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Climate Yield Models for Some Arable Crops in Ondo State.

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ABSTRACT

This study looks at the connection between easily observed climate variables and crop production. Selected arable crops' yield statistics spanning ten years were analyzed, including melon, rice, cassava, yam, and maize. Using multiple linear regression models calibrated for each of the selected crops, the crop yield was the dependent variable in SPSS statistical package version 22.0. The meteorological data, including mean temperature (^{o}C), rainfall (mm), evaporation (mm/yr), and relative humidity (%), were correlated with the crop yield. Standard error of estimates (SE), coefficient of determination (R^2), and correlation coefficient (R) are the goodness-of-fit parameters that are used to validate the models. The results demonstrated that the R-value for maize is 0.83 with a SE of 4.4 tons/ha, and the R-value for cassava is 0.85 with a SE of 10.2 tons/ha. R-values for yam and melon are 0.77 and 44.5 tons/ha, respectively; for rice and cocoyam, the values were 0.64 and 16.6 tons/ha, respectively. Melon has an R-value of 0.69 and 18.6 tons/ha. Factors such as crop management methods, diseases, nutrients, and other factors that are challenging to account for in the current statistical modeling approach could be the cause of the difference in the goodness-of-fit. There is a great need for efforts to produce trustworthy data for agricultural productivity forecasting and planning in the study region as well as all over the nation.

Keywords: Crop yields, Arable crops, modeling, climatic variables

INTRODUCTION

Climate change, heat waves, cyclones, droughts, and floods are examples of extreme weather occurrences that have a negative impact on global socioeconomic, biophysical, and ecological systems (IPCC, 2014). Due to both natural and human activity, climate change is one of the most significant environmental issues the world is currently experiencing (Stern, 2006). More rigorous and scientific methods have been used to support the evidence of fluctuations in temperature, precipitation, and extreme weather events (IPCC, 2007; 2014). Specifically, it is believed that the effects of climate change will be especially felt by the agriculture sector (Hasan *et al*., 2016).

Extreme climatic events, namely, floods, cyclones, droughts, heat waves and climate change harm global socio-economic, biophysical and ecological systems (IPCC, 2014). Climate change is a change due to natural and anthropogenic activities is considered to be one of the serious environmental issues in the world (Stern, 2006). Pieces of evidence of the changes in rainfall, temperature and extreme climatic events have been established on a more systematic as well as scientific basis (IPCC, 2007; 2014). More specifically the agricultural sector is considered to be more vulnerable to climate change (Hasan et al., 2016). Since climatic factors such as rainfall and temperature serve as important direct inputs to the crop sector, any change and

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variability in these variables are inevitable to have a significant effect on crop yields (Barnwal and Kotani, 2013). There is also a generous concern about projected future changes in climatic factors due to rapidly increasing concentrations of greenhouse gases (Aggarwal, 2003) and expected changes in these climate variables would have a direct or indirect impact on food production (Krupa, 2003).

Africa is among the continent's most susceptible to climate fluctuation and change (Boko *et al.*, 2020) because of its heavy reliance on agriculture, which has a low capacity for adaptation and is highly susceptible to weather and climate variables (Kotir, 2016).

Extreme weather and climate variability have been identified as the two main dangers to South Saharan Africa's (SSA) agricultural productivity (Boko *et al.*, 2020). The effects of climate change are felt in many different sectors, but agriculture is one of the most affected. Changes in temperature and precipitation, soil fertility and moisture, the length of the growing season, and the likelihood of extreme weather events are just a few of the ways that these effects manifest (McGuigan, 2002). Climate variability and change are expected to have a significant negative impact on agricultural productivity and food security, particularly access to food, in many African nations and regions (Boko *et al.*, 2020).

Agriculture is already difficult in many African nations due to semi-arid climates, and climate change is expected to shorten the growing season and drive out vast areas of marginal agriculture (Boko *et al.*, 2020). 'Multiple pressures' interact at different levels to exacerbate these circumstances. Multiple stresses, often known as stressors, are a group of nonclimatic variables that make farmers more vulnerable by limiting their ability to adjust to changes in the climate. High farm input costs, restricted market access, growing market influence and shifts, growing fuel and fertilizer costs, scarcity of agricultural equipment, and population growth leading to landholding fragmentation are some of the stressors.

