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Prediction of Climate Change Effects on Plantain Yield in Ondo State, Nigeria

Olotu Yahaya[1] ✉
Atanda E.O.[2]
Rodiya A.A.[3]
Okafor M.C.[4]

[1,2,4]*Department of Agricultural Engineering & Bio-Environmental, Auchi Polytechnic, Auchi, Nigeria.*
[1]*Email: realyahaya@yahoo.com Tel: +2348073135503*
[2]*Email: olugbenga_atanda@yahoo.com Tel: +2348038588145*
[4]*Email: oka4mc@gmail.com Tel: +2348036971245*
[3]*Department of Agricultural Engineering, Federal Polytechnic, Ado, Ado-Ekiti, Nigeria.*
[3]*Email: afolabirodiya@yahoo.com Tel: +2347068347252*

(✉ Corresponding Author)

Abstract

This study investigated the effects of climate change on plantain (Musa spp) for three Agro-Ecological Zones (AEZs) in Ondo State. Climate projections of six selected general circulation models (GCMs) under climate scenarios-Representative Concentration Pathways (RCP 4.5) were applied for different periods; baseline (1975–2005); future periods 2035–2065 [2050s] and 2070–2100 [2080]). The results of regression analysis showed a positive relationship between precipitation and plantain yield, while maximum (T_{max}) and minimum temperature (T_{min}) indicated no significant relationship with plantain yield at P< 0.01 in all the AEZs. The output of trend analysis indicated an increase in T_{max} of 0.046°C/year for Ondo North Agro-Ecological Zone (ONAEZ), while Ondo South Agro-Ecological Zone (OSAEZ) has the lowest increment of 0.003°C/year. T_{min} for Ondo Central Agro-Ecological Zone (OCAEZ) increased by 0.007°C/year and decreased with 0.004°C/year and 0.030°C/year for ONAEZ and OSAEZ. However, analysis of precipitation events in the study areas from 1975-2005 showed that OCAEZ received the highest increase of 7.47 mm/year and decreased by 13.48 mm/year and 2.84 mm/year for ONAEZ and OSAEZ respectively. Largest plantain yield reduction compared to the control-period for CCCMA model was -30.3% and -38.1% for the 2050s and 2080s whereas ICHEC model predicted an average lowest reduction of -7.5% and -12.5% for the short time and long periods in ONAEZ. In OSAEZ, plantain yield decreases varied from -6.3% to -8.4% for CNRM model, -6.1% to -6.7% (MPI) and -36.1% to -37.7% for CCCMA. In conclusion, overall climate change simulations in OCAEZ showed that projected climate may have relatively small negative effects on plantain yield compared to ONAEZ and OSAEZ respectively.

Keywords: General circulation models, RCP 4.5, Climate change, Plantain, Precipitation, Maximum temperature, Minimum temperature, AEZ, Ondo state

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1. Introduction

Climate change due to increased 'greenhouse gases' atmospheric concentrations is expected to have an important impact on the different economy (e.g. agriculture, forestry, energy consumptions, tourism, etc.) [1]. Changes in the climate system and land cover have important consequences on regional and global water resources management and conservation [2]. In particular, for agriculture, such a change in climate may have significant impacts on crop growth and yield, since these are largely determined by the weather conditions during the growing season [1]. According to Robinson [3] plantain is the fourth most important starchy staple after cereals, cassava and yam and based on the food value, the second most expensive starchy staple in the urban market after yam. Extreme climate events, such as high-temperature stress, drought, and flooding, could result in a severe reduction in plantain production.

In Nigeria, banana and plantain farming sector are small in relative to its contribution to the national gross domestic product, and yet remains significant with respect to food production, rural employment and livelihoods particularly in the South-Western region of the country. Plantain production in these regions is during the wet season and the dry mostly under rainfed cultivation. The optimal temperature for growing plantain is 28°C, from 28°C to 20°C, growth will gradually slow down and will become negligible around 16-18°C [4]. Plantain needs a lot of water. It should get around 200 mm per month or effective rainfall between 1650-1700 mm throughout its life cycle [4]. However, considering the increasing pressure that climate change may likely place on plantain cultivation; it is not yet clear how future precipitation and air temperature patterns will change and how such changes will affect plantain water requirements, irrigation water demands, and yields. However, current studies on this subject matter are still very few in Nigeria, but more climate change studies had been conducted on cereal and tuber crops.

Global circulation models (GCMs) are the appropriate tools currently employed in providing climate projections of both present-day and distant future climate variables [5]. GCMs outputs cannot be applied directly because their current resolution is too large to be used on local scales. Based on this, the outputs of global climate models often subjected to downscaling processes in order to be compatible with the local scales. There are two types of downscaling approaches; dynamic and statistical downscaling methods. Dynamic techniques, often viewed as a miniature global climate model they have not gained popularity because they tend to use complex processes and approaches in order to capture local-scale variations [6]. Statistical methods are mostly used in climate studies because they are cheap to apply and provide site-specific climate information [7]. However, this climate change study is based on the latest greenhouse gas emission scenarios called *Representative Concentration Pathways* (RCPs), consisting of RCP 2.6, 4.5, 6.0 and 8.5; measured in watt per metre square ((Wm^{-2}) [8]. Furthermore, most of the previous climate change studies in Nigeria were investigated based on the earlier version of climate change scenarios (A1, A2, B1, and B2) from Fourth Report on Special Report on Emission Scenario in the Intergovernmental Panel on Climate Change (IPCC). Therefore, this current study will be one of the few climate change kinds of research using the newly released RCP emission scenarios in Nigeria.

In this study, the effects of climate change on plantain yield using an ensemble set of six GCMs under RCP 4.5 for the future periods 2035-2065(the 2050s) and 2070-2100 (2080s) relative to baseline period 1975-2005 is investigated for the agro-ecological zones (AEZs) in Ondo State.

