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Effect of climate change on food crop production and vulnerability assessment in Oyo State

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The study assessed household vulnerability to climate change and its effect on yam and cassava production in Oyo state, Nigeria. Primary and secondary data were used for the study. Data on yam and cassava yield between 1990 and 2009 were obtained from the Oyo State Agricultural Development Programme (ADP) while data on climate variables between 1976 and 2010 were obtained from the Nigeria Institute of Meteorology, Oshodi. Primary data on the components of vulnerability that is adaptive capacity, sensitivity and exposure were also obtained from cassava and yam farmers using structured questionnaire to assess their vulnerability to climate change. Multistage sampling technique was employed to select 120 respondents across the three agro-ecological zones of the study area. This was done by purposively selecting five farm villages in each of the three agro-ecological zones in the study area and randomly selecting eight farmers from each of the villages. Trend, regression and principal component analytical tools were used to analyze data collected. The integrated vulnerability assessment approach was adopted using the vulnerability indicator. The result showed that the mean annual temperature and mean annual sunshine hour have been increasing by an average of 0.012oC (p<0.01) and 0.004 hours (p<0.01) per year respectively. This confirms the occurrence of global warming in the study area. The study revealed that sunshine hour significantly (p<0.05) affected yam yield. Household's vulnerability to climate change in the three agro ecological zones as measured by the vulnerability index (VI) was found to be highest in the derived savannah (VI=-0.99) followed by the savannah (VI=0.46) and lowest in the rain forest (VI=0.53). The derived savannah zone recorded the highest vulnerability with a relatively low proportion of the population having access to quality home (2.5%), insecticide (30%), fertilizer (30%), improved seedlings (30%), road (15%), health services (15%), primary and secondary schools (15%), veterinary services (0.03%), food market (42.5%), and microfinance institutions (0.03%). The study recommended among others that crop-breeding researchers should work towards developing improved varieties of cassava and yam that can cope with future expected change in climate. Also, integrated rural development schemes aimed at increasing access to basic social amenities should be established by the government with the cooperation of the residents as this will improve adaptive capacity and thereby reduce vulnerability of farmers to climate change in the study area.

Key words: Climate change, Vulnerability, Food, Crop production, Oyo State

INTRODUCTION

Climate change refers to the variation in the global or regional climates over time. It describes changes in the

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variability or average state of the atmosphere over time scales ranging from a decade to millions of years (Adejuwon, 2004). Climate change may result from factors such as changes in orbital elements (eccentricity, obliquity of the ecliptic, precession of equinoxes), natural internal processes of the climate system or anthropogenic forcing (for example, increasing concentration of carbon dioxide and other green house gases) (Agbola et al., 2007).

Vulnerability to climate change can be explained as the adaptive capacity to climate change less sensitivity and exposure.

Vulnerability = (adaptive capacity) – (sensitivity + exposure)

West Africa is one of the most vulnerable to the vagaries of the climate, as the scope of the impacts of climate variability over the last three or four decades has shown Intergovernmental Panel on Climate Change (IPCC, 2007b; Apata et al., 2009). Recent food crises in countries such as Nigeria are reminders of the continuing vulnerability of the region to the vicissitudes of climatic conditions.

The objectives of this study are to:

i. assess the household vulnerability to climate change in the study area
ii. determine the effect of climate change on the yield of yam and cassava
iii. examine the trend of climate elements (rainfall, temperature, relative humidity, and sunshine hour) over the years

METHODOLOGY

The study area is Oyo state Nigeria. Time series data on weather variables were collected over a period of 35 years (1976-2010) from Nigeria meteorological society (NIMET). The time series data included the annual rainfall, annual temperature mean, annual relative humidity mean, and annual sunshine hour mean in Oyo state over the time period. Time series data on the annual yield of Yam and cassava in Oyo state over a period of 20 years (1990-2009) were also collected from the Oyo state Agricultural development project (ADP) office. The study was restricted to using a 20 year time series because data on annual yield before 1990 were unavailable. Yam and cassava were chosen because they are the major crops grown in the area. With respect to the primary data used for the study, multistage sampling technique was employed to select 120 respondents across the three agro ecological zones of the study area. This was done by purposively selecting five farm villages in each of the three agro ecological zones in the study area and randomly selecting eight farmers from each of the villages.

