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Effects of temporal changes in climate variables on crop production in tropical sub-humid South-western Nigeria

Oluwasegun Olufemi Awotoye and Olaniran Jonathan Matthew*

Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, Nigeria.

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Climate variability and change have been implicated to have significant impacts on global and regional food production particularly the common stable food crops performance in tropical sub-humid climatic zone. However, the extent and nature of these impacts still remain uncertain. In this study, records of crop yields and some climatic variables for a period of 17 years (1990 - 2006) were used to carry out a comprehensive study of the impacts of climate variability on some common classes of food crops (tubers, grains, legumes and vegetables) in South-western Nigeria with a view to determining their responses to observed varying climatic conditions. Crops differed markedly in their responses to the climate variables. Mean temperature varied with the tuber crop production compared with other food crops. Production of other food crops (grains, legumes and vegetables) was largely dependent on the seasonal and inter-annual change in rainfall. However, combinations of a number of interacting factors with both climatic and non-climatic components were responsible for the relatively low coefficient of correlation (r ≤ 0.4) between rainfall amount and the crop yields. The climate projections for South-western Nigeria by 2020 would have direct and adverse impacts on food production, distribution, infrastructure and livelihood assets in Nigeria.

Key words: Climate variability, crop yield and production, regional climate projections, South-western Nigeria

INTRODUCTION

The variability of the climate has been a topical issue in a sustainable environment as the crop yield and production is very important to the economy and livelihood of the people of Nigeria and the world at large. The sub-humid climatic zone of Africa permits the cultivation of a variety of crops in a pattern that emerged in earlier centuries in response to local conditions (Ziervogel et al., 2008; Onyekwelu et al., 2006). It follows therefore that any change in climate may impact the agricultural sector in particular and other socio-economic activities in general. Climate change could have both positive and negative impacts and these could be measured in terms of effects on crop growth, availability of soil water, soil fertility and erosion, incidents of pests and diseases, and sea level rise (Onyekwelu et al., 2006; Ziervogel et al., 2008; Semenov, 2009; Butterworth et al., 2009).

Temperatures throughout Nigeria are generally high with annual mean of about 27°C while diurnal variations are more pronounced than seasonal differences (Salami and Matthew, 2009). Rainfall is the key climatic variable, and there is a marked alternation of wet and dry seasons in most areas (Adefolalu, 1986; Olaniran, 1991a; Olaniran, 1991b). During wet seasons, major portion of the country comes under the influence of moisture-laden tropical maritime air. Spatial variability is evident in the irregular distribution of rainfall at both short-time scale and average conditions while the temporal variability tends to be greater in the Northern and Southern parts of the country (Olaniran, 1991b, Omothoso et al., 2007). The greatest total precipitation is generally in the Southeast, along the coast around Bonny (South of Port

*Corresponding author. E-mail: abefematt@yahoo.com. Tel: 234 703 3312 735, 234 803 3818747.

Harcourt) and east of Calabar, where means annual rainfall is more than 3,000 mm. Most of the rest of the southeast receives between 2,000 and 3,000 mm of rain per year, and the southwest (lying farther north) receives lower total rainfall, generally between 1,250 and 2,500 mm per year (Adefolalu, 1986; Olaniran, 1991a). The regularity of drought periods has been among the most notable aspects of Nigerian climate in recent years, particularly in the drier regions in the north (Olaniran, 1991a; Salami and Matthew, 2009). These drought periods are indications of the great variability of climate across tropical Africa and the most serious effects of which are usually felt at the drier margins of agricultural zones or in the regions occupied primarily by pastoral groups. The high degree of spatial variability of Nigerian rainfall is associated with the intense randomness of the convective process, which is the dominant rain-producing mechanism in the country with the attendant effects on local features such as topography, vegetation and land-cover type among others (Adefolalu, 1986; Omothoso et al., 2007).

Several factors that directly connect climate change and agricultural productivity include, average temperature increase; change in rainfall amount and patterns; rising atmospheric concentrations of CO_2, pollution levels such as tropospheric ozone and climate variability/change with the associated extreme events such as drought and flooding (Onyekwelu et al., 2006; Ziervogel et al., 2008; Semenov, 2009; Butterworth et al., 2009).