2. Study Area

2.1. Location of study area

Ondo state is one of the states in the South-western region of Nigeria. It has a total population of 3,440,024 of which 65% resides in fertile areas. It has a density of 236 persons per square meter and land square area of 15,500Km² [9]. The state has eighteen local government areas which are divided into three geographic zones and population concentration as follows: Ondo-North with a population of 1,064,900; Ondo-South has a population of 1,054,675 and population of 1,320, 449 Ondo Central [9]. Generally, agriculture is the mainstay of the economy, and the chief products are cotton and tobacco from the north, cacao from the central part, and rubber and timber (teak and hardwoods) from the south and east; palm oil, kernels, *banana, and plantain* are cultivated throughout the state. Other crops include rice, yams, corn (maize), coffee, cassava (manioc), vegetables, and fruits. The study area is bounded by the states of Kwara and Kogi on the north, Edo on the east, Delta on the southeast, and Osun and Ogun on the west and by the Bight of Benin of the Atlantic Ocean on the south. Ondo state includes mangrove-swamp forest near the Bight of Benin, tropical rain forest in the centre part, and wooded savannah on the gentle slopes of the Yoruba Hills in the north. Fig.1 shows the map of Ondo State indicating the three agro-ecological areas under study.

2.2. Baseline Climate and Plantain Yield

Historical monthly climate data (maximum temperature, minimum temperature, precipitation,) for 1975-2005 were taken from the CRU TS2.1 database through the Department of Agro-climatological, Ministry of Agriculture & Natural Resources, Ondo-State, Nigeria with a spatial resolution of 30 arc-minutes. Baseline plantains (1975–2005) were collected from Ondo State Ministry of Agriculture and Natural Resources. Plantain yield was collected as the fiscal year basis, such as 1975–1976, 1976–1977, *etc.* Then, these fiscal year data were converted to yearly data, for example, 1975–1976 was considered as 1976. The plantain yield data are consistent with the statistical data from the Food and Agriculture Organization of Nigeria [11].

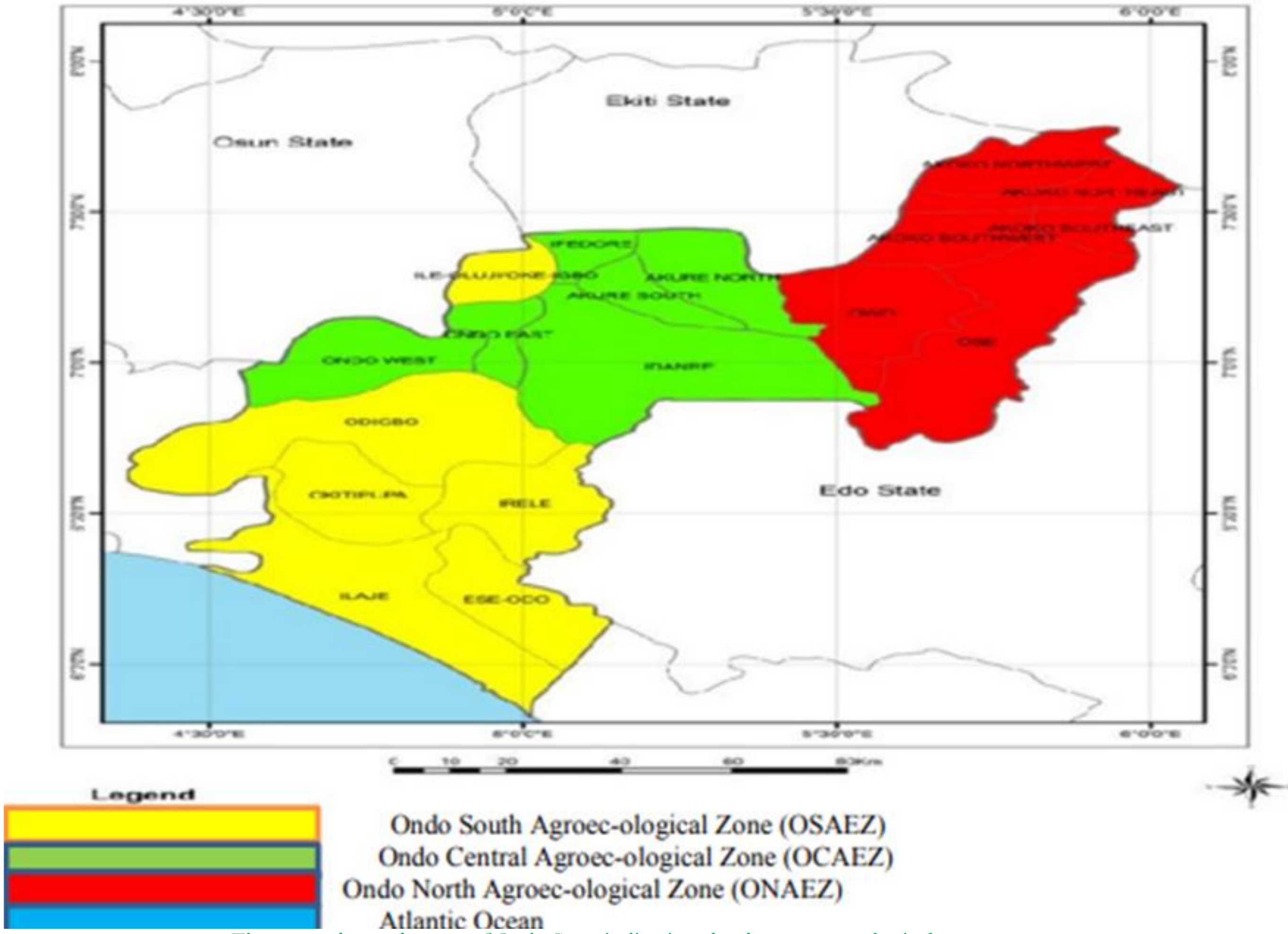

Figure-1. shows the map of Ondo State indicating the three agro-ecological areas.

Source: OSMHUD [10].

