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Effects of Changes in Temperature, Rainfall and Relative Humidity on Banana Production in Ondo State, Nigeria

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ABSTRACT

The effects of climate change on agriculture may have strong impacts on the world's food economy and are likely to threaten both the welfare of the world's population and the economic development of the global society. Hence, the impacts of changes in important climate variables like temperature, rainfall and relative humidity on the production of a major food commodity called banana is investigated using the data obtained within 1998-2012 from Ondo State, Nigeria. The results suggest that excessive rainfall and extremely high temperature can reduce banana productivity while the production is also small when both rainfall and temperature are very low with poor humidity. On the average, the findings show that a mean temperature of about 26 °C and average rainfall of around 1891mm with relative humidity of approximately 77% will lead to good annual banana production above 61,000 tons in Ondo State. Since these climate variables will fluctuate under a future climate change condition, the coping strategies recommended for farmers in the area and in similar places might include planting of drought- and disease resistant banana types, monitoring of weather

conditions, use of irrigation and chemicals. Improved storage facilities are also important while transportation of banana should be done under controlled conditions to avoid spoiling the quality.

***Keywords*:** Banana; Plantain; Rainfall; Temperature; Agriculture; Relative Humidity

1. INTRODUCTION

Food production through agricultural activities is very important for our survival; however, good understanding of the impacts of variations in temperature, rainfall and relative humidity (RH) on agricultural production could help to improve productivity. Several studies suggest that anthropogenic (human made) effects are already having negative impacts on the world's climate [1], affecting rainfall, temperature and RH. Consequently, productivities are affected since there is continued dependence of agricultural production on light, heat, water and other climatic factors [2] while we also rely on agricultural activities for jobs. Hence, there is need to access the possible effects of variations in the temperature, rainfall and RH on a major food product called banana; the aim is to understand the implications of such changes on banana production under a future climate change condition. This is important since bananas and also plantains have been described as farmers' principle staple crops and are also their major source of income; for example, both are the world's second largest fruit crop with an annual production of 129,906,098 metric tons [3]. They are the fourth most important global food commodity after rice, wheat and maize in terms of gross value of production [4].

Banana contains potassium, phosphorus, calcium, magnesium, carbohydrate [5] and vitamins, especially vitamin B [6]. For instance, about 70 million people depend on banana and plantain for 25% of their energy intake in Africa [7]. In Nigeria and many other places, a ripe banana with yellowish back cover could be peeled and ate directly or cooked like those with green cover; it could also be mashed before eating. Ripe bananas are sometimes roasted or fried with oil before eating while the mature fruits are ripened and squeezed to extract juice that is fermented with sorghum to produce wine [8, 9]. Medically, treatment of bronchitis, dysentery, ulcers and diabetes with banana flowers have been reported while the astringent plant sap is used in hysteria, epilepsy, leprosy, fevers and acute dysentery [6]. Antifungal and antibiotic materials against Mycobacteria are found in the peel and pulp of ripe bananas while better mood of people with depression has been reported when the body converts tryptophan in a banana into serotonin [6].

Despite the usefulness of banana, its productivity is declining in recent decades; a condition which has been attributed to soil nutrient depletion [10], pests, diseases [11] and fluctuations in weather pattern. For example, banana requires rainfall of approximately 1500-2500mm while the plant might be damaged by day temperature above 37 °C, but it grows well under mean temperature of 27 °C [12] and within 25 °C to 30 °C in a preferably tropical humid low land [13]. Depending on the variety, high density spacing of banana do lead to poor plant growth and low yields due to competition for sunlight and nutrients while heavy bunch and good yield are possible under 3m x 2m with two plants/hole [14] or 3m x 3m [12]. In general, several climatic factors determine the quantity of banana produced, thus, the aim of this study is to evaluate the effects of changes in temperature, rainfall and RH on banana production. This is important since good understanding of their impacts on banana production

could lead to sustainable systems for improved livelihood amidst extreme future climate events.

