
*Journal of Agriculture and Ecology Research International*

*14(2): 1-14, 2018; Article no.JAERI.40813*
*ISSN: 2394-1073*

# Assessment of Food Crop Production in Relation to Climate Variation in Osun State Southwestern Nigeria

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***Authors' contributions***

*This work was carried out in collaboration among all authors. The study design, data analyses, literature searches and approval of the final manuscript were jointly done by all.*

***Article Information***

DOI: 10.9734/JAERI/2018/40813
Editor(s):
(1) Daniele De Wrachien, Department of Agricultural and Environmental Sciences, State University of Milan, Italy.
Reviewers:
(1) Linli Cui, Shanghai Institute of Meteorological Science, China.
(2) Mohammed Bello Sokoto, Usmanu Danfodiyo University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/24159

***Original Research Article***

***Received 25th January 2018***
***Accepted 10th April 2018***
***Published 14th April 2018***

## ABSTRACT

This study investigated trends in production of nine majorly cultivated food crops between 1992 and 2016 in Osun State, southwestern Nigeria. It also examined the contribution of the State to the total national food production and impact of climate variations on crop yields. It used secondary crop data collected from both the Federal Ministry of Agriculture and Rural Development (FMARD), Abuja and the United Nations Food and Agriculture Organization (FAO) as well as station observation of rainfall, relative humidity, minimum and maximum temperatures. Annual crop productions were estimated and ratio of the State to national crop cultivated area and that of production were computed using both the FMARD and the FAO datasets. The means, standard deviations, interquartile ranges were computed and trend analysis using Mann–Kendall test was done to assess trends and variability in climatic characteristics and basic components of crop production. Multiple regression and synchronization analyses were carried out to investigate the relationship between

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the crop yield and the climate. Cassava production was found to be the highest with about 0.9 million metric tons per year. The State highest contribution to the national crop production was 3.3 - 5.3% (cocoyam) and the least 0.03-0.04% (cowpea). Rainfall increased annually by 3.5 mm, minimum and maximum temperatures by 0.083 and 0.033°C while relative humidity decreased by 0.32%. Decrease in yam and rice productions was attributed to a combined effect of reduction in yield (due to climate variation) and cultivated area (due to socio-economic factor). Correlations between climate and yields at $p < 0.05$ differed among the crop types and 48 to 90% of variations in the yields of tomato, yam, cocoyam and cowpea were strongly accounted for by climatic factors. The findings suggest the drive for irrigation to enhance full utilisation of the State's potential for yam and rice production and propose pragmatic efforts by governments and relevant stakeholders to assist smallholder farmers towards exploiting larger available land area for agricultural production.

*Keywords: Crop yield and production; climate variations; impacts; southwestern Nigeria.*

## 1. INTRODUCTION

Agriculture plays a central and critical role in the economy of African nations. It engages more than 70% of the Nigerian labour force [1,2] and contributes more than 41% of the gross national domestic product [3-5]. In addition, agriculture provides more than 5% of the total exports, and accounts for 88% of non-oil earnings [6].

Crop production in Nigeria and sub-Saharan West Africa at large is generally rain-fed [7-9] and as such, any change in climate is bound to have direct and often adverse impacts on agriculture and other sectors of the economy [10-12]. The impact could, however, be measured in terms of effects on crop growth, availability of soil water, soil erosion, incident of pest and diseases, sea level rises, decrease in soil fertility as well as food insecurity [13]. Consequently, sustainable crop productions in the face of recently observed changes in global and regional climate has been a great issue of concern as the daily diet of large population of Africa is highly dependent on locally produced food crops.