The development of plant genetics, which is attempting more and more to produce goods that can adapt to significant climate fluctuations, may offer a solution. Utilizing genetic modification technology, crops that are suited to specific environments, such as drought-resistant varieties or crops that can withstand high soil salinity, have been produced. Herbicide- and pest-resistant varieties have also been developed, as have crops that are resistant to viruses and fungi (Hug, 2008). Thus, genetically modified crops could provide answers to highly specific climate circumstances that are common in underdeveloped nations, especially in Africa where climates vary greatly. They might also enable more efficient management of pests and fungal infections (Hug, 2008).

But one of the biggest obstacles to the widespread use of genetic modification technology, especially in developing nations, is the increasingly heated discussion surrounding the risks to human health and the environment, biodiversity, social cohesion, science, farmers' autonomy and welfare, and other related issues as described by (Hug, 2008) . The risk associated with agricultural production is mostly attributed to rainfall unpredictability and other climate factors (Murendo *et al.*, 2011).

A sizable portion of the risk associated with agricultural production is attributed to rainfall unpredictability and other environmental factors (Murendo *et al.*, 2011). Given that agriculture in Nigeria and other West African countries is primarily rain-fed, climate variability has been identified as the most important factor influencing crop yield (Ayanlade *et al.*, 2009). In most of Nigeria, including the Guinea Savanna region, subsistence farming is based on rain-fed crop production, which is characterized by low input and output and accounts for more than 95% of the land area cultivated annually in South Saharan Africa (Boko *et al.*, 2020).

One of the main environmental variables that affects crop growth, development, and yields—particularly the rate of development—is temperature. Although extremes in temperature can be harmful to crop growth, development, and yield, crops need certain basic temperatures to complete specific phenophases, especially

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anthesis (the period of a flower's life from bud opening to fruit setting) or the entire life cycle (Luo, 2011). Crop production losses are accelerated when temperatures rise above what is ideal for each (Boko *et al.*, 2020).

METHODOLOGY

Study Area

The study areas for this research are Ondo State. The state is located in south-western Nigeria. it lies between longitude 4˚ 20' and 6˚ 5' east of the Greenwich meridian and latitude 5˚ 45' and 7˚ 52' north of the equator, with a land area of about 15,500 km^2, according to the 2006 census. The state has mean annual rainfall ranging from 2000 mm to 3000 mm and a temperature range of 20 °C to 27 °C. The state falls between the mangroves and the rainforest. With an estimated land size of 15,500 square kilometers, Ondo State is rich in both natural and human resources. The state's borders are as follows: to the south, the Atlantic Ocean and the Bight of Benin; to the west, Ogun and Osun States; to the east, Edo and Delta States; and to the north, Ekiti and Kogi States. The state, which consists of eighteen LGAs, is located between latitudes 5o45l and 7^{o}52'N and longitudes 4^{o}20' and 6^{o}05' E. The NPC estimated that 3,441,024 people lived in the state as of 2006. The main industry in the state is agriculture.

Fig 1: Map showing the study area

Data Source

Data for selected arable crops which include maize, rice, cowpea, yam, cassava and cocoyam respectively were collected from the National Bureau of Statistics,(NBS) while the meteorological data were collected from the National Meteorological Agency (NIMET) Akure, Ondo State for the period of ten years (1988 – 1997).

DATA ANALYSIS

The model developed in this study is based on multiple linear regression analysis. In these analyses, yields were taken as dependent variables while the meteorological variables were the independent variables. A

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general form of multiple regression model is written as :

$$Y_i = \beta_0 + \beta_n X_n \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (3.1)$$

Where, Y = typical value of yield 'Y' dependent variables

β_o ……………………..β_i regression coefficient

X_i……………..X_n independent meteorological variables

The regression equation can be calibrated (i.e. β_o………….. β_n can be estimated) by least square minimization method using SPSS statistical software package.

The goodness –of-fit statistics used to validate the model include correlation coefficient (R), coefficient of determination (R^2) and standard error of estimate (SE) .