2. THE STUDY AREA

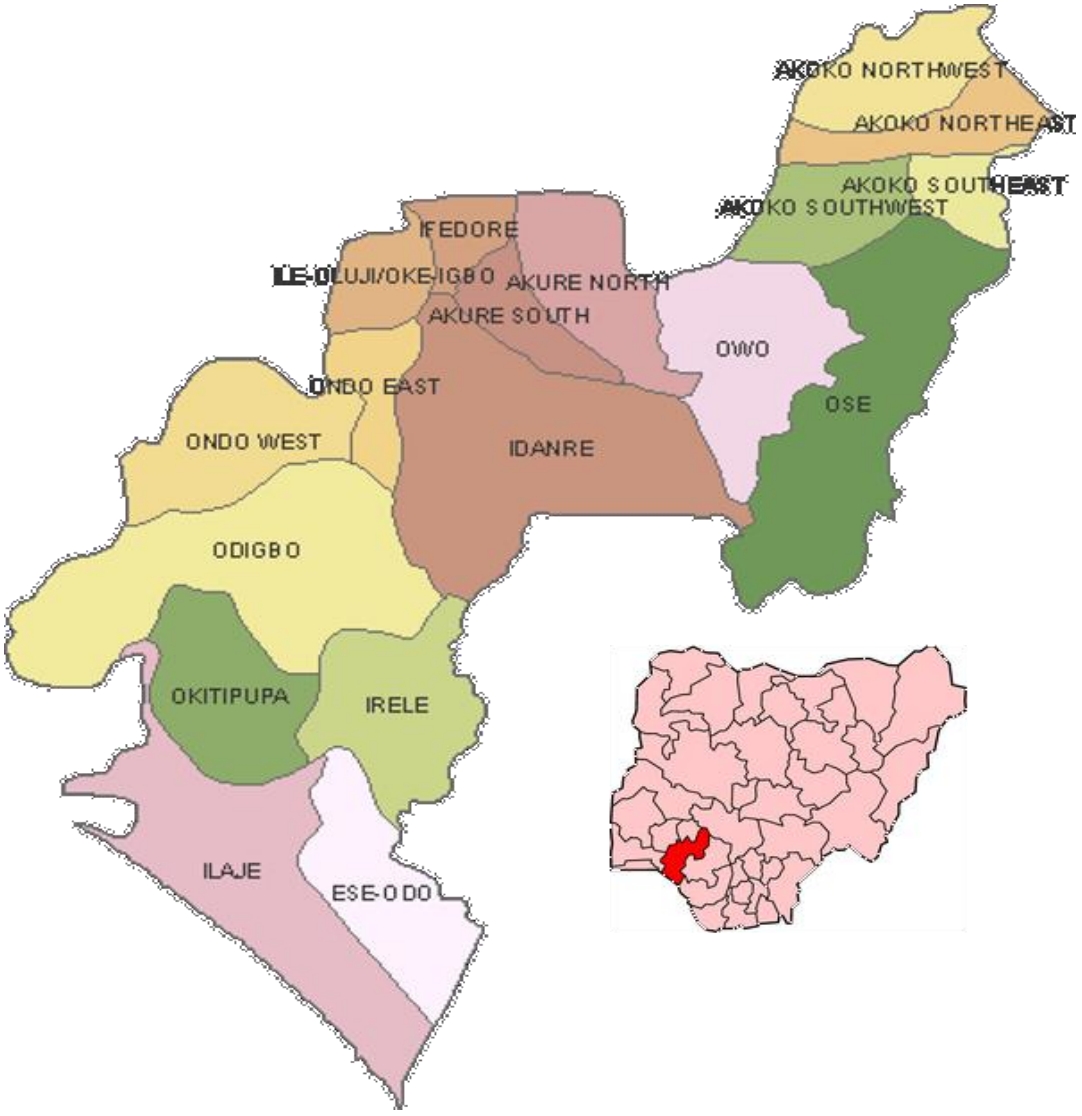

Figure 1. Map of Ondo State showing the 18 local government areas. The inserted map is that of Nigeria to show the location of Ondo State in red colour [adapted from ondostate.gov.ng].