The consequences of changes in variability on the ecosystem may be as important as those due to climate change or shift in the mean climate (Hulme et al., 1999a; 1999b; Carnell and Senior, 1998). The relationship between climate change and food security is complex. Many factors influence food security, which means that often the link is not even made between failed crops and changing weather patterns. One of the banes of farming is the frequent complete loss of crops due to adverse weather conditions or pests. Changing weather patterns or extreme weather events, such as floods or droughts, can have negative consequences for agricultural production (Ziervogel et al., 2008; Tadross, et al., 2005; Misselhorn, 2005; IPCC, 2007). Rural communities dependent on agriculture in a fragile environment are continuously facing an immediate risk of increased crop failure and loss of livestock. Consequently, there is less access to food, which forces the price of the little available food product out of reach of the common man. This translates to secondary effect on the living standard of farmers, fishers and forest-dependent people who are already vulnerable to poor living conditions.

In order to ensure food security in south-western Nigeria, a region that feeds more than 45% of the nation's population, information on the extent to which climate variability and change contribute to a decline in agricultural productivity may assist in proffering management strategies for a sustainable and improved crop yield. This study therefore investigates the impacts of climate variability (1990 - 2006) on some common classes of food crops (tubers, grains, legumes and vegetables) in south-western Nigeria, with the view to determining the responses of these classes of food crops to observed varying climatic conditions.

MATERIALS AND METHODS

Secondary data on average climatic variables [such as temperature (°C), relative humidity (%), rainfall amount (mm) and number of wet days] from 1990 to 2006 for a tropical sub-humid zone in South-western Nigeria were obtained from the Nigerian Meteorological Agency. The limitations of the crop-yield data availability and accessibility influenced the selection of the period for the climatic variability study. The yield/production rates for some common staple food crops (cassava, yam, maize, melon, groundnut, sorghum, cowpeas and tomato) in the region were obtained from Oyo State Agricultural Development Programme (OYSSADEP) Office, Ibadan, Nigeria. In order to adequately examine the response of different classes of food crops to varying climatic conditions, the crops under investigation were grouped into four classes as follows: Tubers (yam and cassava), grains (maize and sorghum), legumes (groundnut and cowpeas) and vegetables (melon and tomato) all expressed in metric tonnes per hectare (mt/ha). The annual mean temperature and rainfall as well as number of raining days during both the wet and dry seasons were computed from the observed climatic data. The plots, dependence and correlation of climatic variables on the crop yields in South-western Nigeria during the special observation period were determined.

RESULTS

Table 1 shows the inter-annual average climatic variables in South-western Nigeria from 1990 - 2006. The estimated anomalies of the climate variables indicate that the amount of rainfall and number of wet days varied appreciably from year to year. The trend of the rainfall over the region shows that the more recent years recorded higher annual rainfall compared with the earlier years indicating that the region is becoming wetter. Figures 1 and 2 depict the relationships between yields of the major crops and the climatic variables in the study area. Mean temperature appeared to vary with the tuber crop production compared with other food crops. In contrast, the production of all the food crops did seem to be more dependent on the amount of rainfall (Figure 2). Figure 3 (a-d) shows the seasonal variations in climatic variables in the selected region during the special observation period. During the wet season, the years 2004 and 2006 had the highest rainfall with seasonal total of 1644.70 mm and 1612.20 mm respectively while the years 1997 and 2000 had the lowest (Figure 3b). The years 1995, 1998, 2001 and 2004 witnessed very wet dry season as they recorded about five to seven raining days (Figure 3d). These trends are indications that the rainfall amount was the most variable climatic index in the study area during the wet and dry seasons. The year 2004 recorded the highest amount of rainfall during both the dry and wet seasons. Consequently, the seasonal change

Table 1. Observed inter-annual mean climate parameters between 1990 – 2006 in South-western Nigeria.