2.3. Statistical Downscaling Model

Statistical downscaling model (SDSM) was applied to simulate 31-year historical dataset (1975-2005) from the study regions using different general circulation models (GCMs) and project future climate (2035-2065 and 2070-2100) under representative pathway concentration (RCP 4.5). The climate models included Canadian Centre for Climate Modeling & Analysis (CCCMA), Max Planck Institute for Meteorology (MPI), Met Office Hadley Centre (MOHC), and Model for Interdisciplinary Research on Climate (MIROC), Irish Centre for High-End Computing (ICHEC) and National Centre for Meteorological Research (CNRM). In this study, these models were used to produce climate variables as one stochastic set of data for the baseline period and for future periods under a climate change scenario (RCP 4.5). The outputs of simulated climate variables were used to develop climate-plantain model useful to predict the climate change effects of future climate on plantain reduction yield in the three agro-ecological zones. Table 1 and Table 2 show the study regions and selected GCMs respectively.

Table-1. Categorization of Agro-Ecological Zone in Ondo-State.

S/N	OSAEZ	OCAEZ	ONAEZ
1	Odigbo	Akure South	Akoko N.W
2	Okitipupa	Akure North	Akoko N.E
3	Irele	Ileoluji/Okeigbo	Akoko S.W
4	Ilaje	Ifedore	Akoko S.E
5	Ese-Odo	Ondo-East	Owo
6	Idanre	Ondo-West	Ose

Source: ODSMA [9].

Table-2. GCMs selected for the research study.

Models	Emission scenarios	Spatial resolution
CCCMA	RCP 4.5	48×96 cells, 3.75^0 ×3.75^0
MPI	RCP 4.5	96×192 cells, 1.9^0 ×1.9^0
MOHC	RCP 4.5	88×176 cells, 2.0^0 × 2.0^0
MIROC	RCP 4.5	67× 134 cells, 1.12^0 × 1.12^0
CNRM	RCP 4.5	64×128 cells, 2.8^0 ×2.8^0
ICHEC	RCP 4.5	60 × 120 cells, 2.9^0 × 2.9^0

Source: Soden and Held [5].

2.4. Data Analysis

2.4.1. Mann Kendall and Sen's Slope Analysis

Mann Kendall (M-K) test is a non-parametric statistical test widely used for the analysis of the trend in climatologic and other fields of science and engineering. One advantage of this test is that the data need not conform to any particular distribution [12]. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series [13]. Using M-K test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered), the observations of x_i are randomly ordered in time, against the alternative hypothesis, H_1 which indicates increasing or decreasing trends. The estimation technique procedure for M-K test applies the time series of n data points and X_i and X_j as two subsets of data where i = 1,2,3,…, n-1 and j = i+1, i+2, i+3, …, n as indicated in Equation 1. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1 as expressed in Equation 2. The net result of all such increments and decrements yields the final value of *S* [14].

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{Sgn}(x_j - x_i) \quad (1)$$

$$Sgn(x_j - x_i) = \begin{cases} +1 \ if \ x_j - x_i > 0 \\ 0 \ if \ x_j - x_i = 0 \\ -1 \ if \ x_j - x_i < 0 \end{cases} \quad (2)$$

Where X_j and X_i are the annual values in years j and i, j > i, respectively [15]. To derive an estimate of the slope S, the slopes of all data pairs are calculated as follows:

2.5. Climate-Crop Yield Relationship

The impact on climate change on plantain (Musa spp) yield was investigated and evaluated using developed newly empirical-statistical models of current and future time periods. This model does not attempt to capture details of plant physiology or crop management; they do capture the net effect of the entire range of processes by which climate affects yields, including the effects of poorly modeled processes [16]. Correlation coefficient and multivariate regression analyses were performed to determine the climate-crop yield relationship using the Statistical Package for Social Sciences *(SPSS)*. Pearson's correlation coefficient was used to measure the strength of the association between crop yield and climatic variability [16]. This produced a linear association. The range of correlation coefficients is -1 to +1. The complete dependency between two variables is expressed by either -1 or +1, and 0 represents the complete independence of the variables as shown in Equation 3. A correlation coefficient is mathematically performed as follows:

$$r = \frac{\Sigma(x-x)(y-y)}{\sqrt{\Sigma(x-x)^2(y-y^2\ )}} \quad (3)$$

The x represents the independent (climate) variable and y (plantain yield) represents the dependent variable.

Multivariate regression analysis of climate and crop yield was performed to estimate the percentage of the response of variations (plantain yield) from the predictor variables (minimum and maximum temperature and precipitation). Baseline plantain yield was estimated using a regression model in Equation 4, while Equations 5,6,7 8 were used to estimate projected plantain yields for periods 2035-2065 and 2070-2100 under CCCMA and MOHC models respectively. The multiple linear regressions with first differences in yield (ΔYield) as the response variable, and first differences of minimum temperature (Δt_{min}), maximum temperature (Δt_{max}) and precipitation (Δppt) as predictor variables.

$$Y_{baseline} = \phi + (\alpha * PPT) + (\beta * Tmin) + (\gamma * Tmax) \quad (4)$$

$$\Delta Y_{CCCMA-2035-2065} = \phi + (\alpha * \Delta PPT_{CCCMA}) + (\beta * \Delta Tmin_{CCCMA}) + (\gamma * \Delta Tmax_{CCCMA}) \quad (5)$$

$$\Delta Y_{CCCMA-2070-2100} = \phi + (\alpha * \Delta PPT_{CCCMA}) + (\beta * \Delta Tmin_{CCCMA}) + (\gamma * \Delta Tmax_{CCCMA}) \quad (6)$$

$$\Delta Y_{MOHC-2070-2100} = \phi + (\alpha * \Delta PPT_{MOHC}) + (\beta * \Delta Tmin_{MOHC}) + (\gamma * \Delta Tmax_{MOHC}) \quad (7)$$

$$\Delta Y_{MOHC-2035-2065} = \phi + (\alpha * \Delta PPT_{MOHC}) + (\beta * \Delta Tmin_{MOHC}) + (\gamma * \Delta Tmax_{MOHC}) \quad (8)$$