The data used in this investigation were collected from the meteorological Department of Ondo State Ministry of Agriculture and Banana Output, Akure, Ondo State, Nigeria. The data range is 1998-2012 and it consists of rainfall, temperature, RH, numbers of rainy days per year and the quantity of the annual banana production in Ondo State. The state is located in the south-western part of Nigeria; it has 18 Local Government Areas with the capital at

Akure (Fig. 1), West Africa. The latitudinal and longitudinal coverage of the state is between 5°45' to 8°15'N and 4°30' to 6°00'E respectively [15] while the fixed land coverage is approximately 13,595.00 km^2 [15]. In the projection for the state by Ondo State Ministry of Finance, Economic Planning and Budget for 1996 to 2000, the population of the state during the study period was put at about 3,222,243 people for 2005 at a growth rate of 2.6% [15]. The state is bounded in the east by Kogi, Edo and Delta States, north by Ekiti and Osun States, in the west by Ogun State and in the south by the Atlantic Ocean [15]. The inhabitants are mainly the Yoruba speaking people while the remaining occupants of the area are from the other parts of the country [15]. The area is known for large numbers of farmers that specializes in planting cash crops like cocoa, palm oil of which bananas are not an exemption. Food crops like cassava, maize, yam and vegetables are also cultivated. Other inhabitants of the area that are working in agricultural sector are cocoa merchant traders and artesian with products like yam, cocoyam, cassava and plantain.

Ondo State has a tropical type of climate with annual rainfall of about 2000mm in the south and around 1,150mm in the northern areas [15] while the humidity and temperature are relatively high; the region has an annual temperature range of approximately 21°C-29°C. The rainy season in the state is from April to October while the dry season starts in November and ends in March of the following year [15]. However, the annual banana crop cycle in Ondo State include the growing season (April-August) where higher temperature and most rainfall are needed for the plant to grow well while the ripening period covers September-November and the harvesting time is December to March. Unlike the growing season, heavy rainfall reduces crop's content and makes harvesting difficult.

3. THE RESULTS

A. Banana Production and the Rainfall Pattern

The first assessment of the available data is seen in Figure 2 where the banana production (tons) and the associated rainfall (mm) recorded from the study area are plotted against year. The blue line represents the curve for the quantity of banana produced while the black curve stands for the magnitude of rainfall observed within the study period (1998-2012). The figure reveals two important periods that include the time from 1998 where the high productivity continues to rise until it gets to 71,422 (tons) in 1999 before descending with some lower intermediate peaks to reach the least production level of 53, 085 tons in 2005. Except for the weak (strong) rainfall of 1,564 mm (1,946 mm) that occurred in 2001 (2002), the overall rainfall pattern shows a corresponding decreasing trend over these periods, but with an earlier termination of the trend in 2004 compared to 2005 for the banana production. Beside the high quantity seen in 2002, the 60,314 tons in 2000 showed a downward trend to lower productivity level between 2001 and 2004 which could be due to reduction in the rainfall from 1,576 to 1,564 mm over the period.

The second important observation is from 2004 to the later end of 2012 where an upward trend that initiates another round of high rate of rainfall is observed while the actual increase in the productivity level of the banana starts in 2005 (Fig. 2). The rainfall level (banana production) peaked in 2008 (2009) before a downward trend with a small peak in both cases in 2011. However, the high production of 71,422 tons recorded in 1999 is smaller compared to the 77,671 tons in 2009; the production of 43,085 tons starts to rise in early 2005

to reach the highest productivity level in 2009. This success recorded in the banana harvest during the 2009 might be associated with the abundant rainfall seen a year earlier which is necessary since it could help the banana to achieve their potential height from sprouting stage through to growing period. However, it is important to note that the observed rainfall patterns in 2004 and 2005 are out of phase with the quantity of banana produced during the 2004 and 2005 periods. Also, the year 2012 has more than 1960 mm of rainfall but a low productivity of about 53,000 tons while in 2006 with low rainfall of 1675 mm, a productivity level of around 62,000 tons is observed.