Literature has shown that successful cultivation of a crop in a particular area is largely determined by the climatic factors (e.g. temperature, solar radiation, rainfall and humidity) and edaphic/ecological factors (soil type and fertility, pests and diseases *etc.*) of that particular locality [14-16]. In Nigeria, crop cultivation and distribution are largely dependent on crop physiology, soil type and climatic conditions [17]. It has also been established that change in temperatures could have both positive and negative effects on crop yields. For example, high temperature could reduce yields and quality of many crops, most importantly cereal and food grains crop [13,18-20]. Higher temperatures result in a shorter grain filling period, smaller and lighter grains and, therefore, lower crop yields and perhaps lower grain quality [20,21]. Similarly, reduction in transpiration due to high temperatures could be 30% in some crop plants [22,23]. A significant positive relationship was established between rainfall and crop yields [13,24]. In addition, yields of some crops are found to be more sensitive to rainfall anomalies such as decline in annual rainfall, change in the peak, retreat of rainfall and false start of rainfall [19,24,25]. A delay of one or two weeks in the onset of rainfall is sufficient to destroy the hopes of a normal harvest [26,27,28]. Similarly, a false start of planting, encouraged by a false start of rainfall, may be followed by prolonged dry spells whose duration of two weeks or more may be critical to crop emergence and/or growth [27]. Soil erosion from excessive rainfall during the crop growing period might lower the yield due to nutrient losses through leaching and can cause disease infestation in crops. Conversely, too little can be detrimental to crop yields, especially if dry periods occur during critical development stages. Moisture stress during the flowering, pollination, and grain-filling stages is especially harmful to cereal crops [16]. All these evidences are suggestive of possible adverse impacts of climate change on crop yields.

Although yield increase has predominantly contributed to increased crop production over the recent decades, increased cropping (or harvested or cultivated) area as well as increase in cropping intensity, especially in the tropics, have also played a substantial role [29]. Most recent works ignored the influence of cultivated (or harvested) area in their studies on the impacts of climate on crop production; they based their conclusions only on the climate-yield interactions. However, a few studies have estimated the separate responses of all basic components of crop production (*i.e.* yield, harvested area and cropping intensity or number of crops grown within a year) to climate variations [29-31]. There is a need, therefore, to consider changes in crop cultivated area as an important aspect of production to get a more complete understanding of the future impacts of climate change in Nigeria and Africa at large, where more than 80% of farmers are smallholders [32]. Therefore, this present study assessed the trends and changes in observed regional climate, yields and harvested areas of 9 majorly cultivated food crops in Osun State from 1992 to 2016. It also examined the effects of variations in the mean climate on crop yields and determined the State's contribution to total Nigeria's crop production with a view to identifying opportunities for increased crop productions. This paper is a prelude to the ongoing research project on developing Climate-Smart Agriculture (CSA) technologies for southwestern Nigeria. The work was motivated by the growing calls from leading agricultural science and policy institutions for CSA, arising from the urgent needs for sustainable agricultural development under future changing climate.

## 2. MATERIALS AND METHODS

### 2.1 The Study Area

The study location is Osun State, southwestern Nigeria (Fig. 1). The area lies between latitudes 7.05$^o$ N and 8.10$^o$ N and longitudes 4.05$^o$ E and 5.15$^o$ E. It covers about 9,251 km$^2$ which is about 0.97% of Nigerian total landmass. Agricultural sector forms the base of the overall development thrust of the State with human population of about 3,416,959 [33]. The leading crops produced in the State include cassava tuber, yam, cocoyam, sweet potato, maize, rice, cowpea/beans, tomato, okra, pepper, garden egg, groundnut, [17]. The people in the State are mostly farmers producing food crops such as yam, maize, cassava, cowpea, cocoyam, okra, pepper, garden egg, groundnut, banana and a number of cash crops (such as cocoa, coffee, kola, cashew, and oil palm among others) [17]. The rainy season starts around the middle of March and continues till late October, while the dry season starts in November and lasts until February [28,34]. The area is warm throughout the year with an average temperature ranging between 28 and 35$^o$C. Rainfall ranges between 900 and 1600mm annually and humidity between 85 and 95% [34].