Method of analysis

Descriptive, trend, regression, and principal component analysis were all used to analyse the data.
The trend model is of the implicit form $C_i = f(T,e)$ and was subjected to linear, quadratic, cubic, power, semi log, exponential functional forms to determine the best based on the value of the adjusted R^2

C_i= climate variables
T= time
e= error term

The regression model is of the implicit form $Y=f(X_1, X_2, X_3, X_4, X_5, e)$

Y= Annual crop yield (for yam and cassava) (Kg/Ha)
X_1= Total annual rainfall/precipitation (mm)
X_2= Mean Annual temperature (°C)
X_3= Mean Annual relative humidity (%)
X_4= Mean annual Sunshine hour (hours)
X_5= Time period

Vulnerability is calculated as the net effect of adaptive capacity, sensitivity and exposure.

Vulnerability = (adaptive capacity) – (sensitivity + exposure)

It is however necessary to attach weights to the indices and this was accomplished using the principal component analysis (PCA). PCA is frequently used in research that is based on constructing indices for which there are no well defined weights. The use of asset-based indices for measurements of wealth across different social groups is a good example (Filmer and Pritchett, 2001; Langyintuo, 2005; Sumarto et al., 2006; Vyas and Kumaranayake, 2006). As with the asset based indices for wealth comparison, there are no well-defined weights assigned to the vulnerability indices chosen for this research work; therefore a statistical method (PCA) was employed to generate the weights. The indicators used for the analysis and their unit of measurement are shown in Table 1.

RESULTS AND DISCUSSION

Trend of annual rainfall

Statistical record of rainfall in Oyo State of Nigeria between 1976 and 2010 shows an increasing trend with the highest in 1996 and lowest in 1983. The value of the highest volume of rainfall which was recorded in 1980 was 1967.7mm while the lowest was recorded in 1983 with value of 865.4mm and the mean and standard deviation of the rainfall data in the zone from 1976-2010 are 1298.06 and 238.05 mm respectively. The standard deviation shows that there is a large variability in the amount of rainfall from year to year. The coefficient of correlation between rainfall and time has a value of 0.121, implying that there is a weak positive relationship between rainfall and time. This correlation is however not statistically significant.

Trend of annual temperature mean

Data on temperature from 1976-2010 shows an increasing trend with the minimum temperature (26.09°C) recorded in 1976 and maximum temperature (27.79°C) recorded in 1998. The mean value of temperature and its standard deviation over the period are 27.11°C and 0.379°C, implying that there is a slim variability in temperature values from year to year. The trend coefficient is 0.012 and is statistically significant at 1%. The coefficient of correlation of temperature and time is 0.715 and is statistically significant at 1%, implying that temperature

Table 1. Descriptive and trend analysis of data on climate from 1976 – 2010.

	Rainfall (mm)	Temperature (°C)	Relative humidity(%)	Sunshine h
Mean	1298.06	27.11	65.35	4.911
Standard deviation	238.05	0.379	7.402	0.304
Maximum value	1967.7	27.79	72.83	5.81
Minimum value	865.4	26.09	42.33	4.38
Trend coefficient	0.025	0.012^{xxx}	-0.037	0.004^{xxx}
Correlation coefficient	0.121	0.715^{xxx}	0.243	0.613^{xxx}

*** significant at 1%. Source: NIMET, Oshodi and Computer printout of SPSS result.

has significant positive relationship with time. Therefore, temperature changes with time significantly. The warming is real and significant.

Trend of annual relative humidity mean

Relative humidity record of the study area from 1976-2010 shows a decreasing trend with its highest value for the period (72.83%) recorded in 1979 and lowest value (42.33%) recorded in 2001. The mean and standard deviation values of the relative humidity over the period are 65.35 and 7.402%, implying that relative humidity has a considerable variability from year to year. The trend coefficient is 0.037 and it is a decreasing trend. It is however also statistically insignificant. The coefficient of correlation has a value of 0.243, showing a weak negative relationship between relative humidity and time; also it is statistically insignificant.

Trend of annual sunshine hour mean

Sunshine duration data 1976 and 2010 show an increasing trend with a trend coefficient of 6.972 h per year and is statistically significant at 1%. The maximum value of sunshine hours (5.81 h) was recorded in 2001 while the minimum (4.38 h) was recorded in 1983. The mean and standard deviation values over the period are 4.911 and 0.304 h, implying that there is a narrow variability in the value of sunshine hours from year to year. The trend coefficient is 0.004 and is statistically significant at 1%. The coefficient of correlation is 0.613, indicating that there is a strong relationship between time and sunshine hours; also it is statistically significant at 1%.