3. Results and Discussion

3.1. Current Climate and Plantain Yield

3.1.1. Temperature and Precipitation Trends

Current minimum and maximum temperature from 1975 to 2005 for the three agro-ecological zones (ONAEZ, OSAEZ, and OCAEZ) in Ondo-State were analyzed using non-parametric Mann-Kendall and Sen's slope estimates. The results of the trend analysis are showed in Table 3. The rate of increase in maximum temperature was highest in ONAEZ with 0.046°C/year while Ondo South Agro-Ecological Zone (OSAEZ) has the lowest increment of 0.003°C/year. Similar results were obtained by Soden and Held [5].This region is characterized as swamp rainforest zone with high rainfall duration, intensity, and depth. The outputs of Sen's slope estimates for minimum temperature (T_{min}) followed a different pattern. The T_{min} for OCAEZ increased by 0.007°C/year where the remaining two regions (ONAEZ and OSAEZ) decreased by 0.004°C/year and 0.030°C/year as indicated in Table 3. The maximum temperature increased across the studied agro-ecological zones indicating warming throughout the period of consideration Figures 2-4. In addition, an increasing trend in maximum air temperature was found in Ondo State [17].

Table-3. Statistical calibration for minimum and maximum temperature for three Agro-Ecological Zones.

Study regions	T_{max}	Det.Corr	Corr.	Sig. Val	T_{min}	Det. Corr	Corr.	Sig. Val
AEZ	Sen's slope (mm)	R^2	r	P-Value	Sen's slope (mm)	R^2	r	P-Value
ONAEZ	0.046	0.151	0.388	0.031*	-0.004	0.020	-0.390	0.833^b
OSAEZ	0.003	0.020	0.045	0.812^b	-0.030	0.044	-0.210	0.256^b
OCAEZ	0.004	0.001	0.025	0.890^b	0.007	0.006	0.079	0.674^b

Source: Simulation output, 2018.

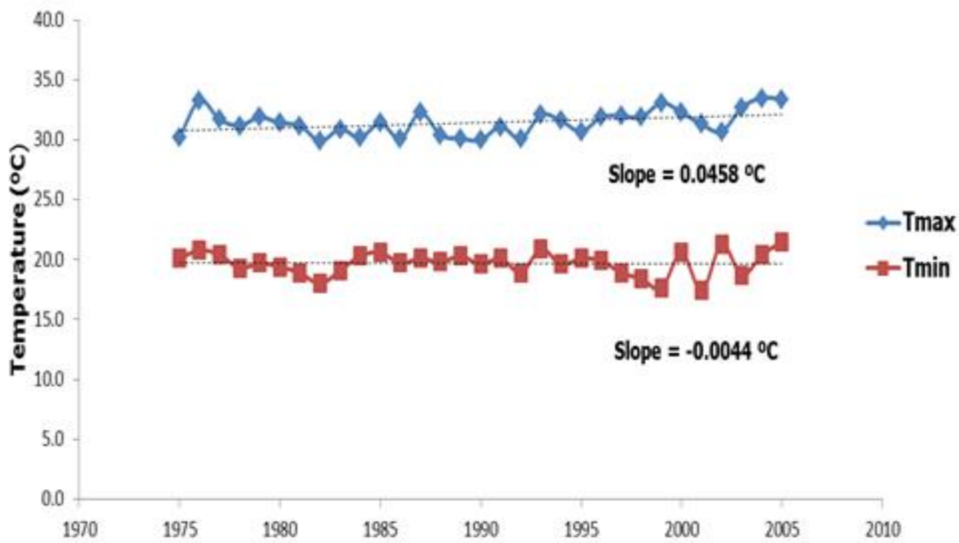

Figure-2. Annual Minimum and maximum temperature trends at ONAEZ from 1975-2005.
Source: Simulation output, 2018.

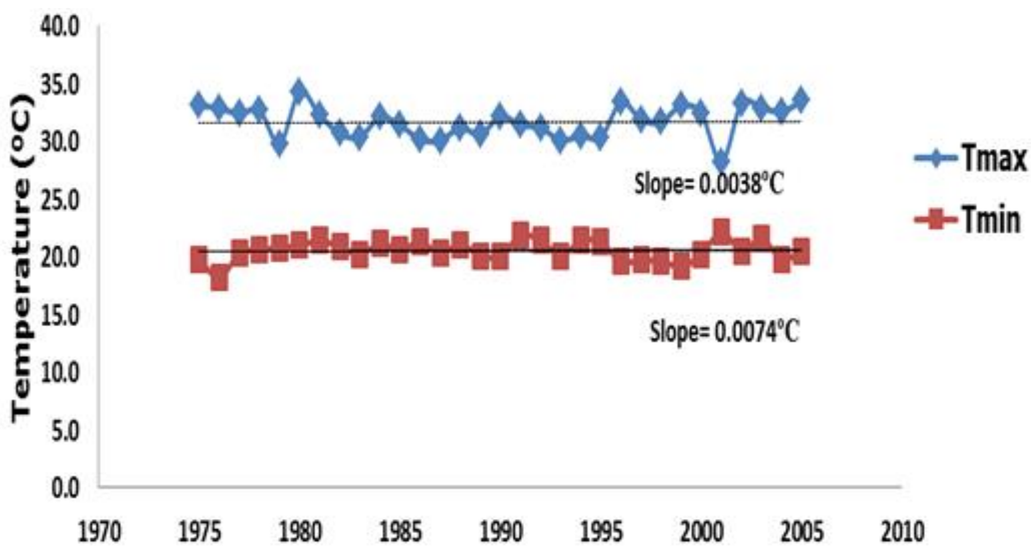

Figure-3. Annual Minimum and maximum temperature trends at OCAEZ from 1975-2005.
Source: Simulation output, 2018.