Year	Climate parameters							
	Temperature (°C)		Rainfall amount (mm)		Relative humidity (%)		Number of wet days	
	Annual mean	Anomalies	Annual total	Anomalies	Annual mean	Anomalies	Annual total	Anomalies
1990	26.70	0.04	1296.20	-68.92	80.20	-0.96	105.00	0.35
1991	26.80	0.01	1106.40	-258.72	77.30	-3.86	101.00	-3.65
1992	26.50	-0.16	1406.10	40.98	83.00	1.84	115.00	10.35
1993	26.60	-0.06	1315.60	-49.52	80.80	-0.36	100.00	-4.65
1994	26.70	0.04	1162.90	-202.22	80.80	-0.36	109.00	4.35
1995	26.80	0.14	1499.10	133.98	83.00	1.84	111.00	6.35
1996	27.00	0.34	1321.70	-43.42	82.80	1.64	104.00	-0.65
1997	26.90	0.24	966.30	-398.82	80.70	-0.46	115.00	10.35
1998	26.50	-0.16	1581.70	216.58	81.90	0.74	121.00	16.35
1999	26.70	0.04	1302.90	-62.22	80.80	-0.36	103.00	-1.65
2000	27.00	0.34	966.10	-399.02	81.10	-0.06	114.00	9.35
2001	26.70	0.04	1515.30	150.18	83.10	1.94	119.00	14.35
2002	26.80	0.14	1233.70	-131.42	78.20	-2.96	87.00	-17.65
2003	26.50	-0.16	1457.10	91.98	81.70	0.54	95.00	-9.65
2004	26.20	-0.46	1869.60	504.48	80.90	-0.26	109.00	4.35
2005	26.50	-0.16	1436.20	71.08	82.60	1.44	87.00	-17.65
2006	26.30	-0.36	1770.20	405.08	80.80	-0.36	84.00	-20.65

in relative humidity between the seasons was not apparent (Figure 3c).

DISCUSSION

The trends of the inter-annual (Table 1) and seasonal (Figures 3a-d) variations in climatic variables are indications that the rainfall amount was the most variable climatic index in the study area in both the wet and dry seasons. This present study agrees with the observations made by Adefolalu (1986) and Olaniran (1991a & b). The inter-annual variability of rainfall was high and this may often result in climate hazards, especially floods, with devastating effects on food production and associated calamities and human sufferings.

The productivity of crops in tropical regions is highly vulnerable to inter-annual and sub-seasonal climate variability (Challinor et al., 2004). The results of this study showed that crop yields and amount of rainfall varied significantly from year to year and there was a significant relationship between crop yields and temperature or rainfall variability (Figures 1 and 2). The non-linearity of the crop-yield plots and relatively low correlation coefficients ($r \leq 0.4$) could be attributed to several confounding factors (such as farm management practices, soil fertility, pests, seed type and quality and planting period) that were not necessarily climatic.

The region under this study produced predominantly tuber (yam and cassava) than other crops (Figures 1 and 2). The production trend for cassava and yam were very similar, implying that similar factors affected their production. The yields of yam and cassava were about same in 2004 which coincided with the sharp decrease in mean temperature that favoured the growth and yield of both crops. Very wet dry seasons recorded in 1997 and 2000 might have accounted for the high yields of all the crops except yam in the years that immediately followed (1998 and 2001 respectively). This establishes that all round dry season favours yam production.

The yields for the grains (maize and sorghum) do not follow the same trend in some years, but they have peaks

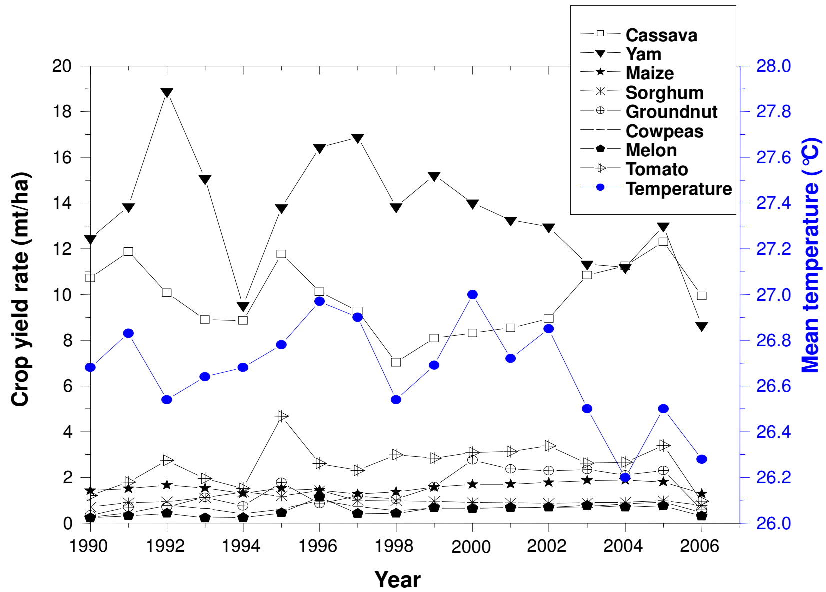

Figure 1. Crop yields versus temperature (1990 – 2006) in South-western Nigeria.

