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AN ASSESSMENT OF CLIMATE CHANGE IMPACTS ON MAIZE (*ZEA MAYS*) YIELD IN SOUTH-WESTERN NIGERIA

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ABSRACT

Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food in Nigeria. Africa produces 6.5% of maize worldwide. Nigeria with nearly 8 million tons of maize, emerged the largest producer in Africa. However, most maize production in Africa is rain-fed. Given the current trends in climate change and its uncertain specific effects on the crop yields in general and that of maize in particular, formulating practical,affordable andacceptable response strategies formaize production in Nigeria required a study that evaluates the impacts of climate change on maize under varying climatic conditions.

Data on maize yield in South-western Nigeria, for eleven years(1999-2009) were obtainedfrom the Agricultural Production Survey of the Federal Ministry of Agriculture and Rural development, Nigeria. A corresponding climatic data (minimum and maximum temperature, solar radiation and rainfall) for the period were obtained from the Nigeria Meteorological Agency (NIMET), Oshodi, Nigeria. The data sets were smoothened and adjusted for appropriate statistical analysis to generate model that could be adopted for seasonal planning and future yield optimization of *Zea mays* in the region. A linear regression model expressed as$\mathrm{Yield} = 55.503\mathrm{SRAD} + 2.054\mathrm{Tmax} + 29.501\mathrm{Tmin} - 0.052\mathrm{RAIN} - 1459.373$was generated where SRAD = Solar Radiation, Tmax = Maximum Temperature, Tmin = Minimum Temperature and RAIN = rainfall. The performance of the model was evaluated using the normalized root mean square error otherwise called percentage error(PE) as being capable of serving as yardstick for future assessment of climate change impact on maize yield in South-western Nigeria.

KEYWORDS: *Zea Mays*, Climate Change, Yield Optimization, South-Western Nigeria

INTRODUCTION

Maize is grown widely throughout the world in different agro-ecological environments and is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food in Nigeria. Africa produces 6.5% of maize worldwide. Nigeria, with nearly 8 million tons of maize, emerged as the largest producer in Africa. Africa imports 28% of the required maize from countries outside the continent. Most African agricultural productions in general and maize production in particular are rain-fed. Thus irregular rainfall can trigger famines during occasional droughts (IITA, 2015).

Agriculture and climate changetake place on a global and regional scales. They are both interrelated processes. In spite of the uncertainties about the precise magnitude of climate change on regional scales, an assessment of the possible impacts of climate change on agricultural resources under varying conditions is important for formulating response strategies, which should be practical, affordable and acceptable to farmers.Several studies have shown that potential yield assessment (by evaluating previous performance) help in identifying the yield limiting factors and in developing suitable strategies to improve the productivity of a crop (Aggarwal and Kalra, 1994; Lansigan *et al*., 1996; Evenson *et al*., 1997; Naab *et al*., 2004). This assessment on agriculture might help to properly anticipate and adapt farming to maximize agricultural production under variable and changing climatic conditions

Climate change is projected to have significant impacts on conditions affecting agriculture. The critical elements in this regard are: temperature, solar radiation, precipitation and the interaction among them. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture has hitherto being observed and reported (Fraser, 2008) to depend on the balance of these climatic parameters.

This study thus aimed at assessing the impact of climate change on maize yield in south-western Nigeria.The objectives of this study are to:

- determine the bivariate and multiple relationships between maize yield and the selected climatic variables in the study area
- formulate model relating the climatic variable with maize yield; and
- validate the model with known values of the climatic variables and the maize yield

METODOLOGY

Study Area

The study area is the south-westernNigeria Figure 1 located between longitude 30° and 7°E andlatitude4° and 9°N. The region comprises six States; Oyo, Osun, Ogun, Ondo, Ekiti and Lagos State Figure 1. The total land area is about 191,843 square kilomaters (Iloeje, 1981).The weather conditions exhibits two distinct seasons; the rainy season (March - October) and the dry season (November - February). The dry season is characterized by harmattan dust and cold dry winds from Sahara deserts.