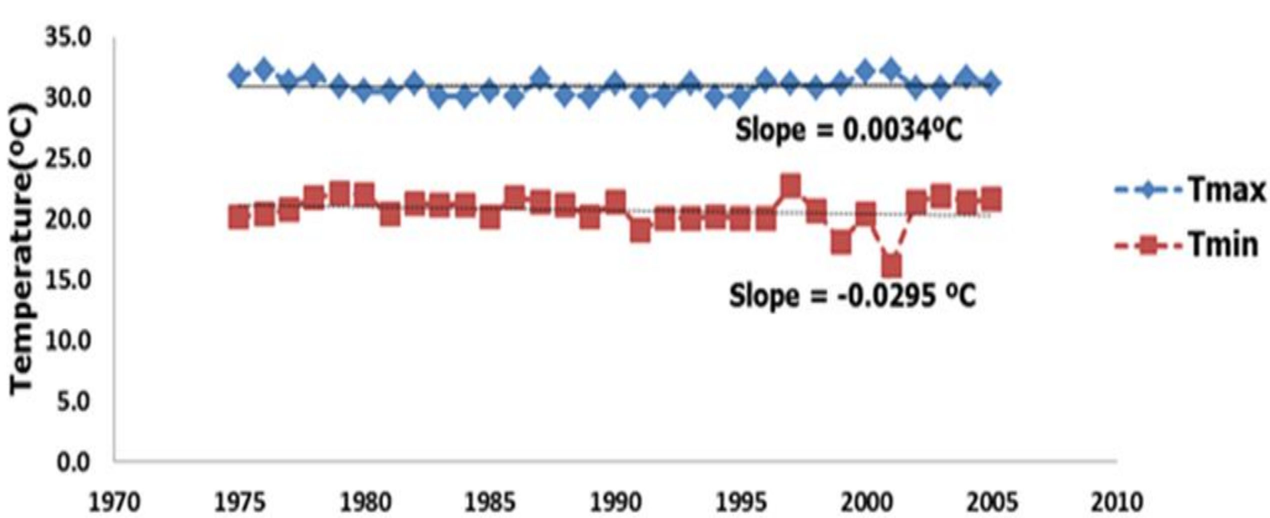

Figure-4. Annual Minimum and maximum temperature trends at OSAEZ from 1975-2005.
Source: Simulation output, 2018.

The analysis of precipitation events in the study areas from 1975-2005 showed that OCAEZ received the highest increase of 7.47 mm/year Table 4, Figure 5. However, total annual precipitation at ONAEZ and OSAEZ decreased by 13.48 mm/year and 2.84 mm/year.

Table-4. Statistical metrics for annual precipitation for the Agro-Ecological Zones.

Study regions	Sen's slope (mm)	R^2	R	P-Value	Alpha-Value	Sig.
ONAEZ	-13.475	0.138	-0.409	0.022*	0.050	Yes
OSAEZ	-2.837	0.067	0.314	0.086^b	0.050	No
OCAEZ	7.470	0.016	-0.126	0.500^b	0.050	No

Source: Simulation output, 2018.

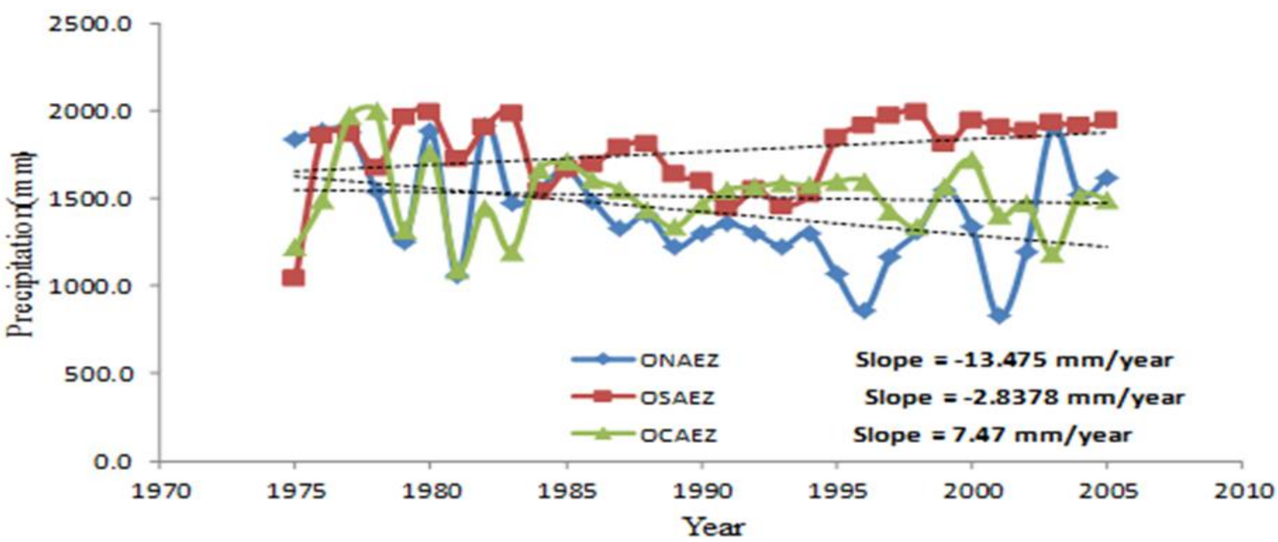

Figure-5. Annual precipitation trends at ONAEZ-OSAEZ-OCAEZ from 1975-2005.

Source: Simulation output, 2018.

3.2. Plantain (Musa spp) Yield Trend

Plantain yield trend showed fluctuation over the period of consideration in all the studied agro-ecological zones. The yield increase of 0.039 ton/ha yearly is highly significant (P< 0.05) in OSAEZ Again, the yield reduced by -0.022 ton/ha in ONAEZ and -0.033 ton/ha in OCAEZ Table 5. These reductions were not significant (P > 0.05) within the baseline period (1975-2005). Figure 6 depicts the plantain trend analysis. The trend of plantain yield in OSAEZ is similar to the production pattern in Nigeria for more than two decades with the country harvested 2.103 million tons from 389,000 ha [18]. However, the country experienced a great depression in plantain production between 1987–1988 and 1990 [18]. This reduction pattern is very similar to plantain yield trends in ONAEZ and OCAEZ respectively.