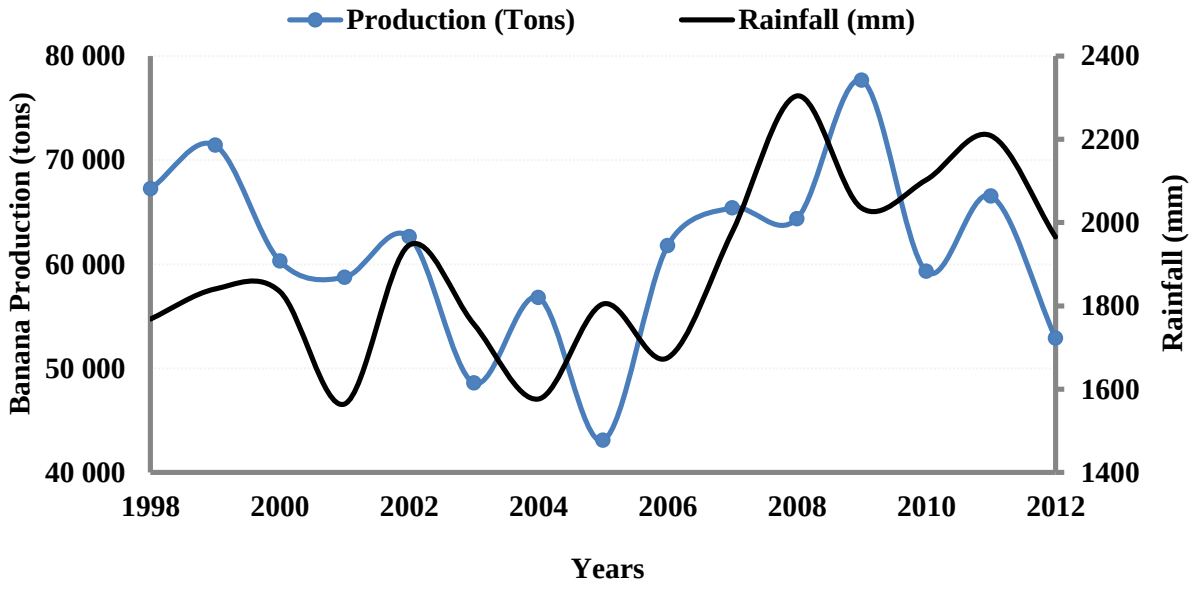

Figure 2. The graph of banana production (in tons) against year together with the graph of rainfall (in mm) versus year.

B. Banana Production and the Temperature Pattern

An investigation to ascertain the influence of temperature on the banana production is shown in Figure 3 which represents the plot of minimum and maximum temperature values against the banana production. The brown (green) line stands for the maximum (minimum) temperature while production maintains blue line. The overall temperature ranges between 18-33 °C where the minimum (maximum) temperature is within 18-22 °C (30-33 °C). Year 2001 with a production of 58,746 tons has the minimum temperature of 18.46°C while 2009 with the highest quantity of 77,671 tons was at least 20.85 °C warm. Like in 2012, the figure shows that both the minimum temperature and banana production are mostly out of phase as seen between 2001 to 2006; a period where the minimum temperature (production) reached the highest (lowest) value.

In addition, the figure generally shows that the banana production reduces as the maximum temperature rises. The exceptions to this are seen in year 2003 where the reduced temperature of 30.95 °C is accompanied by low banana production of 48,498 tons and around 2009 where the high temperature of 32.04 °C lead to the highest quantity produced. Hence for

a good harvest of banana to be recorded in the study area, the temperature should generally stays within 18-33 °C. Thus, low rainfall, excessive rainfall and low temperature or very high temperature affect the productivity level of banana as banana tends to produce less under these climatic conditions. Also, strong wind could damage the crop, resulting in an overall reduction in the banana productivity from a wind affected banana farm.