Food crop trend

Yam and cassava yield show a decreasing trend with a trend coefficient of 237.345 and 424.249 kg per hectare per year respectively. Trend of yam yield is statistically significant at 1% while trend of cassava yield is not statistically significant. The maximum value for yam yield (18892.83kg/ha) and cassava yield (11868.71kg/ha) were recorded in 1992 and 1991 respectively while the minimum values for yam yield (9304.00kg/ha) and cassava yield (7032.62kg/ha) were recorded in 2008 and 1998 respectively.

Effect of climate on cassava yield

In order to determine the effect of climate change on cassava yield, a model was subjected to regression analysis in four functional forms (linear, semi-log, exponential and double-log functional form). The semi-log function was chosen as the lead equation ($Y = -159769.912 + 4016\ln X_1 + 49074.724\ln X_2 - 2210.773\ln X_3 - 13974.645\ln X_4 - 854.105\ln X_5$) for further discussion because it has the highest adjusted R^2 value, and also has the highest F – ratio value (0.894). The result of the semi-log form shows that the coefficient of multiple determination (R^2) is 0.242 (24.2%), implying that the independent variables ($X_1 \ldots X_5$) jointly explained 24.2% of variation in cassava yield. Consequently, the interpretation of the results of the regression indicates the following:

Rainfall (X_1) and Temperature (X_2) were positively related to cassava yield; however, they were not significant statistically.

Relative humidity (X_3), Sunshine hour (X_4) and Time (years) (X_5) have a negative relationship with cassava yield but it is not statistically significant.

The F-ratio which determines the overall significance of the regression is not statistically significant at the 10% level as F-calculated value (0.894) is less than F-tabulated value. We therefore conclude that there is no significant relationship between climate change and cassava yield. Cassava is not affected by climate change as shown in the result. Cassava planting can therefore serve as a viable alternative for farmers living in areas prone to climate change so that they can have something to fall back on in times when other crops fail.

Effect of climate change on yam yield

The model was subjected to regression analysis with four

Table 2. Predicted future values of climatic variables.

	2020	2030	2040	2050
Temperature (°C)	27.51	27.58	27.64	27.68
Rainfall (mm)	1313.13	1319.73	1325.25	1330.00
Humidity (%)	62.06	61.60	61.22	60.90
Sunshine (H)	5.50	5.73	6.00	6.20

Source: Derived by the Researchers.

functional forms (semi-log, double-log, exponential and linear functional forms). The semi-log form was chosen as the lead equation ($Y=141024.414+2522.765LnX_1-11434.344LnX_2-9940.463LnX_3-38020.236LnX_4+1641.322LnX_5$) because it has the highest adjusted R^2 value (0.446), and also has the highest F-calculated (4.058). The coefficient of multiple determination (R^2) has a value of 0.592 (59.2%), implying that the independent variables jointly accounted for 59.2% of the variation in yam yield.

Rainfall (X_1) is positively related with yam yield, implying that as rainfall increases yam yield increases, and vice versa. The result revealed that a unit increase in rainfall, keeping all other variables constant will result to 2522.765 unit increase in Yam yield. This effect is in agreement with the *a priori* expectation. The effect is however statistically insignificant as t-calculated value (0.853) is less than the t-tabulated value at 1, 5, and 10%.

Temperature (X_2) has a negative relationship with yam yield, implying that temperature increase will result in decrease in yam yield and vice versa. The relationship is however not statistically significant as the value of t-calculated (0.181) is less than t-tabulated value at the 1, 5 and 10% levels of probability.

Relative Humidity (X_3) is negatively related to yam yield. This means that a unit increase in sunshine duration (sunshine hour), keeping all other variables constant will result to 9940.463 unit decrease in Yam yield. This effect is statistically significant at 10% level of probability as t-calculated value (2.037) is greater than t-tabulated value (1.677) at 10% level of probability.

Sunshine duration (X_4) has a negative relationship with yam yield. The result revealed that a unit increase in sunshine duration (sunshine hour), keeping all other variables constant will result to 38020.236 unit decrease in Yam yield. This relationship is statistically significant at 5% level of probability as t-calculated value (2.775) is greater than t-tabulated value at 5% level of probability.

Time (years) (X_5) has a negative relationship with yam yield that is the yield reduces with time but it is statistically insignificant as the t-calculated value (0.800) is less than t-tabulated value (1.699) at 10% level of probability.

The F-ratio which determines the overall significance of a regression is statistically significant at 5% level of probability as F-calculated value (4.058) is greater than F-tabulated value. We therefore conclude that climate change significantly affected yam yield.