Table-5. Statistical metrics for plantain yield trends for the Agro-Ecological Zones.

Study regions	Sen's slope (ton/ha)	R^2	R	P-Value	Alpha-Value	Sig.
ONAEZ	-0.022	0.044	-0.211	0.256	0.050	No
OSAEZ	0.039	0.136	0.368	0.042*	0.050	Yes
OCAEZ	-0.033	0.108	-0.329	0.071	0.050	No

Source: Simulation output, 2018.

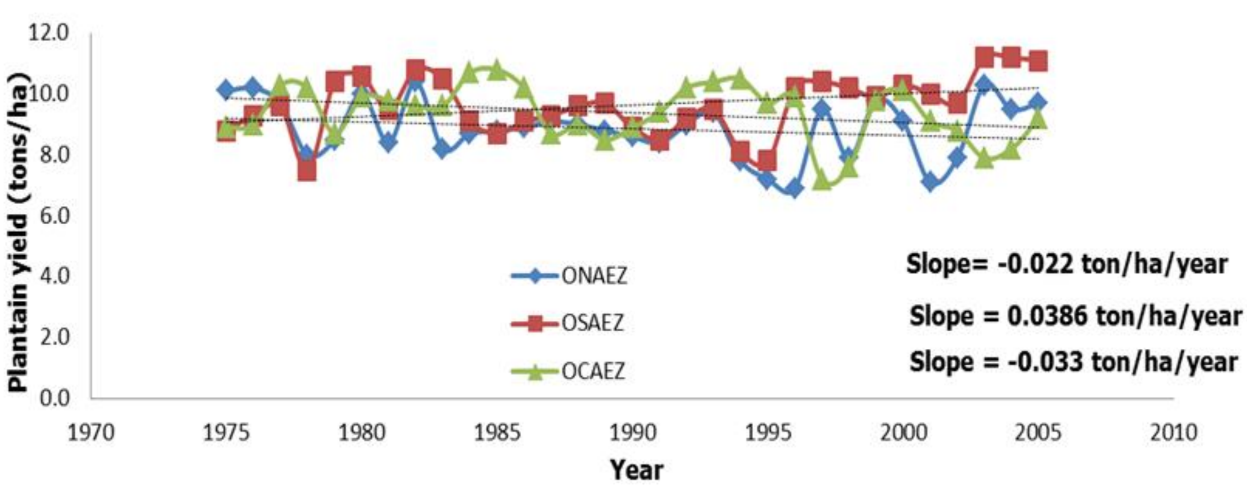

Figure-6. Plantain yield trends in three Agro-Ecological Zones from 1975-2005.

Source: Simulation output, 2018.

3.3. Plantain Yield-Climate Simulation

Relationship between the control-base plantain yield and climate variables in all the three agro-ecological zones were performed using correlation and regression models. The results of sensitivity analysis in Table 6 reveal that positive and strong correlation values (r = 0.80; 0.63 and 0.68) for ONAEZ, OSAEZ, and OCAEZ respectively. Shahid [14] reported the same results in Bangledesh. Conversely, an estimated relationship between precipitation and plantain yield is significant (P < 0.01) in all the study regions. These results indicate that an increase in annual precipitation could lead to an increase in plantain yield per hectare in all the agro-ecological zones (ONAEZ, OCAEZ, and OSAEZ). Coefficient of determination between plantain yields and minimum temperature for three agro-ecological is very weak with R^2 = 0.005(ONAEZ), R^2 = 0.042 (OSAEZ) and R^2 = 0.053 (OCAEZ) with insignificant association at 95% confidence interval (P < 0.05). While testing the effects of annual maximum temperatures, no significant relationship was observed in the yield of plantain in all the studied agro-ecological zones. However, the coefficient of maximum temperature was very weak with R^2= 0.07, R^2 =0.04 and 0.01 for ONAEZ, OSAEZ and OCAEZ Table 6. Therefore, plantain yield decreases with increasing maximum and minimum temperatures. The findings are in agreement with the studies [2, 3].

Table-6. Statistical for Plantain yield-Temperature-Precipitation for the AEZs(1975-2005).

Study regions	Precipitation				T_{max}				T_{min}			
AEZ	R^2	r	Std.dev	P-Value	R^2	r	Std.dev	P-Value	R^2	r	Std.dev	P-Value
ONAEZ	0.65	0.80	299.6	0.00001*	0.005	0.07	1.00	0.699^b	0.07	0.26	1.07	0.165^b
OSAEZ	0.40	0.63	216.4	0.00001*	0.042	0.21	1.27	0.268^b	0.04	0.20	0.70	0.277^b
OCAEZ	0.46	0.68	252.8	0.00001*	0.053	0.23	1.19	0.149^b	0.01	-0.11	1.23	0.510^b

Source: Simulation output, 2018.

3.4. Estimation of Climate Change Impacts on Plantain Yield

Direct impacts of climate change on plantain yield for the three agro-ecological districts were estimated using a developed multiple linear regression model under control period (1975-2005) and the future periods (the 2050s and 2080s). Average baseline plantain yields considered were 8.5 tons/ha, 8.6 tons/ha and 8.7 tons/ha for ONAEZ, OSAEZ and OCAEZ respectively. The results of multivariate regression analysis reveal the estimated potential impacts of climate change on plantain yield across the AEZs as shown in Tables 7-9. Simulation outputs indicate that all the GCMs predicted future reductions in plantain yield in all the three agro-ecological zones. CCCMA model has the highest decrease in plantain yields. Yield reductions of 2,567.0 kg/ha and 3,085.5 kg/ha were predicted for the time periods of the 2050s and 2080s in ONAEZ Table 8 whereas plantain yield decrease of 3,068.5 kg/ha and 3,204.5 Kg were projected in OSAEZ Table 9 using CCCMA model. Smit and Skinner [6] showed similar observation with CCCMA simulations

However, for all the future time periods (the 2050s and 2080s) plantain yield reduction is marginally predicted in Ondo Central Agro-Ecological Zone Table 7. Largest plantain yield reduction percentage compared to the control-period across 1975-2005-2065 for CCCMA model was -30.3% and -38.1% for the 2050s and 2080s respectively in ONAEZ Table 8. However, ICHEC model predicted an average lowest reduction of -7.5% and -12.5% for a short time and long periods.