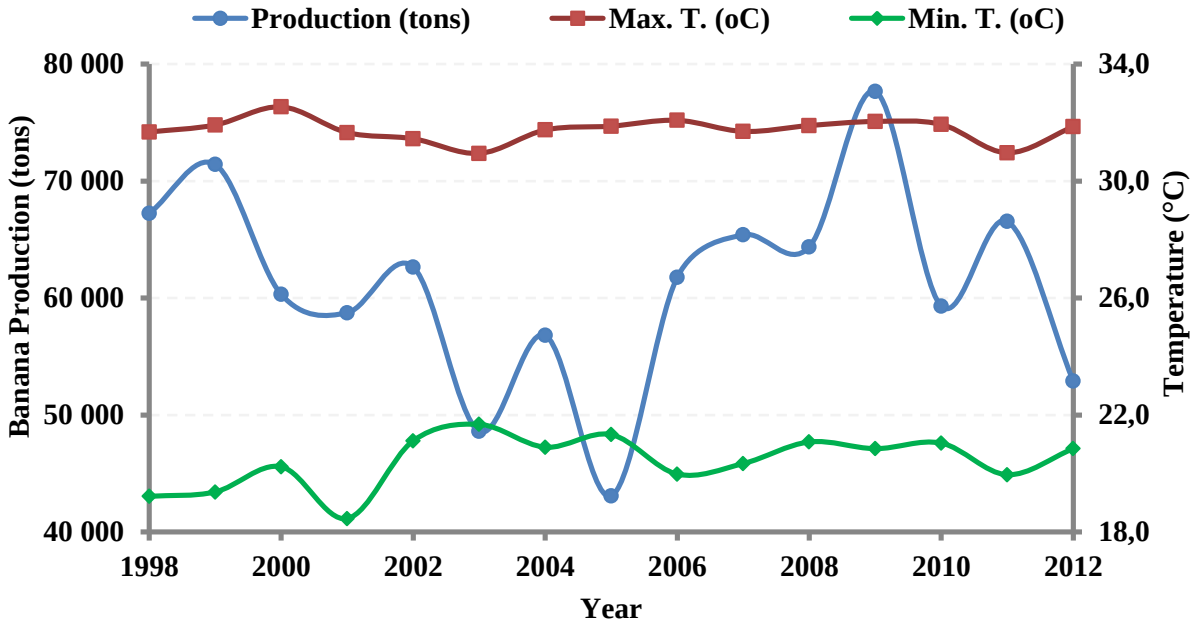

Figure 3. Plot of banana production (tons) against minimum and maximum temperature values.

In addition, the figure generally shows that the banana production reduces as the maximum temperature rises. The exceptions to this are seen in year 2003 where the reduced temperature of 30.95 °C is accompanied by low banana production of 48,498 tons and around 2009 where the high temperature of 32.04 °C lead to the highest quantity produced. Hence for a good harvest of banana to be recorded in the study area, the temperature should generally stays within 18-33 °C. Thus, low rainfall, excessive rainfall and low temperature or very high temperature affect the productivity level of banana as banana tends to produce less under these climatic conditions. Also, strong wind could damage the crop, resulting in an overall reduction in the banana productivity from a wind affected banana farm.

Figure 4 shows the plot of production against the mean temperature (red curve); for clarity, note the different scales used when compared to y-axis in Figure 3. The mean temperature is obtained by adding the maximum temperature and the minimum temperature and dividing the results by two. The mean temperature gives the best agreement with the banana production which is generally out of phase with the temperature; however, the exception is observed around 1998 where both the mean temperature and the banana production are high. Also, there is little or no productivity when the temperature falls outside 25-26 °C range; thus suggesting that the banana will start to do well in the study area within this temperature range. Furthermore, a comparison of the mean temperature pattern with the

rainfall distribution reveals good agreements between the two variables (see Fig. 2 and Fig. 4). However, the mean temperature has a strong out-of-phase relationship with both the banana production and the rainfall pattern within 2002 to 2006; a period characterized by an overall low production that might be explained by the poor water supply from the low rainfall and the excessively warm condition. The regular occurrences of clear skies caused by reduced rainfall and the resulting high sunshine intensities could be responsible for the out-of-phase relationship between the rainfall and the mean temperature. In addition, the mean temperature pattern conforms with that obtained from the maximum temperature but it has better agreement with the minimum temperature pattern (Fig. 3 and Fig. 4).