RESULTS AND DISCUSSION

Variation in Yield

The crops yield distribution variation for ten years is presented in Table 1. Yam has the highest average yield of 255.1 ton /ha and standard deviation of 5.29, cassava 69.1 ton/ha and standard deviation of 12.11, cocoyam 42.1 ton/ha and standard deviation of 13.2, melon 31.3 ton/ha and standard deviation of 15.23, maize 21.1 ton/ha and standard deviation of 5.05 and rice average yield is 12.3 ton/ha with standard deviation of 44.34, having the least yield for the crops. Figure 2 shows that, there are variations in yield for the 10 years under review. This may be due to management practices, pests, diseases, soil nutrients, and changes in climatic parameters, most especially rainfall and temperature. For example, higher temperatures reduce the life cycle of grain crops, resulting in a shorter grain filling period, so the plants produce smaller and lighter grains, culminating in lower crop yields and perhaps poorer grain quality, i.e., lower protein levels (Wolfe, 1995). Ahn (1993) also affirms that the availability of rainfall during the critical phases of plant development accounts for much of the variation in agriculture's potential and crop yield.

Tables 1: Crop Yield Data in Ondo State 1988-1997 (ton/ha)

Crops	**1988/89**	**1989/90**	**1990/91**	**1991/92**	**1992/93**	**1993/94**	**1994/95**	**1995/96**	**1996/97**	**1997/98**	**Mean**	**SD**
Rice	15	25	9	7	6	9	10	12	14	16	12.3	5.29
Maize	20	23	30	20	18	16	12	20	25	27	12.1	5.05
Melon	2	1	47	30	23	40	43	38	43	46	31.3	15.23
Cassava	64	73	70	50	47	68	73	78	80	88	69.1	12.11
Cocoyam	60	59	38	28	18	30	38	49	50	51	42.1	13.2
Yam	300	314	255	260	201	189	210	224	298	300	255.1s	44.34

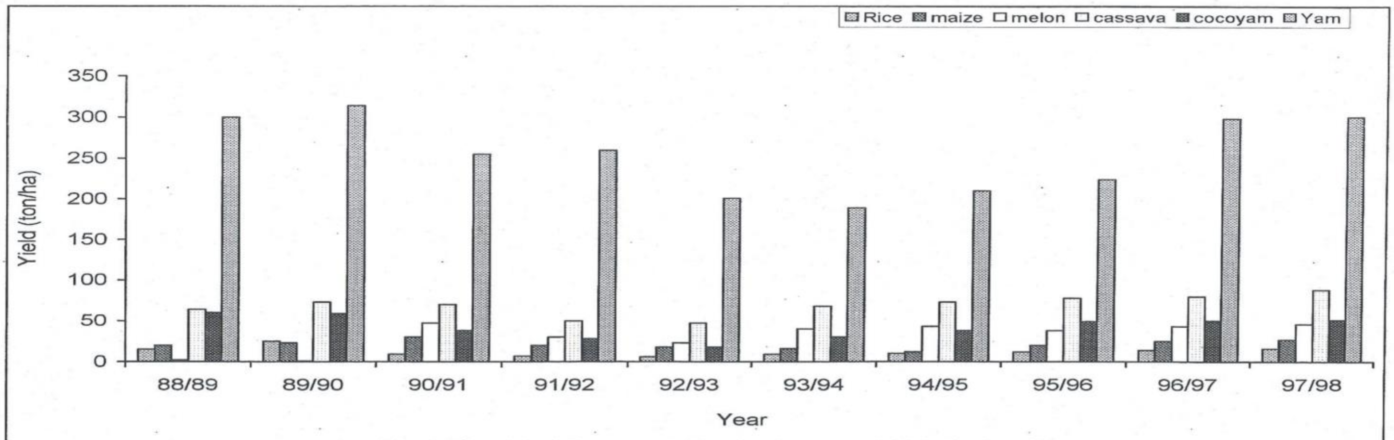

Fig. 2: Graphical Representation for the crop yield in Ondo - State

There is an appreciable variation in the meteorological data for the years under review. The temperature of the years (1988–1997) in Figure 3a has a maximum average temperature of 31.580 °C in 1994 and a minimum average temperature of 30.580 °C in 1991. Figure 3b reveals the variability in rainfall between the years 1988 and 1997. The year 1991 had the maximum annual rainfall of 1854.5 mm/yr, while 1994 had the minimum average rainfall of 1333.8 mm/yr for the 10 years. The average maximum relative humidity observed for the years under review was 81.4% (1988), while the average minimum relative humidity of 62.5% was recorded in 1994. Figure 3d shows the 10-year variation in relative humidity for Ondo State.