Table-7. Projected climate change effects on plantain yield (%) relative to baseline period for OCAEZ.

GCMs	Plantain yield reduction (%) Period (2050s)	Period (2080s)	Plantain yield reduction (Kg/ha) Period (2050s)	Period (2080s)
Models	2035-2065	2070-2100	2035-2065	2070-2100
CNRM	0.3	0.7	25.5	59.5
MPI	0.6	0.8	51.9	65.5
MIROC	0.7	1.0	62.9	82.5
MOHC	0.7	1.0	57.0	80.8
CCCMA	1.0	1.2	86.7	102.0
ICHEC	0.1	0.2	2.6	17.0

Source: Simulation output, 2018.

Table-8. Projected climate change effects on plantain yield (%) relative to baseline period for ONAEZ.

GCMs	Plantain yield reduction (%) Period (2050s)	Period (2080s)	Plantain yield reduction (Kg/ha) Period (2050s)	Period (2080s)
Models	2035-2065	2070-2100	2035-2065	2070-2100
CNRM	14.5	22.4	1232.5	1904.0
MPI	19.4	24.2	1649.0	2057.0
MIROC	3.6	33.9	306.0	2881.5
MOHC	35.1	33.9	2983.5	2881.5
CCCMA	30.2	36.3	2567.0	3085.5
ICHEC	7.3	12.1	620.5	1028.5

Source: Simulation output, 2018.

Table-9. Projected climate change effects on plantain yield (%) relative to baseline period for OSAEZ.

GCMs	Plantain yield reduction (%) Period (2050s)	Period (2080s)	Plantain yield reduction (Kg/ha) Period (2050s)	Period (2080s)
Models	2035-2065	2070-2100	2035-2065	2070-2100
CNRM	6.3	8.4	535.5	714.0
MPI	6.1	6.7	518.5	569.5
MIROC	+1.8	17.1	153.0	1453.5
MOHC	1.5	-1.9	127.5	161.5
CCCMA	36.1	37.7	3068.5	3204.5
ICHEC	1.8	2.4	153.0	204.0

Source: Simulation output, 2018.

In OSAEZ region, a substantial reduction in plantain yield is estimated by 2050s and 2080s compared with baseline yield. Yield decrease varied from -6.3% to -8.4% for CNRM model, -6.1% to -6.7% (MPI), -1.5% to -1.9% (MOHC), -36.1% to -37.7% (CCCMA), -1.8% to -2.4% (ICHEC). However, an increase of plantain yield of 1.8% is estimated by the MIROC model in 2050s and reduction of -17.1% in 2080s as indicated in Figure 7b. It could be deduced that plantain will largely decrease in OSAEZ and ONAEZ Figure 7a and 7b. A possible explanation for this could be related to the projected increase in minimum and maximum temperature in the regions. Higher temperature influences increase in evapotranspiration (ET_o) and increase plantain water requirement. In Ondo Central Agro-Ecological Zone (OCAEZ), predicted outputs from selected GCMs indicate decrease in plantain (*Musa.spp*) yield under two future scenarios Figure 7c. However, MIROC and MOHC simulations indicate equal reduction values of 0.6% and 0.8%; ICHEC predicted least decrease of 0.02% and 0.2% for the periods the 2050s and 2080s respectively Figure 7c. Overall simulations of impacts of climate change in OCAEZ showed that projected climate will have relatively small negative effects on plantain yield compared to the results predicted in ONAEZ and OSAEZ respectively.

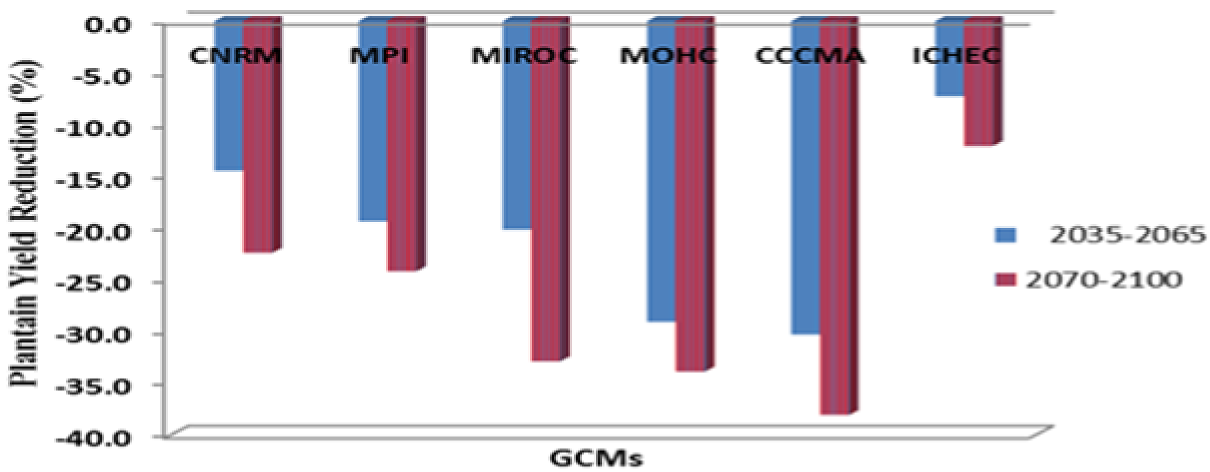

Figure-7a. Predicted plantain yield (%) for period (2035-2065) and (2070-2100) relative to 1975-2005 over ONAEZ.
Source: Simulation output, 2018.