### 2.2 Data Analyses

Secondary data were used for this study. The yield and cultivated land data of 9 selected food crops (cassava, yam, maize, cocoyam, sweet potato, rice, tomato, okra and cowpea/beans) in Osun State from 1992 to 2016 were obtained from the Federal Ministry of Agriculture and Rural Development (FMARD), Abuja. The choice of these crops was based on available data and their economic importance or value in the State.

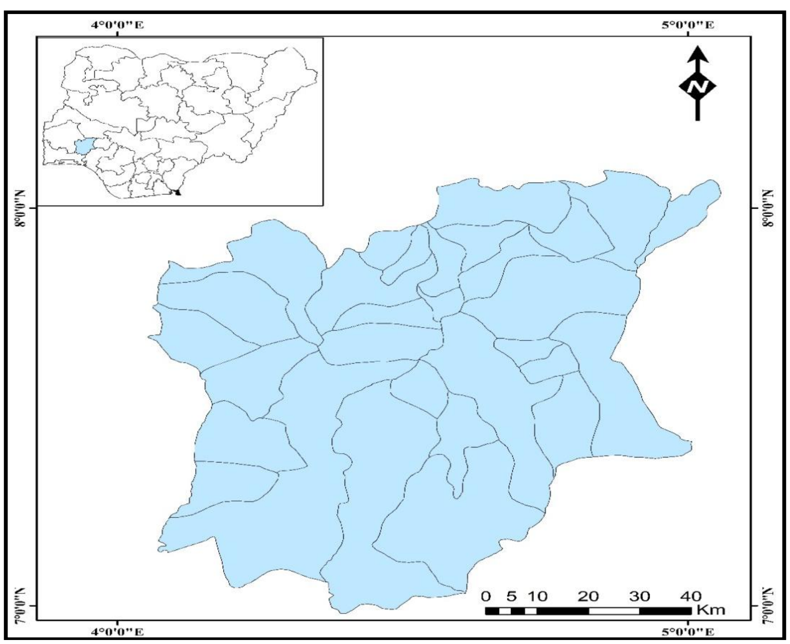


**Fig. 1. Map of the Osun State, southwestern Nigeria**

Total annual crop production, ***P*** (kilogram or kg; $10^3$ kg =1 metric ton or MT), per year was derived as [29]:

$$P = \sum_{i=1}^{n}(A_i \times Y_i) \quad (1)$$

Where A (hectares or ha) and Y (kg $ha^{-1}$ per harvest) is, respectively, the harvested area and yield of an intended crop for the cropping season ***i*** in a given year and ***n*** (times) is the number of completed cropping cycles within a given year.

The ratio of the State to national crop cultivated area and production was computed for both the FMARD and the Food and Agriculture Organization of the United Nations (FAO) datasets. Observed daily meteorological data (maximum and minimum air temperature, rainfall and relative humidity) during the 25-year period were collected from the Nigerian Meteorological Agency (NIMET), Abuja. The variabilities in climatic characteristics were analysed and their effects on crop yields and production were examined during the study period. Data collected were subjected to appropriate statistical analysis. These include; computations of the means, standard deviations, interquartile range, and trend analysis using Mann–Kendall test. Multiple regression analysis was also carried out to investigate the relationship between the crop yield (dependent variables) and the observed climatic parameters (independent variables) at $p < 0.05$ significant level. Synchronization, η, defined as [34]:

$$\eta=\left(\frac{n-n'}{n}\right) \times 100\% \quad (2)$$

(where $n'$ is the number of years the crop yield anomaly is out of phase with climatic parameter and n is the total number of years under study) was performed to determine the significant positive or negative impact of climate variabilities on the crop yield.