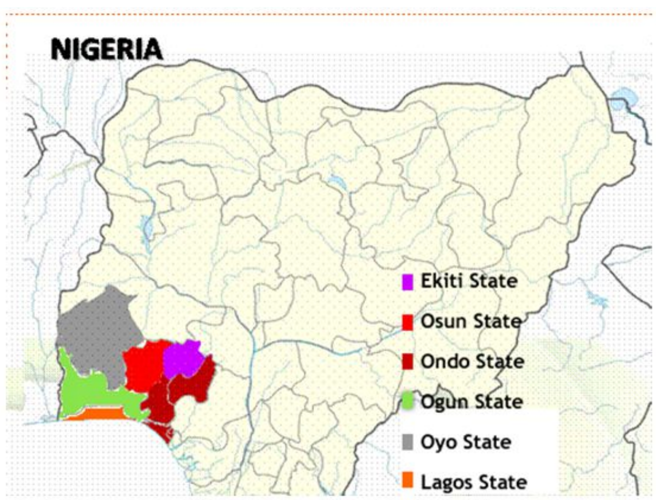

Figure 1: Map of Nigeria Showing the States in the South-Western Nigeria (Longitude 30° and 7°E and Latitude 4° and 9°N)

Data Collection

Data for yield and growth parameters of maize for eleven years (1999-2009) were obtained from the Agricultural Production Survey (APS, 2009) under the National Programme for Agriculture and Food Security (NPAFS) of the Federal Ministry of Agriculture and Rural Development, Nigeria. Daily climatic data (minimum and maximum temperature, solar radiation and rainfall) for the same period were obtained from the Nigeria Meteorological Agency (NIMET), Oshodi, Nigeria. Data collected were sorted and arranged for the correlation and regression analysis.

Data Analyses

Relationship between the climatic variables and maize yield were determined with the aid of Pearson's correlation. Pearson's correlation coefficientcan take on the values from -1.0 to 1.0, where -1.0 is a perfect negative (inverse) correlation. Correlation coefficient of value 0.0 indicates no correlation while that of value 1.0 shows a perfect positive correlation. The closer the correlation is to 1 or -1.0, the closer it is to a perfect linear relationship. Regression Analysis was used to generate equations relating climatic variable with maize yieldand to make predictions. The linear regression model is expressed as $y = c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + k$(y is the dependent variable which is the yield, k is a constant value, and x_1, x_2, x_3 and x_4 are independent variables where x_1 = Solar Radiation (SRAD), x_2 = Maximum Temperature (Tmax), x_3 = Minimum Temperature (Tmin) and $x4$ = RAIN). The c_1, c_2, c_3 and c_4 are the respective coefficients of the independent variables.

The models generated were validated with climatic data and maize yield from 2004 to 2007. The models were analyzed to test the reliability of data using normalized root mean square error otherwise called percentage error (PE) following Loague and Green (1991). RMSE is described (Willmott, 1981) as one of the best overall measures of model performance because is more sensitive to extreme values due to its exponentiation. It therefore can be considered as a high estimate of actual average error. RMSE as percentage of means of observation is Percentage Error (PE). If PE is less than 10%, the model is of a good reliability measure.

RMSE and PE are mathematically expressed as:

$$\mathrm{RMSE} = \sqrt{[\sum(\mathrm{Pi} - \mathrm{Oi})^2/\mathrm{n}]} \qquad \text{Eq 1}$$

$$PE = \frac{RMSE}{\bar{O}} x\ 100. \qquad \text{Eq 2}$$

Where:

RMSE = Root Mean Square Error

Pi = Predicted value

Oi = Observed value

Ō = Mean of observed value

n = Number of replicates/locations

∑= Summation sign

√ = Square root

RESULTS AND DISCUSSIONS

Aminimum SRAD of 16.92 $MJ/m^2/d$ (2005) and maximum of 18.62 $MJ/m^2/d$ (2008) with an overall average of 17.49 $MJ/m^2/d$ were recorded for the region over the period under consideration. The coolest year was 2002 with a minimum temperature of 22.45 ^oC and the hottest being 2007 with maximum temperature of 28.91 ^oC. The highest total annual rainfall (1491.37 mm) was also recorded in 2007. Highest yield of 315.6 tonnes/ha was recorded in 2009 though the same year recorded the lowest total annual rainfall of 1086.35 mm Table 1 Since water requirements for crops (including maize) varies from one developmental stage to the other, farmers are encouraged to plan their farming operations using predicted rainfall pattern so as to target maize water requirement for its different developmental stages. Figure 2 shows the trend of maize yield in the region. As depicted in the Figure, the yieldis on the increase regardless of the variations in the climate. This could be as a result of increase in demand for maize because of increase in population as it is the most popular cereal crop consumed in this area (IITA, 2015).

