population. Apart from providing the staple diet for the population, maize is also an important crop in industrial and livestock production in the country. Maize is highly yielding, easy to process, readily digested and cost less than other cereals. It is also a versatile crop, allowing it to grow across a range of agro-ecological zones (IITA, 2001). Despite its importance in society, maize is faced with so many problems among which are weeds, pests and diseases and weather conditions. Generally, temperature, rainfall, daylight, solar radiation, humidity and soil fertility are the major factors that interact to varying extents to limit the growth and development of maize plants (IITA, 1982). The specific objectives of this study are to:

i. Evaluate and estimate the average maize yield per hectare and climatic parameters in Nigeria from 1961 to 2020,
ii. Establish the effect of climatic elements (rainfall & temperature) on the yield of Maize in Nigeria, and
iii. Identify implications of the effect of climatic change on the actuary.

2. Materials and Methods

The study was carried out in Nigeria, Nigeria is bounded in the north by Niger, east by Cameroon, Gulf of Guinea to the South and in the west by the Republic of Benin. The major food crops grown in the zone are yams, cassava and maize, there are six major eco-climatic zones in the country, including; Humid forest, Southern Guinea savanna, Derived savanna, Northern Guinea savanna, Sahel savanna and Sudan savanna. Nigeria is the most populous black nation in the world and agriculture is one of the mainstays of the economy.

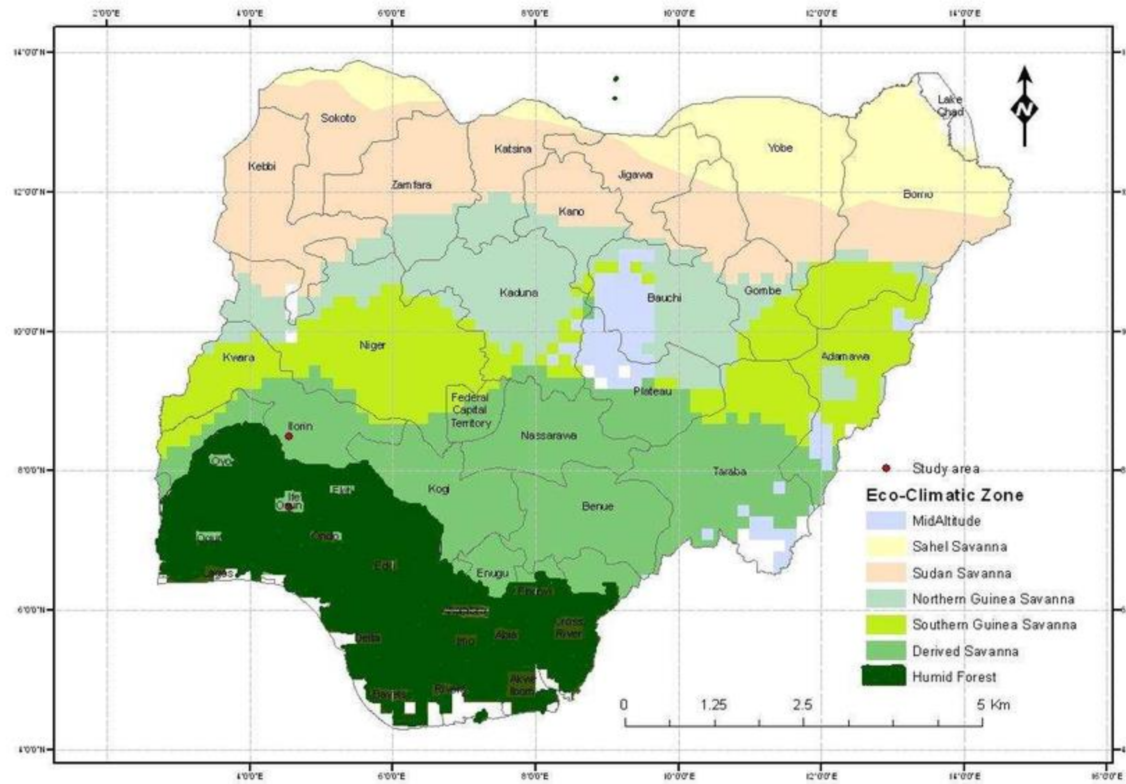

Figure 1: Map of Nigeria showing the various Eco-Climatic Zones.

The data for the study were obtained from secondary sources. These sources include the report of Food and Agricultural Organisation Statistical Division (FAOSTAT), Database of the World Bank Group. These data are time-series data for a period of sixty (60) years from 1961 to 2020 which included data on the Maize Yield (MY), Temperature (TP) and Rainfall (RF).