## 3. RESULTS AND DISCUSSION

### 3.1 Magnitude and Trends of Climate and Crop Production Components

Fig. 2 illustrates the observed mean annual cycle of rainfall, minimum and maximum temperatures as well as relative humidity in the Osun State between 1992 and 2016. The results showed that annual cycle of rainfall was bimodal with the peaks of 220 mm and 256 mm in June and September respectively (Fig. 2a). Rainfall amount was, however, less than 40 mm/month between November and February. The maximum and minimum monthly temperatures peaked (35.3 and 24.4°C) in February and March respectively but both had the least values (28.1 and 21.6°C) in August (Figs. 2b and 2c). Relative humidity was found to be higher than 65% in all months and ranged between 88.8% in September/October and 68.6% in March (Fig. 2d).

Figs. 3 to 5 are the boxplots (indicating the mean, median, minimum and maximum values and interquartile range) of the yields, cultivated area and production of food crops in the State respectively. Cassava had the highest yield of 15, 100 kg $ha^{-1}$ of yield (Fig. 3) followed closely by yam (14, 310 kg $ha^{-1}$). Cocoyam was next with 11, 013 kg $ha^{-1}$ then potato (8, 305 kg $ha^{-1}$), tomato (2, 672 kg $ha^{-1}$), okra (2, 597 kg $ha^{-1}$), maize (1, 747 kg $ha^{-1}$), rice (1, 601 kg $ha^{-1}$) and cowpea (564 kg $ha^{-1}$). The range in yield was about 2000 kg $ha^{-1}$ for both cassava and cocoyam, 1000 kg $ha^{-1}$ for yam and potato but less than 200 kg $ha^{-1}$ for other crops. This is an indication that yields of cassava and cocoyam varied as twice as those of yam and potato across the years.

The cultivated area for cassava was foremost with 60, 189 ha of land, followed by 49, 822 ha (maize), 27, 750 ha (yam), 13, 881 ha (cocoyam), 12, 558 ha (rice), 3, 733 ha (tomato), 2, 848 ha (potato), 1, 656 ha (okra) and the least 1, 122 ha for cowpea (Fig. 4). It implies that more than 85% of the agricultural land area in the State was used for the cultivation of cassava (34%), maize (28%), yam (16%) and cocoyam (8%). In addition, the soil type in the State might not be very suitable for the production of cowpea/beans but suitable for other crops. The highest mean inter-annual variation of 22, 000 hectares in area cultivated was recorded for both cassava and yam. This was followed by about 10, 000 hectares for maize and rice and less than 200 hectares for other crops. This suggest very high changes in annual area cultivated for cassava and yam. Similarly, the State made the highest average production of 9× $10^5$ MT of cassava per year (Fig. 5). This was followed by 4× $10^5$ MT (yam), 1.5× $10^5$ MT (cocoyam), 0.9× $10^5$ MT (maize), 0.26× $10^5$ MT (potato), 0.20× $10^5$ MT (rice), 0.1× $10^5$ MT (tomato), 0.04× $10^5$ MT (okra) and 0.006× $10^5$ MT (cowpea) annually. The inter-annual variability in crop production was very high (3× $10^5$ MT or 0.3 million metric tons) for both cassava and yam compared to other crops.