Table 1: Average Maize Yield and Corresponding Weather Data for Maize Planting Season (April-October)In South-Western Nigeria

Year	Yield(Tonnes/Ha)	Srad($MJ/M^2/D$)	$T_{max}(^OC)$	$T_{min}(^OC)$	Rain(Mm)
1999	130.3	17.26	28.06	22.56	1271.23
2000	122.4	17.53	28.38	22.86	1115.90
2001	136.2	17.39	27.96	22.76	1093.97
2002	144.5	17.06	28.15	22.45	1203.87
2003	146.3	17.39	27.80	23.17	1109.50
2004	158.0	16.97	27.75	22.90	1131.67
2005	189.1	16.92	27.83	22.81	1064.75
2006	211.1	17.30	27.69	22.92	1315.15
2007	224.1	17.63	28.91	23.16	1491.37
2008	252.4	18.62	27.90	23.63	1337.03
2009	315.6	18.26	27.36	23.85	1086.35
Average	**184.5**	**17.49**	**27.98**	**23.01**	**1201.89**

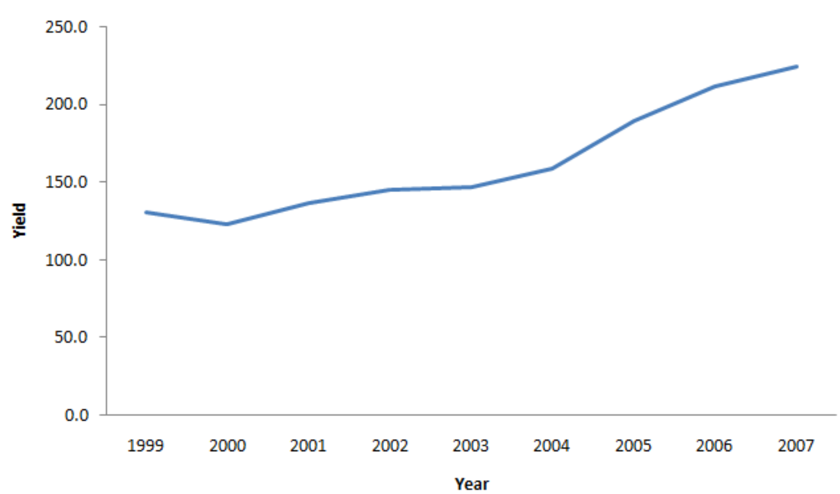

Figure 2: Maize Yield Trend in South-Western Nigeria between. 1999 -2009

Using Pearsons correlation analysis, the relationship between yield and the selected climatic variables, showed that there were significant positive relationships between maize yield and SRAD ($\alpha = 0.01$) and T_{min}($\alpha = 0.01$)Table 2. The maximum temperature and rainfall however were observed to have no relationship with the yield Table 2. This implies that increase in maximum temperature and rainfall will lead to reduction of yield. Though highest yield was recorded with highest temperature as against the established relationship in this study, total input was not considered and commensuration of the recorded yield to the input could not be established.

Table 2: Correlation between Maize Yield and Weather Variables in South-Western Nigeria between 1999 And 2009

	SRAD	T_{max}	T_{min}	RAIN
Yield	0.326**	-0.185	0.345**	-0.15
P-level (α = 0.01)	0.008	.137	.005	.720

**Correlation is significant at the 0.01 level

The analysis of variation observed in the yield as affected by the combined effect of the four climatic factors considered revealed a significant relationship with P value = 0.003 for degree freedom = 65 at 0.01level of significance. The regression model for this dependence is represented as:

$$\text{Yield} = 55.503\text{SRAD} + 2.054\text{Tmax} + 29.501\text{Tmin} - 0.052\text{RAIN} - 1459.373 \ldots \ldots \quad \text{Eq 3}$$

Table 3 shows the performance of the regression model using the RMSE/PE method described earlier. Since PE calculated (31.16%) is more than 30%, the model is said to be fair. It must only be used for maize yield prediction in the observed region considering the fact that the yield can be 31/16% more or lesser than the predicted yield value.

Table 3: Evaluation and Validation of the Generated Equation Model

Year	Observed	Simulated	RMSE	%PE
2004	158.00	215.23	12.4644	31.16
2005	189.08	209.37		
2006	211.05	233.87		
2007	224.10	261.32		

Water requirements of maize will fluctuate throughout the season depending on weather conditions and the growth stage. Maizerequires very little water during the seedling stage, while the most water just before and during the reproductive stage. When maize does not receive enough water to meet evapotranspiration demands during the reproductive growth stages, significant reductions in yield can occur. However water supply after physiological maturity will be of no yield benefit. The water availability does not only depend on total rainfall but also on the temperature since higher temperature leads to higher evapotranspiration (ET) hence, higher water demand of water by the crop. Solar radiation also influences ET

SUMMARY AND CONCLUSIONS

Proper understanding of impacts of these variables will go a long way in attaining good yield and as such good economic return. From this experiment, a model capable of assessing an overall effect of climate change on maize yield prediction was formulated and validated (Fraser, 2008)with substitution of predicted climatic variables into the equation. The equation could only be used if only the climatic variables are considered as the equation does not take into cognisance other production factors.

An understanding of corn water use can help guide more efficient irrigation applications.

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