The variation in evaporation rate in Figure 3c shows a maximum average evaporation rate of 4.16 mm per year in 1989 with a minimum average evaporation of 2.94mm in 1996. The variations in the climate variables can be linked to climate change, which has contributed to the variations in some of the variables, according to Adejuwon (2004), who reported that rainfall and temperature are the most significant variables of climate that are changing unpredictably, and these may have effects on the yield of crops in the study area. Climate change affects agro-ecosystems in different ways, with either positive or negative consequences dominating different agricultural regions and also causing a probable change in phenological dates, crop growth and yield, crop water requirements (CWR), and water availability in most of the affected places (Pereira and De Melo-Abreu, 2009).

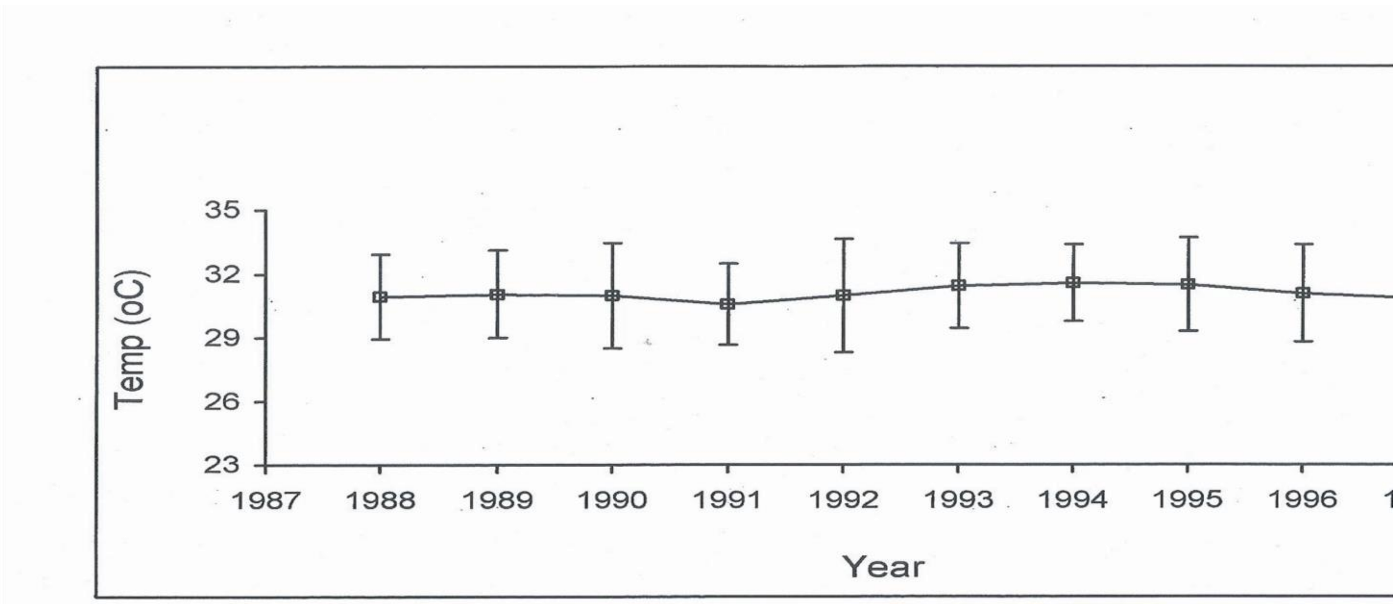

Fig 3a: Graph of Temperature (^{o}C) in Ondo State (1988-1997)