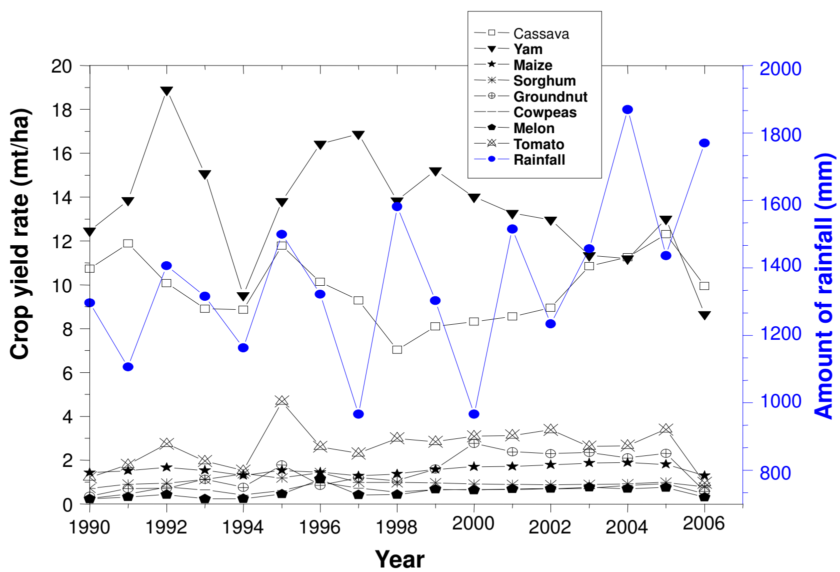

Figure 2. Crop yields versus rainfall (1990 – 2006) in South-western Nigeria.

occurring in the years (1996 and 2004), which recorded even rainfall distributions (Figures 1 and 2). This suggests that similar environmental factors may probably be involved in the grains production. Initially, there was a steady increase in the yield of maize and sorghum from 1990 to 1992 but while the increase in the yield of sorghum continued, that of maize declined. In 2000, the amount of rainfall was low and the yield of sorghum also decreased. As the amount of rainfall increased in 2002 and 2004, the yield of maize also increased. This indicates that increase or decrease in rainfall to a large extent plays a major role in determining the yield of cereal crops. However, temperature had no significant impact on the yield of maize and sorghum. For example, despite the fact that the surface temperature range was 0.8°C between 1990 and 2006, the yield of sorghum was almost stable (Figure 1).

In contrast to the cereals production within the region, the peaks of cowpea and groundnut yields occurred differently. Although both crops are legumes, the factors controlling their yield may not be the same. The groundnut yield was highest in 2000 with production rate of over