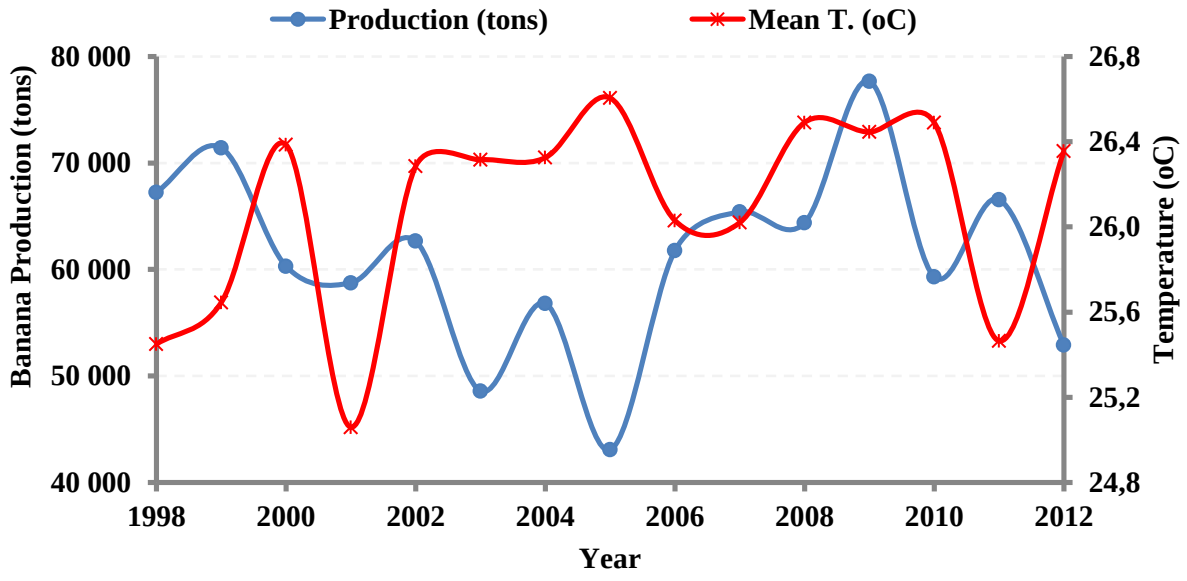

Figure 4. The graph of banana production (tons) against mean temperature (°C).

C. Banana Production and Relative Humidity (RH)

The plot of the banana production against relative humidity, RH (curve in purple colour) indicates that reduced banana productivity is accompanied by low RH while the output rises as the RH increases slightly (Fig. 5). However, the high quantity of banana produced in 1998 (67,252 tons) rises to 71,422 tons along with a reduction in the RH from the highest peak of 79.43% in that year to 76.55% in 1999 before descending to the lowest value of 74.75% in 2003 where the production is 48,598 tons. With the exception of a slight reduction in the RH in 2007, an upward trend from 2003 reached a peak value of 78.3% in 2008 and then reduced to 75.45% in 2011 where it starts to increase again. The result shows a general agreement between the RH and the banana production. For instance, a low peak in the banana production in 2004 (56,812 tons) is followed by a strong decline to 48,085 tons before rising to the maximum value in 2009 after which the continuous reduction in the production is interrupted by a slight increase in 2011. Overall, the banana production is high at moderately high humidity while the production declines as the RH reduces; the banana grows well in the study area within RH of 74-79%.

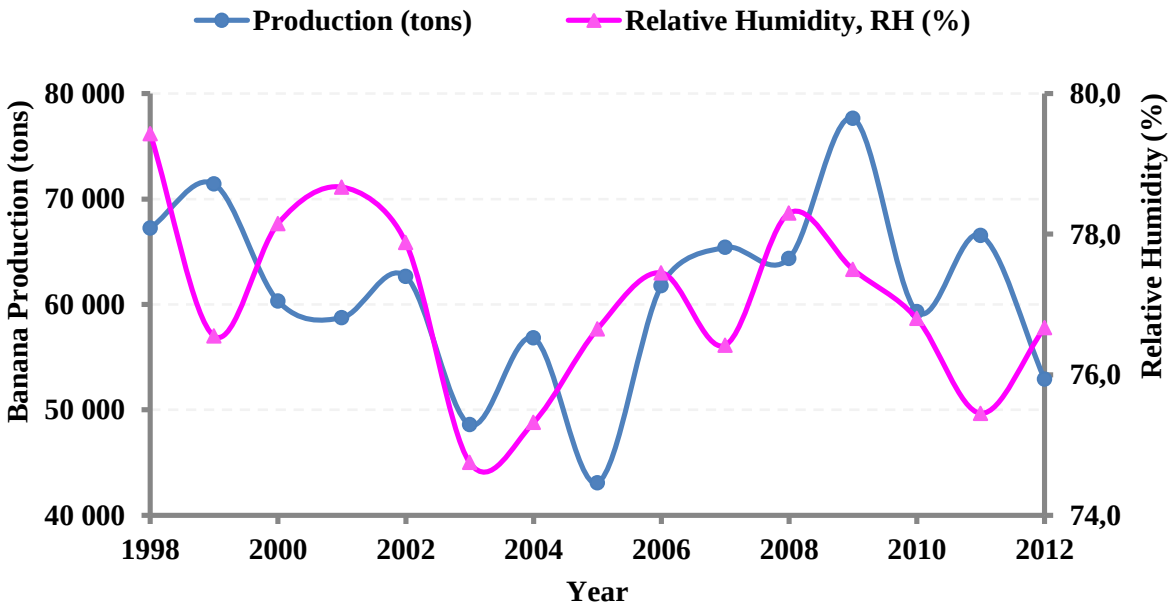

Figure 5. The graph of banana production (tons) against RH (%).