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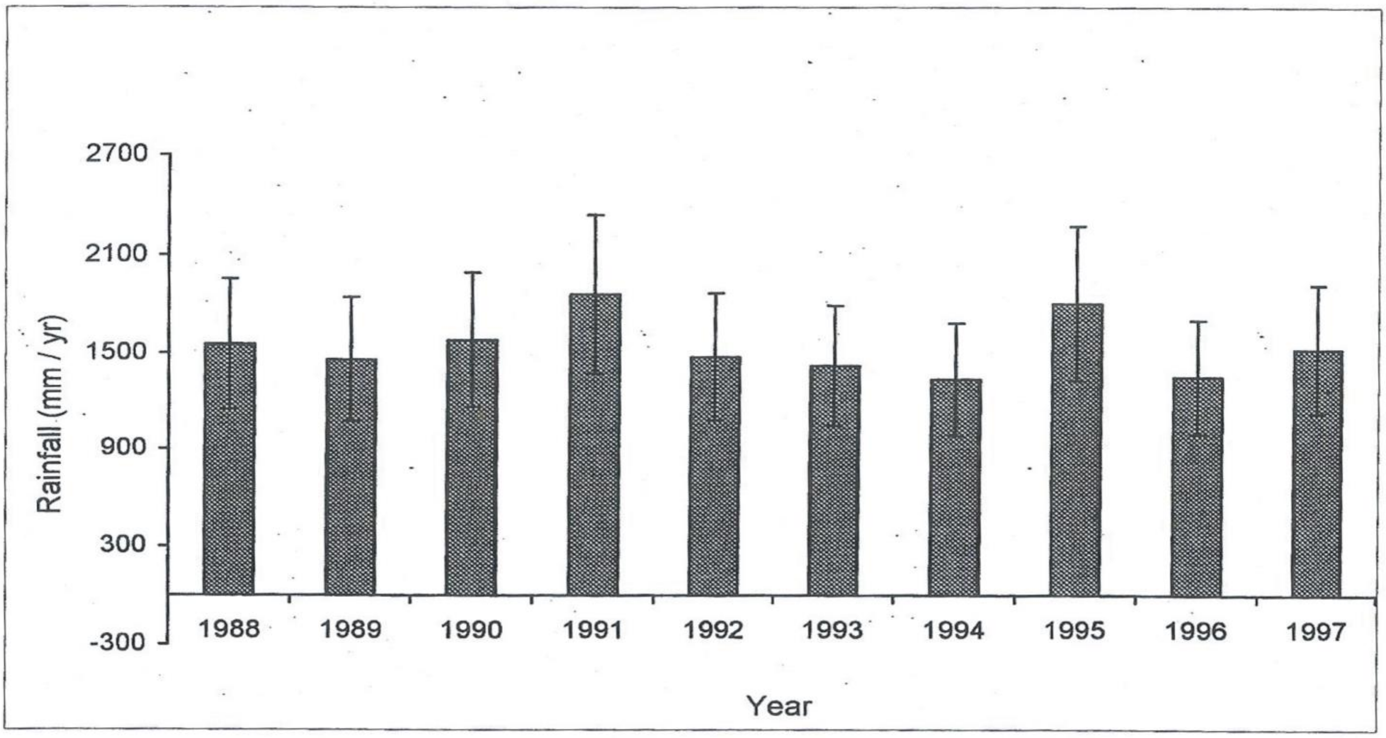

Fig 3b: Graph showing Variation in Rainfall (mm) in Ondo State (1988-1997)