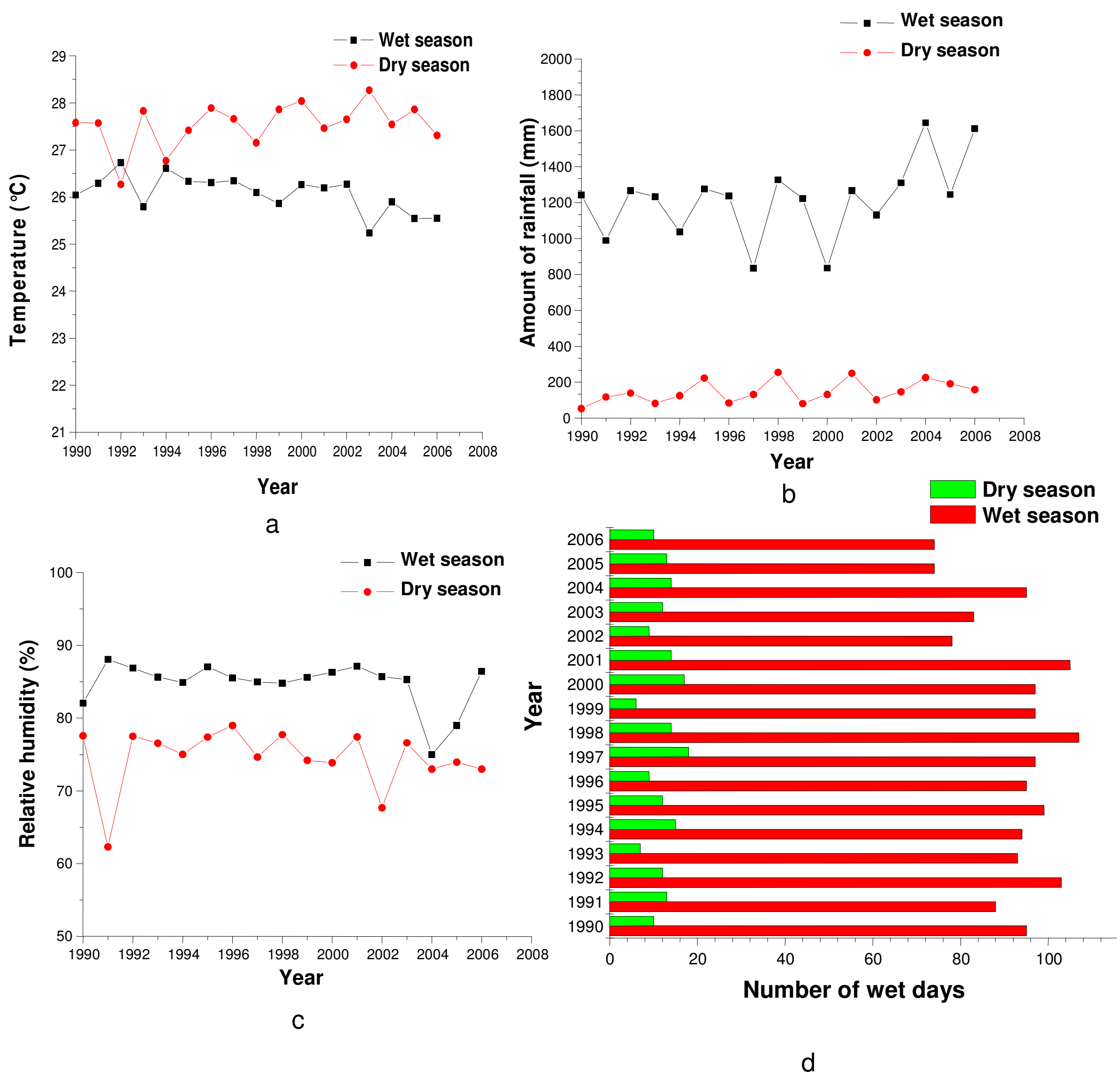

Figure 3. Seasonal variability in temperature (a) rainfall (b) relative humidity and (c) number of wet days (d) in South-western Nigeria.

2.5 mtha^{-1} while the yield of cowpea fluctuated frequently (Figure 2). The sharp increase in yield of groundnut from 1998 to 2000 indicated that other factors not necessarily associated with climate variables (as highlighted earlier) may likely influence its yield and production. The effect of amount of rainfall on the yield of leguminous crops could not be clearly established as their yields appeared generally low and fairly constant.

Vegetable production was influenced by variability/ change in the amount of rainfall. This is to be expected since vegetable production in this environment is under rain fed rather than irrigated conditions. Efforts are been made however, to increase the vegetable production through the *Fadama* agriculture in the region.

Most climate projections over the South-western Nigeria and sub-tropical humid region of Africa in general show that rainfall by year 2100 may be about 50 - 80% of the 1900 values (IPCC, 2007). With increase in ocean temperatures, however, there could be an increase in the frequency of storms in the coastal zone of South-eastern and South-western Nigeria, which may adversely affect crop yield. The extent to which climate change may be responsible for declining agricultural productivity in Nigeria will for a longer time, remain a subject of research considering that other factors influence agricultural productivity. This is because agricultural productivity is socially, economically and environmentally vulnerable (Fischer et al., 1988).

In conclusion, a reasonable relationship between crop yield and climate variability, particularly the temporal change in rainfall amount has been established. The year preceded by a very wet dry season and high annual rainfall had very high yield for all the crops studied. The low computed correlation coefficient ($r \leq 0.4$) for all crops yields with climatic variables implies that crop production may largely depend on combinations of number of interacting factors which are of both climatic and non-climatic components. Although crop yields could be climate dependent, other variables such as farm management practices, soil fertility, pests, seed type and quality and planting period may contribute significantly to variations in crop yield. Inappropriate management practices such as soil compaction during the site clearing and preparation, topsoil and litter repositioning, burning of debris, harvesting methods and management of harvest residues (Chen et al., 2004; Onyekwelu et al., 2006) have been reported to influence crop yield.

In this study, the temperature range between 1990 and 2006 was 0.8°C and most recent climate models predicted an increase in the regional annual temperature to be 0.2°C per decade (Hansen et al., 2007; Salami and Matthew, 2009). With this rate and magnitude of surface warming, the future of agricultural products particularly crops that respond more quickly to temperature variation within this region may be on a serious threat. Therefore, specific technologies and management styles may need to be developed to ensure the sustainability of agricultural products.

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