This study employed multiple regression analysis model, specified on the basis of a hypothesized functional relationship between Maize Yield and climatic elements (rainfall & temperature). The model is estimated via time-series properties using E-view 9. The procedure for regression is given as:

i. The stationary test was performed to avoid spurious regression problems that are normally associated with time series econometric modelling using the Augmented Dickey-Fuller (ADF) test for estimating unit-roots (Granger & Newbold, 1974; Koop, Strachan, van Dijk & Villani, 2006).
ii. If the series are integrated of the same order, that is, all variables at either I(1) or I(2), it becomes extremely important to carry out a co-integration and probably error correction model if co-integration is met. If the series are not integrated in the same order, that is combination of I(1) and I(2), use the Auto-regressive model. If it constitutes I(0) and I(1), use ARDL Model (Granger, 1981; Engle, & Granger, 1987).

The model used is stated as MY = f(TP, RF) which is specified into random or stochastic models as:

$$LNMY = \beta_0 + \beta_1 LNTP + \beta_2 LNRF + \varepsilon$$

Where, $\beta_0, \beta_1, \beta_2,$ are the regression constants,
LN is the natural logarithm,
MY represents the Maize Yield,
TP represents the Temperature, and
RF represents the Rainfall.

3. Results and Discussions

This study adopted time-series data for a period of sixty (60) years from 1961 to 2020 which included data on Maize Yield (MY), Temperature (TP) and Rainfall (RF). The analysis includes the descriptive statistics, unit root test, cointegration analysis and error correction model.

Table 1: Descriptive Analysis of Data

Statistics	Maize (hectogramme per hectare)	Annual Mean Temperature (Degree Celcius)	Annual Mean Rainfall (Millimeter)
Mean	13040.7	26.98967	1151.293
Standard Error	434.4691	0.051086	11.49888
Median	13081	27	1157.905
Mode	#N/A	27.06	#N/A
Standard Deviation	3365.383	0.395714	89.06992
Sample Variance	11325801	0.15659	7933.451
Kurtosis	-0.20753	-0.64668	0.563138
Skewness	0.056154	-0.14529	-0.4243
Range	16230	1.6	463.24
Minimum	5731	26.21	872.04
Maximum	21961	27.81	1335.28
Sum	782442	1619.38	69077.58
Count	60	60	60
Confidence Level (95.0%)	869.3706	0.102224	23.0092

Source: Researchers' Computation using Microsoft Excel

Table 1 shows that the mean of the Maize Yield (MY), Temperature (TP) and Rainfall (RF) clusters around 13040.7 hg/hc, 26.98967 ^{0}C, and 1151.293mm respectively. The implication of this is that all the series display a high level of consistency as their mean values are perpetually within the maximum and the minimum values of these series. Maize Yield (MY) is positively skewed to the right while, Temperature (TP) and Rainfall (RF) are negatively skewed. The positive skewness indicates that the degree of departure from the mean of the distribution is positive, revealing that there was a consistent increase in Maize Yield (MY) from 1961 to 2020. The negative skewness indicates that the degree of departure from the mean of the distribution is negative, revealing that there was a consistent decrease in Temperature (TP) and Rainfall (RF) from 1961 to 2020. The table also shows that Maize Yield (MY), Temperature (TP) and Rainfall (RF) have a platykurtic distribution (Kurtosis < 3), indicating that the series are not normally distributed.

Table 2: Summary of Unit Root Test Results

Variables	Order of integration	ADF test statistics	Critical ADF Statistics at 1%	Critical ADF Statistics at 5%	Critical ADF Statistics at 10%
***LN*MY**	I(1)	-7.81497	-2.60616	-1.94665	-1.61312
***LN*TP**	I(1)	-11.5158	-2.60616	-1.94665	-1.61312
***LN*RF**	I(1)	-12.7738	-2.60544	-1.94655	-1.61318

Source: Researchers' Computation using E-views 9.0

Table 2 shows that Maize Yield (MY), Temperature (TP) and Rainfall (RF) are stationary in their first difference form, which are integrated at order one (1). At this order of integration, their ADF test statistics are greater than their critical value at 1%, 5% and 10% critical ADF statistics in their absolute terms. Since the variables are found stationary at the first difference, there is a need to investigate co-integration among the variables.

Table 3: Summary of Co-integration Result

Sample (adjusted): 1963 2020
Included observations: 58 after adjustments
Series: MY TP RF
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue9 +	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.438459	50.54174	29.79707	0.0001
At most 1 *	0.211579	17.07163	15.49471	0.0287
At most 2	0.055042	3.283685	3.841466	0.0700

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.438459	33.47011	21.13162	0.0006
At most 1	0.211579	13.78795	14.26460	0.0593

At most 2	0.055042	3.283685	3.841466	0.0700

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Source: Researchers' Computation using E-Views 9.0

Table 3 shows that both the trace and the Max-Eigenvalue statistics reject the null hypothesis of no cointegration at 0.05 level since there are two (2) co-integrating equation(s) at the 0.05 level for trace statistic and one (1) co-integrating equation(s) for the Max-Eigenvalue statistics. Cointegration essentially means two-time series have a long-run relationship. Since there is a long-run relationship, there is a need to carry out *Error Correction Model (ECM).*