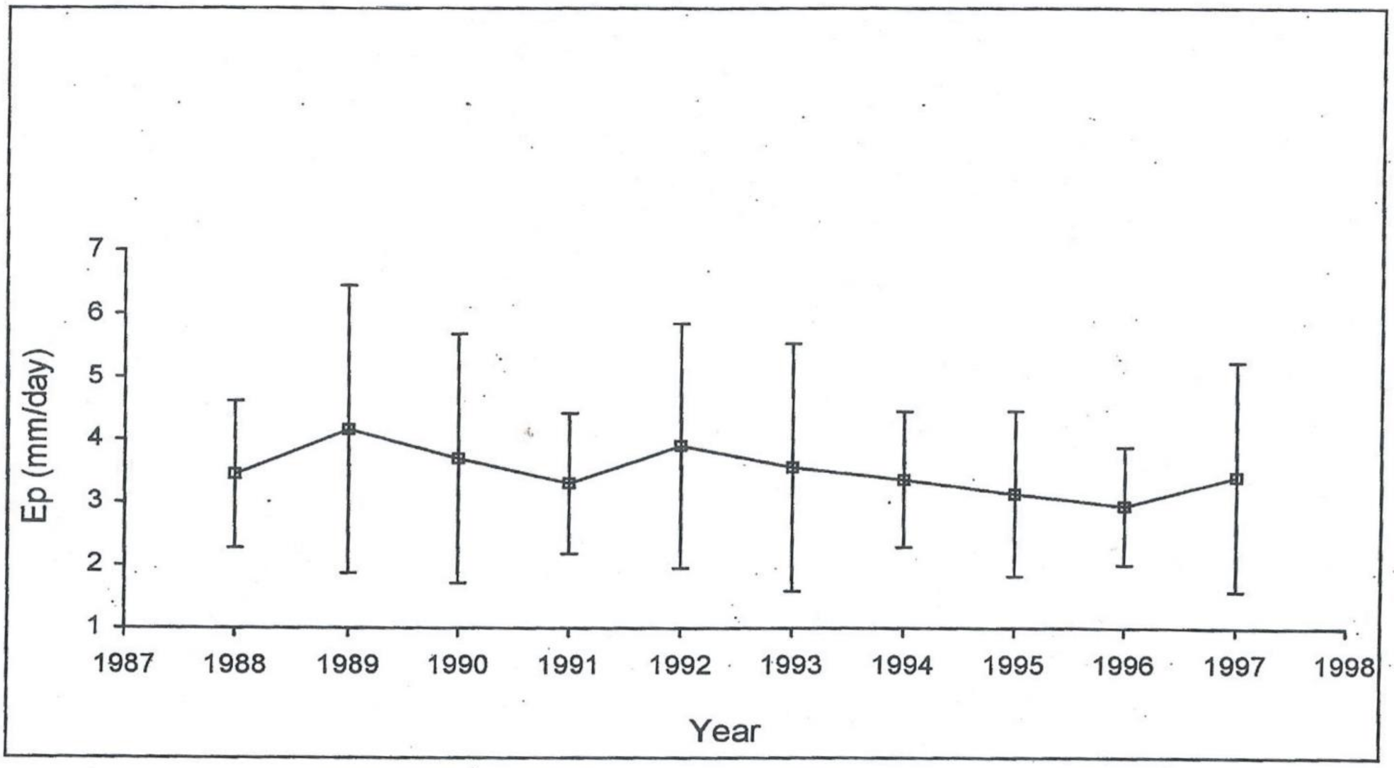

Fig. 3c: Graph showing the variability of Evaporation (mm) in Ondo State (1988-1997).

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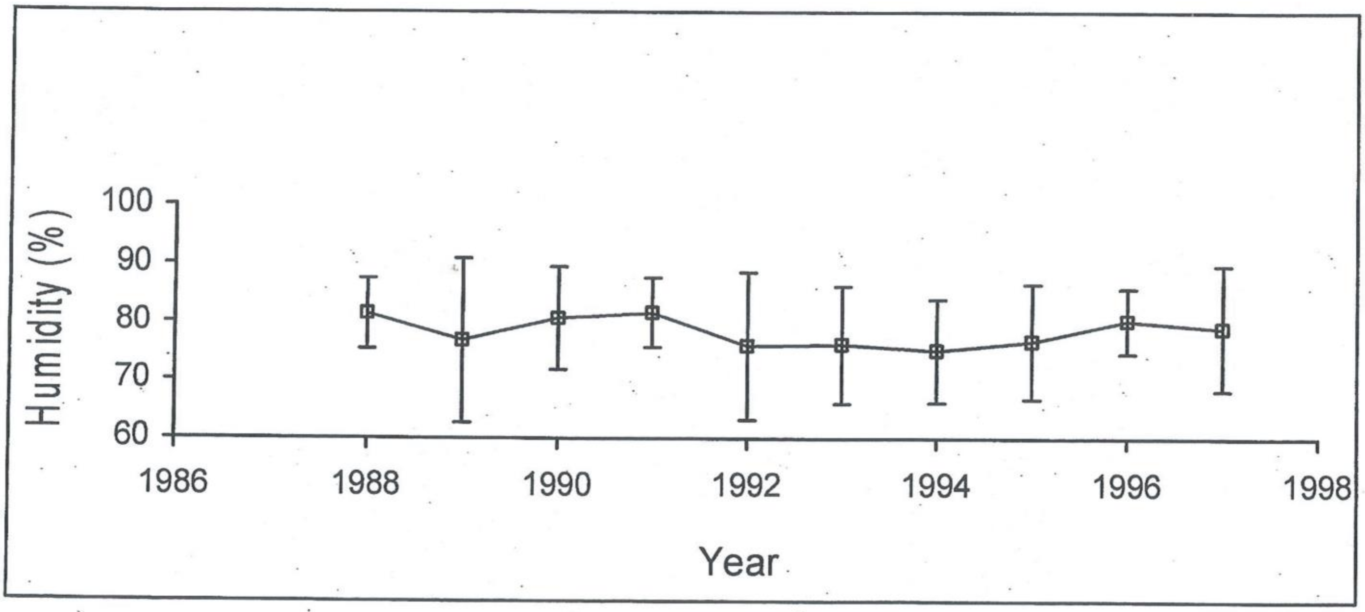