4. DISCUSSION OF RESULTS

The focus of this study is to investigate the impacts of changes in climate variables like temperature, rainfall and relative humidity on banana production within Ondo State, Nigeria. The results suggest that high productivity of banana is associated with moderately strong rainfall and averagely high temperature and good RH level. While excessive rainfall and extremely high temperatures can reduce the banana productivity, the banana quantity is also low when both rainfall and temperature are very low with poor humidity. The result is supported by the correlation of -0.33, 0.34 and 0.34 between the banana production and the respective values of the average temperature, rainfall and RH; indicating that productivity lowers as the warming rises while more are produced under moderately high rainfall and RH. However, the low correlations suggest that other factors are having impacts on the quantity of banana produced. Thus, the maximum temperature maintains few cases of high productivity within the range of 70000 to 80000 tons at 30-33 °C while the production under minimum temperature stays around 40000 to 50000 tons at 20-23 °C range after which productivity rises. For instance, most of the observed high productions of 50,000-70,000 tons are found within mean temperature range of 25.3-26.3 °C. On the average, the results indicate that a mean temperature of about 26 °C and average rainfall of around 1891mm with mean RH of approximately 77% will lead to good banana production above 61,000 tons in the study area.

Further investigation into the reasons for the extremely low banana production below the mean value in 2003-2005 is done by comparing the numbers of rainy days in each year with the quantity produced (Fig. 6). The result clearly shows that the extreme drought induced by low levels of rainfall in 2003 and the possible flooding experienced between 2004-2005 where the highest numbers of rainy days are recorded might be responsible for the low production during this period. However, the poor banana production with low rainfall level

between 2003 and 2005 (Fig. 2) does not fit well with the corresponding patterns of the rainy days which is sometimes very high (Fig. 6). For instance, year 2004 saw poor production despite having the highest numbers of rainy days; the rainfall favoured only slight increase in the productivity level while the associated flooding and the spill-over effects might also be responsible for the low banana production in 2005.

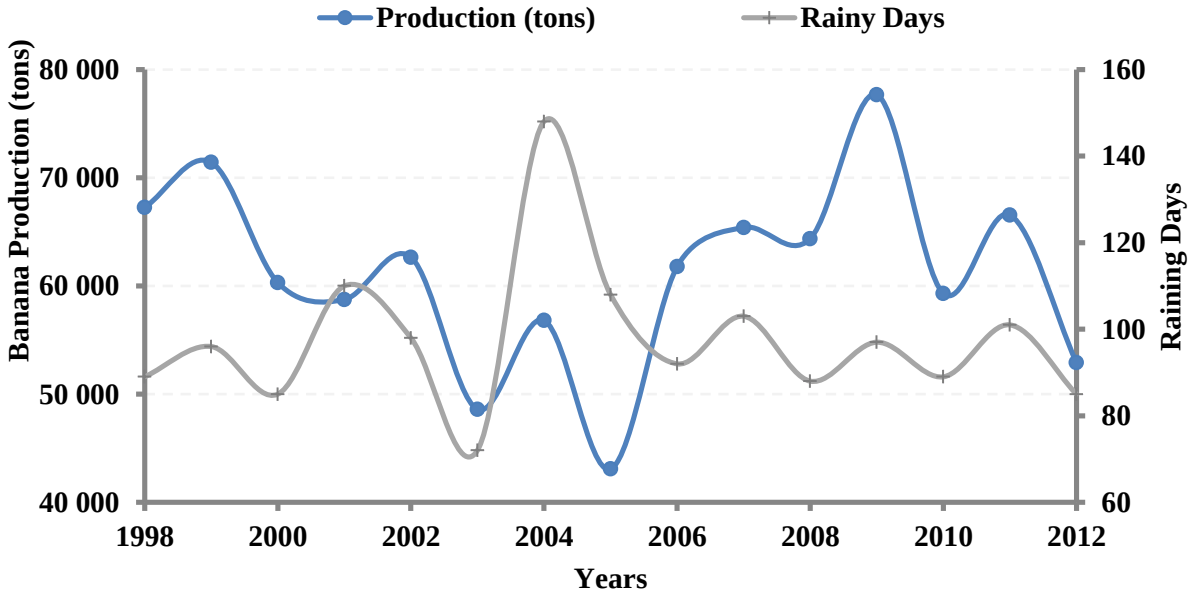

Figure 6. The graph of banana production (tons) against rainy Days in each year.