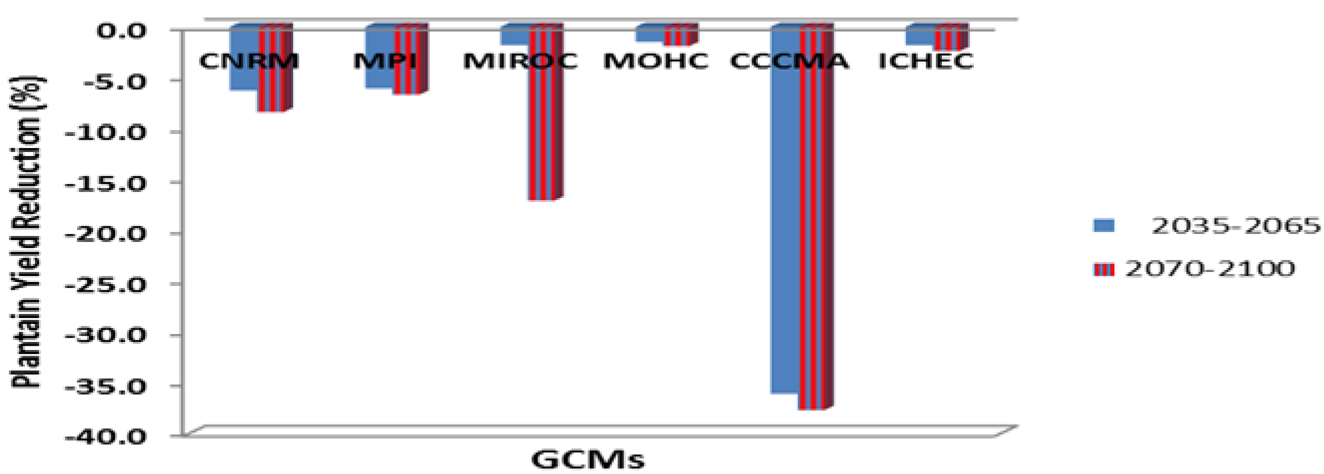

Figure-7b. Predicted plantain yield (%) for period (2035-2065) and (2070-2100) relative to 1975-2005 over OSAEZ.
Source: Simulation output, 2018.

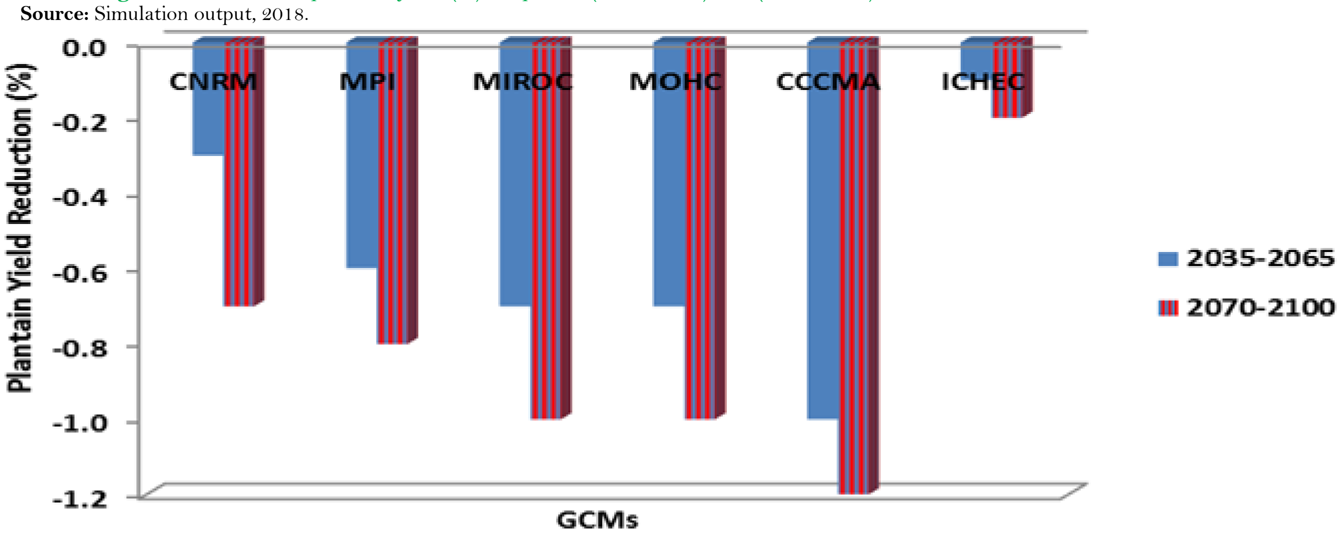

Figure-7c. Predicted plantain yield (%) for period (2035-2065) and (2070-2100) relative to 1975-2005 over OCAEZ.
Source: Simulation output, 2018.

4. Conclusion

The estimated relationship between baseline precipitation and plantain yield is significant ($P < 0.01$) in all the studied regions indicating an increase in seasonal precipitation could lead to increase in plantain yield per hectare in all the agro-ecological zones (ONAEZ, OCAEZ, and OSAEZ). Plantain yield was reduced under projected future climate (the 2050s and 2080s) and the decrease was different based on different GCMs outputs. CCCMA model has the highest decrease in plantain yields in all agro-ecological zones compared to other global climate models. This could be related to the projected increase in minimum and maximum temperature which influence evapotranspiration (ET_o) and increases plantain water requirement. In OSAEZ region, a substantial reduction in plantain yield is estimated by 2050s and 2080s compared with baseline yield. Overall simulations of impacts of climate change in OCAEZ showed that projected climate may likely have relatively small negative effects on plantain yield compared to the results predicted in ONAEZ and OSAEZ respectively.

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