Fig. 3d : Graph showing the variation in Relative Humidity (%) in Ondo State (1988-1997)

The mean variability of the weather variables in the analysis is presented in the figures above. Figure 3a shows the mean annual temperature (^{O}C) variation for the 10 years under review. The mean annual Rainfall is shown in Figure (3b) and the mean Evaporation (mm) variation is shown in Figure (3d). From the preliminary analysis, it is clear that there are strong impacts of weather on the length of growing season. In particular, the result in Figure 3a and Figure 3b suggest that the effects of rainfall and temperature are most important in determining crop yield.

Model Results

Multiple linear regression equation was used to obtain the climatic yield models for the selected arable crops as shown below:.

Model for maize

R = 0.592, SE = 36.14

Model for Rice

R = 0.723, SE = 11.19

Model for Yam

R = 0.716, SE = 357.41

Model for Cocoyam

R = 0.548, SE = 31.96

Model of Cassava

R = 0.639, SE = 1309.1

Model for Cowpea

R = 0.89, SE = 9.56

Where Y = Crop yield, (ton/ha)

EP = Piche Evaporation (mm)

T = Température (^{O}C)

R = Rainfall (mm)

R = Corrélation coefficient (ton/ha)

H = Relative humidity (%)

Crop Yield Model Summary

The R-value, R^2 and SEE from the entire table, where R is the correlation coefficient, R^2 implies coefficient of determination, and SEE means standard error of estimate. The R-value varied from 0.5 to 0.8 for the crops. Cowpea has the highest R-value of 0.89 while cocoyam has the lowest R-value of 0.54.Similar study was carried out by Food Agricultural Organization (FAO) and they reported R-value of 0.72 and 0.83 for cowpea and rice. However, the R-value obtained was slightly different from the developed one in Food Agricultural Organization (FAO, 1997). The difference may be due to different in data collection consistency in data collection method. Also, human activities can lead to the difference. This can only be improved by using more accurate data set from a reliable and dependable source.

However, the relationship between the crop yields and weather parameter cannot be over emphasized because to have suitable, reliable and buoyant yields, the basic necessary criteria needed depend solely on these meteorological parameters which include rainfall, sunshine hour, temperature, relative humidity and piche evaporation. This means that the crop yields and meteorological parameters work hand in hand to ensure maximum yields.

Also, the new regression model developed shows that cassava has the highest standard error of estimate of about 1390.2 ton/ha with the regression coefficient of 0.64 while cowpea has the least standard error of estimate of 9.56 ton/ha with the regression coefficient of 0.89. This means that the model developed for cassava is more reliable and dependable compared to others.

Model summary

Crops	R-value	R^2-value	Standard error of estimate
Maize	0.592	0.350	36.135
Rice	0.723	0.522	11.191
Yam	0.716	0.512	357.41
Cassava	0.639	0.408	1309.19
Cowpea	0.890	0.791	9.56

CONCLUSION AND RECOMMENDATION

The main goal of this research is to create a multiple linear regression model that links crop yield to climatic variables by analyzing the association between crop yield and weather indicators. The association between the yield of a few chosen arable crops, including cowpea, cassava, yam, cocoyam, and maize, and meteorological information, including temperature, relative humidity, rainfall, and pie crust evaporation, was examined using multiple linear regression models. With regard to the utilization of long-term data sets, this work offers valuable information for climatic yield models. A comparable model might be created for many crops and locations.

Consequently, the generated model might be suggested for various crops in a certain area as well as in other places, which is why this study is recommended.

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