Table 4: Summary of Error Correction Model

Dependent Variable: D(MY)
Method: Vector Error Correction Estimates
Sample (adjusted): 1963 2020
Included observations: 58 after adjustments

	Coefficient	Std. Error	t-Statistic	Prob.
ECM(-1)	-0.283691	0.083495	-3.397683	0.0013
D(MY(-1))	0.133769	0.146457	0.913367	0.3652
D(TP(-1))	-1.717231	1.915926	-0.896293	0.3741
D(RF(-1))	0.013554	0.235218	0.057622	0.9543
C	0.009605	0.019976	0.480833	0.6326

R-squared	0.193454	Mean dependent var	0.010135
Adjusted R-squared	0.132582	S.D. dependent var	0.162476
S.E. of regression	0.151323	Akaike info criterion	-0.856544
Sum squared resid	1.213621	Schwarz criterion	-0.678919
Log likelihood	29.83977	Hannan-Quinn criter.	-0.787355
F-statistic	3.178070	Durbin-Watson stat	1.967924
Prob(F-statistic)	0.020554		

Source: Researchers' Computation Using E-views

From the error correction model shown in Table 4, it is clear that the coefficient of the error term is negative as theoretically expected, and also statistically significant at a 5% significance level. The negative sign implies that any deviations from equilibrium by a variable will be corrected or reversed in the future. It also indicates that the explanatory variables maintain the Maize Yield (MY) equilibrium throughout time.

The Durbin-Watson statistics of 1.967924 obtained suggest that there is an absence of serial correlation or autocorrelation problem of regression in our models. This approximately conforms to the benchmark of 2.0 for the absence of autocorrelation problem of regression. The result shows that the R-squared = 0.193454, indicating that 19.35% of the total variations in measures of the

Maize Yield (MY) is explained by the variations in Temperature (TP) and Rainfall (RF). Adjusted R^2 shows variations in the volatility captured by the independent variables after taking into consideration of the additional explanatory variables. That is, it explained 13.25% of the total variations in the dependent variable. The t statistics show that Temperature (TP) and Rainfall (RF) have no significant effect on Maize Yield (MY) in Nigeria.

4. Implications of the Result for Actuaries

To analyse the overall implication of the relationships as confirmed in the previous sections, we considered a farmland with adequate insurance and a maize plantation for commercial purposes. Midway into the planting season, excessive rainfall is recorded and farmland gets totally wiped out due to the effect of flood. Who in this situation bears the loss? Farmer, insurance company or the bank? However, there is every possibility that in the process of developing the premium to be paid, the weather condition perhaps was normal, hence, there is no reason to suspect a possible change in weather to such a magnitude. Therefore, we suspect that the premium being paid for such insurance cover will be less than what it should be. This is because the actuary that calculated the premium would not have considered climate change as a major factor in the premium formulation process. It is important to note that calculating premiums involves a lot of considerations (Shapiro, 1982).

The nature of the business environment demands the ability to react quickly to changes and new opportunities. Actuaries, as guardians of the pricing process, are called on to develop detailed forecasts and evaluate anticipated and future scenarios, and at the same time work with assumptions that are difficult to predict with accuracy. Although the procedural details of premium formulation process may vary from company to company and from one line of business to another, the general pricing process can be divided into four phases as follows; (1) defining the pricing plan, (2) establishing the actuarial assumptions, (3) determining products and prices, and (4) operating and managing the results. In a bid to establish the needed actuarial assumptions as required in phase 2, external factors must be reviewed, owing to the fact that the business environment is considered volatile and uncertain.

The premium formulation is a continuous and circular process; the experience from one round of product development is used as the basis for the next round. In most cases, changes in climate are not factored into or considered when reviewing external factors for the model. Therefore, outcomes or results that are churned out as premium's values from the model are sometimes not adequate reflection of the severity of the risk at hand. Climate change is an additional variable that must be considered in the general model for premium formulation. This might take care of all necessary hazards caused by the changes in climate that are not usually factored into the premium calculation's model.

5. Conclusions and Recommendations

Climate change is a major threat to agricultural productivity. Although Nigeria has not felt the serious effect of its variations, unlike some other parts of the world where severe cases of hurricanes and landfalls have been recorded. Climate change has no significant effect on yield of maize in Nigeria. Factoring climate change in premium calculation is not significantly required. Actuaries who are long-term thinkers are required to have a long-range view of this topic and understand how it affects their profession. This study revealed that Nigeria is likely not to battle the effect of climate change in the long run, as such actuaries should not really consider climate change as part of their input variables in the premium formulation model. Other agricultural risk such as institutional risk, production risk, human risk, price risk, and financial risk could be considered.

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