In addition, the low production in the 2004-2005 might also be associated with the concentration of all the rainfall episodes into fewer days, resulting in more frequency of flood and soil erosions which could destroy the banana plants and cause low productivity. Also, year 2003 with the least numbers of rainy days (Fig. 6) but a slightly higher mean rainfall than 2004 (Fig. 2) might probably be due to the fact that the observed few rainy days in 2003 are characterized by heavy downpour while the intensities of most of the rains in 2004 are possibly weak. When compared to years between 2002 and 2006 that are characterized by excessively high mean temperature (Fig. 4), the result further suggests that the low banana productivity within the period is due to the strong heat stress. Besides, the poor harvest could also be partly caused by weather hazards like strong wind, pests and diseases while the production will rise under proper use of fertilizers, pesticides and good weather condition.

This result agrees well with the findings reported by Espino et al. (1992) [16] where poor banana fruit production and chilling injury is attached to temperature below 15 °C while commercial banana production is possible at about 27 °C [16]. At higher temperatures, heat induced damages to some types of banana plants tend to occur at a day (night) temperature of above 37 °C (30 °C) [13]. Furthermore, the good quality of ripe banana fruit under medium-high RH is reduced at low RH due to increase in water loss from the fruit. Thus, under a global warming condition for instance, low banana production and poor quality might be caused by heat stress associated with climate-induced high temperature, low RH and weak

moisture level from unreliable rainfall patterns, prolonged droughts while floods and strong winds are other factors. Hence, Ondo State, like other tropical regions, seems to be vulnerable to climate change since tropical crops are closer to high temperature optima and experience high temperature stress than places outside tropics, their vulnerability increases under economic and social constraints [2].

5. CONCLUSIONS AND RECOMMENDATIONS

The overall results indicates that the quantity of banana produced in Ondo State, or places with similar weather condition, will be high under a moderate temperature, adequate level of rainfall and good RH. However, low productivity is expected under extremely high or very low temperature, excessive rainfall or strong drought and poor RH. Therefore, as climatic factors change on a long-term, a host of consequences will ripple through the agricultural system as human respond with decisions involving farm management, storage facilities, transportation infrastructure, regional markets and trade patterns [2]. These eventualities can be dealt with more easily if anticipated [2].

Hence, agricultural policy must be made to have strong influence on Ondo State's agricultural sector's ability to adapt successfully to variations in weather patterns and also to climate change. This is important because since very few lands are irrigated, climate variables translate into variable production levels in banana and other crops [17]. Hence, adequate education and credited farmers' capacity to adapt to climate variations should be made available while information dissemination must be improved and ensure its applicability at the farm and household levels [18].

In a future climate change condition, the needs of people vulnerable to the effects of climate change on their food supply should be addressed [2]. For example, plant breeders should probably place more emphasis on the development of scientifically controlled heat- and drought resistant banana and other crops [2].

Irrigation should be improved while proper use of fertilizer, planting of disease and drought resistant banana will also raise production under a well monitored weather condition in the study area and in other similar places. Others include using different planting dates, shifting crop mix to more droughts tolerant and short season varieties [19]. Also, storage and transportation of banana from production sites (farms) to cities and supermarkets should be done with suitable transportation methods under controlled temperature and humidity to avoid damages that could spoil the quality [19]. However, greater economic and individual dependence on agriculture, widespread poverty, inadequate technologies, and lack of political power are likely to exacerbate the impacts of climate change in the tropical regions [2], especially on agriculture in Ondo State and in Nigeria as a whole. Therefore, there is an overwhelming and urgent need to put in place mechanisms that will improve banana productivity and promote societal adaptation to a future climate change condition.

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