Predicted future values of climatic variables

The projections for values of climate variables derived from the trend models for rainfall, temperature, relative humidity, and sunshine respectively is presented in Table 2.

The table reveals that by 2020 the average temperature of the state is projected to have a value of 27.51°C and by 2030, 2040, 2050 temperature values are expected to be increasing from 27.58°C to 27.64°C and to 27.68°C respectively. The table also reveals that rainfall in the zone is predicted to have the following values from 1313.13, 1319.73, 1325.25, and 1330.00 mm in 2020, 2030, 2040, and 2050 respectively. This implies that values of rainfall are projected to be increasing signifying that floods could be experienced in the zone in the future if the trend continues. Relative humidity will have values decreasing from 62.06% in 2020, 61.60% in 2030, 61.22% in 2040, and 60.90% in 2050. For sunshine hours, the values are expected to be increasing from 5.50 h in 2020, 5.73 h in 2030, 6.00 h in 2040, and 6.20 h in 2050.

The optimal range of each of the climate variables for the growth of yam and cassava is presented in Table 3. The table reveals that the optimal range of rainfall for the growth of yam and cassava are 1700 – 3000 mm and 1700 – 2500 mm respectively. The table also shows that the optimal range of temperature for the growth of the crops is 25 – 30°C for yam and cassava. The optimal range of relative humidity for the growth of the crops is 75-80% for yam and cassava, while the optimal range of sunlight hours for the growth of both crops is 4-5 h.

Comparing Tables 2 and 3, it can be inferred that the projected values of the climatic variables in the future do not fall within the optimal conditions for the growth of cassava and yam except for the temperature. This implies that by 2050 the projected climatic conditions then will not be favourable for optimal growth of yam and cassava. This is consistent with the findings of Molua and Lambi (2007) in Cameroon, Deressa et al. (2008a and 2008b) and Yesuf et al. (2008) in Ethiopia, Adejuwon

Table 3. Optimal climatic conditions for the growth of yam and cassava.

	Rainfall (mm)	Temperature (°C)	Humidity (%)	Sunshine (H)
Yam	1700 – 3000	25 – 30	75 – 80	4 – 5
Cassava	1700 – 2500	25 – 30	75 – 80	4 – 5

Table 4. Factor scores of the first principal component.

Vulnerability	Factor Scores
Ownership of livestock	-0.053
Ownership of radio	0.079
Quality of house	0.075
Non agricultural income	-0.070
Insecticide and pesticide supply	0.080
Fertilizer supply	0.070
Improved seeds supply	0.078
All weather roads	0.059
Health services	0.078
Telephone services	0.047
Primary and secondary school	0.080
Veterinary services	0.075
Food market	0.080
Microfinance	0.069
Literacy rate	-0.059
Frequency of extreme climates	-0.064
Change in Temperature	0.009
Change in precipitation	0.009
Eigen value	12.524
Proportion of variance	69.576
Cummulative proportion	69.576

Source: Computer printout of SPSS result.

(2004) in Nigeria.

Vulnerability assessment

For the analysis, principal component analysis (PCA) was run on the indicators listed in Table 4 using data analysis and statistical software (SPSS).

The PCA of the data set on vulnerability indicators revealed two components with eigen values greater than 1. These two components explain 100 percent of the total variation in the data set. The first principal component explained most of the variation (69.576 percent) and the second principal component explained 30.424 percent.

Based on earlier argument for the use of PCA, in constructing indices, the first principal, which explained the majority of the variation in the data set was chosen. It was observed from the factor scores that the first PCA (the vulnerability index, in this case) was positively associated with the majority of the indicators identified under adaptive capacity and negatively associated with the indicator for sensitivity. It is however not negatively associated with the indicators categorised under exposure because the three districts have similar temperature and rainfall amount. Thus for the construction of the vulnerability indices, the indicators of adaptive capacity which are positively associated with the first PCA and the indicator of sensitivity which is negatively related were selected. This reduced the indices remaining to just thirteen. Higher values of vulnerability index show less vulnerability and vice versa.

The factor scores from the principal component in Table 4 were then employed to construct indices for each agro ecological zone.

Figure 1 shows the vulnerability index for each agro ecological zones.

Figure 1 shows that the net effect of adaptation, exposure and sensitivity is positive for the rainforest and Savannah zones while it is negative for the derived savannah zone. This indicates that household

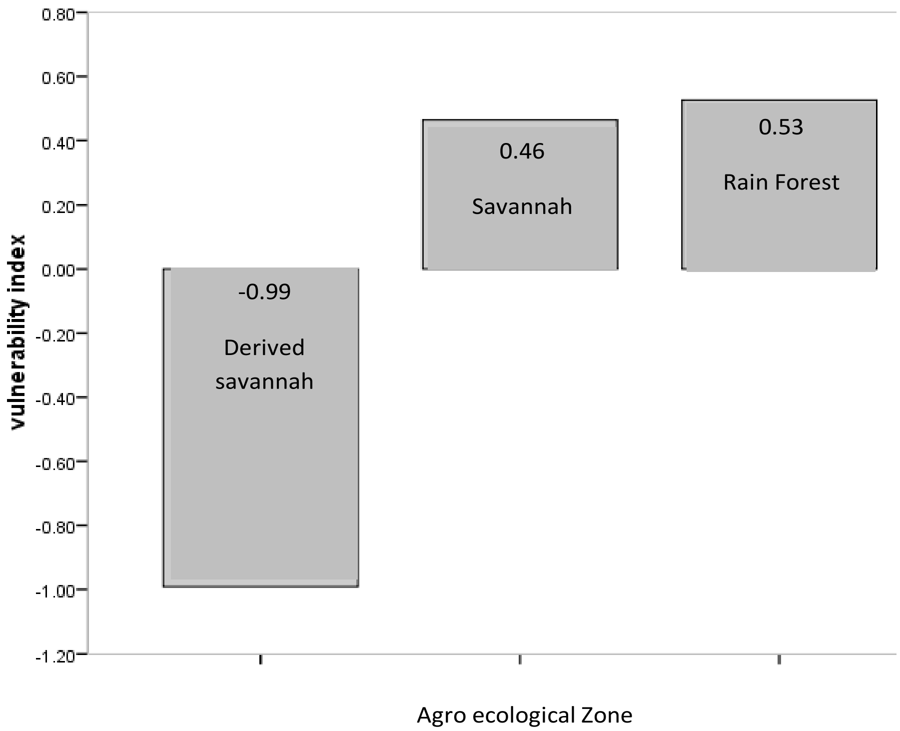

Figure 1. Vulnerability indices of the three agro ecological zones in Oyo State.

vulnerability was found to be highest in the derived savannah (VI=-0.99) followed by the savannah (VI=0.46) and lowest in the rain forest (VI=0.53).

Conclusion

From the study, it can be concluded that the much publicized global warming is real. It is also evident that there is high negative correlation between humidity and sunshine hour.

The increasing trend of rainfall also puts the area at the risk of flooding in the future if proper environmental norms are not adhered to.

It can also be concluded that yam yield is much more affected by climate change in contrast with cassava yield. Vulnerability was calculated as the net effect of sensitivity and exposure on adaptive capacity. The derived savannah zone recorded the highest vulnerability with a relatively low proportion of the population having access to quality home (2.5%), insecticide (30%), fertilizer (30%), improved seedlings (30%), road (15%), health services (15%), primary and secondary schools (15%), veterinary services (0.03%), food market (42.5%), and microfinance institutions (0.03%).

RECOMMENDATION

The government of Oyo State should enforce environmental laws that will forbid citizens from dumping refuse in drainages, that is, proper waste disposal management so as to forestall the incidence of flooding as the amount of rainfall is projected to rise in the future.

Farmers are to ensure that their farmlands are well drained to avert the disaster of water logging and flooding.

Farmers should be encouraged to plant cassava as an insurance against climate hazard as cassava was found to be least affected by climate change.

Researchers in the field of plant breeding should work towards developing varieties that would be able to adapt or cope with the effects of the expected change in climatic variables.

The scale of analysis for the study on vulnerability is at the agro ecological zone level which is highly aggregated. Each zone included in this study covers a very wide area of land characterized by different biophysical and socio economic attributes. These variations within each agro ecological zone should be considered in order to target areas that are very vulnerable and to recommend appropriate interventions. Future research should focus on local levels, especially Local government or village levels, where the actual dynamics of vulnerability to climate change take place.

In general, house hold vulnerability to climate change in Oyo state is highly related to poverty (loss of coping or adaptive capacity) in the zone that was indicated as vulnerable. Integrated rural development schemes aimed at increasing access to basic social amenities should be established by the government with the cooperation of the residents as this will improve adaptive capacity and thereby reduce vulnerability of farmers to climate change in the study area.

Conflict of Interests

The authors have not declared any conflict of interests.

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