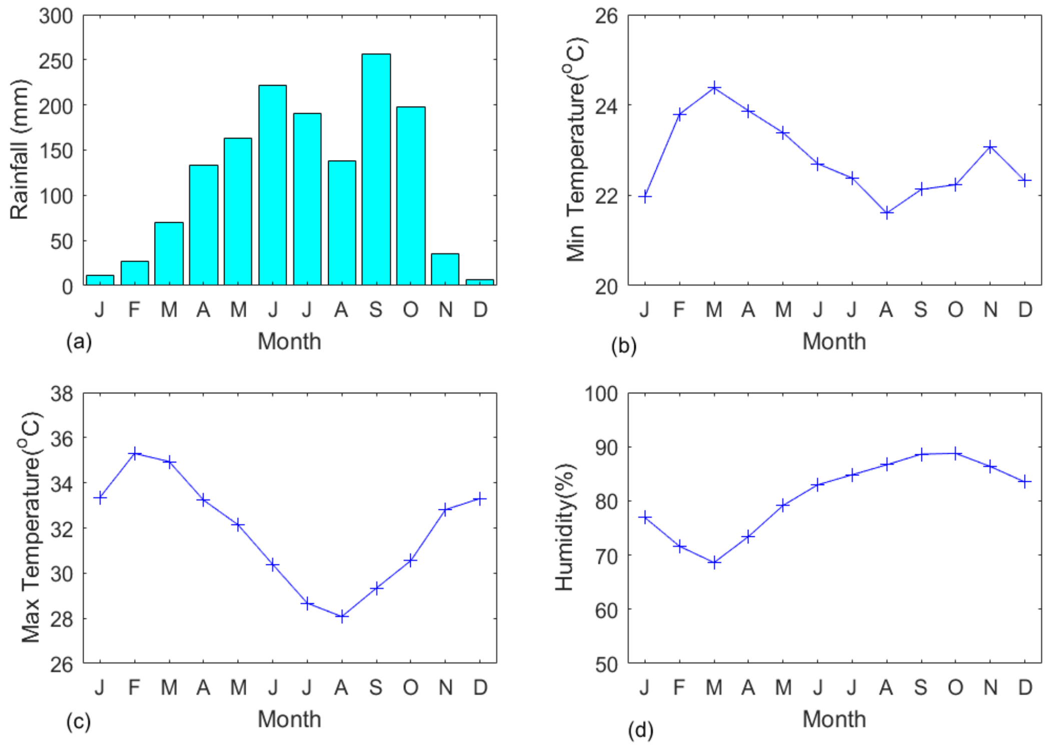


**Fig. 2. Observed mean seasonal climatology over Osun State, Nigeria (1992-2016): (a) rainfall, (b) minimum temperature, (c) maximum temperature and (d) relative humidity**

The magnitudes and trends in the inter-annual climatology is depicted in Fig. 6. The annual mean rainfall, minimum and maximum temperature and relative humidity were 1437 mm, 22.6°C, 31.8°C and 78.3% respectively (Figs. 6a-c). The annual climatic parameters ranged between 1052 mm and 1694 mm; 20.4°C and 23.8°C; 30.1°C and 33.0°C; and 60.3% and 84.0%.

Rainfall and temperatures showed increasing trends while relative humidity decreased. Specifically, annual rainfall increased by 3.5 mm per year while minimum and maximum temperatures increased by 0.083 and 0.033°C per year. By implication, rainfall amount had increased by 87.5 mm from 1992 to 2016. Similarly the minimum and maximum temperatures had increased by about 0.8 and 2°C respectively. Relative humidity, however, decreased by 8.0% during the 25-year study period (Fig. 6d). The decrease in relative humidity implies lesser water in the atmosphere, which may affects plant transpiration, photosynthesis and water uptake. Increase in temperature leads to changes in rainfall patterns and variability thus the need for farmers to adopt different techniques to mitigate this effect such as early planting, planting at different times, growing of different crops and making use of different inputs. The observed rise in rainfall and temperature over the region is in agreement with the range reported in literature [35].

Table 1 describes the trend patterns of the crop yield, cultivated area and production. The yield of tomato decreased by about 43 kg $ha^{-1}$ per year while that of other crops increased in trend. However, the cultivated area of cassava, yam and rice decreased by 280, 540 and 470 ha per year. Aggregately, only the production of yam and rice decreased by 4624 and 8 MT per year respectively. The decrease in annual production of yam and rice could be attributed to a combination of reduction in yield (due to number of interacting factors such as climate, pests and poor crop management etc.) and cultivated area (due to social-economic factors such as bad economy, land ownership tussle, farmers' choice of crop, lack of fund etc.) in agreement with the speculation of Iizumi and Ramankutty [29].

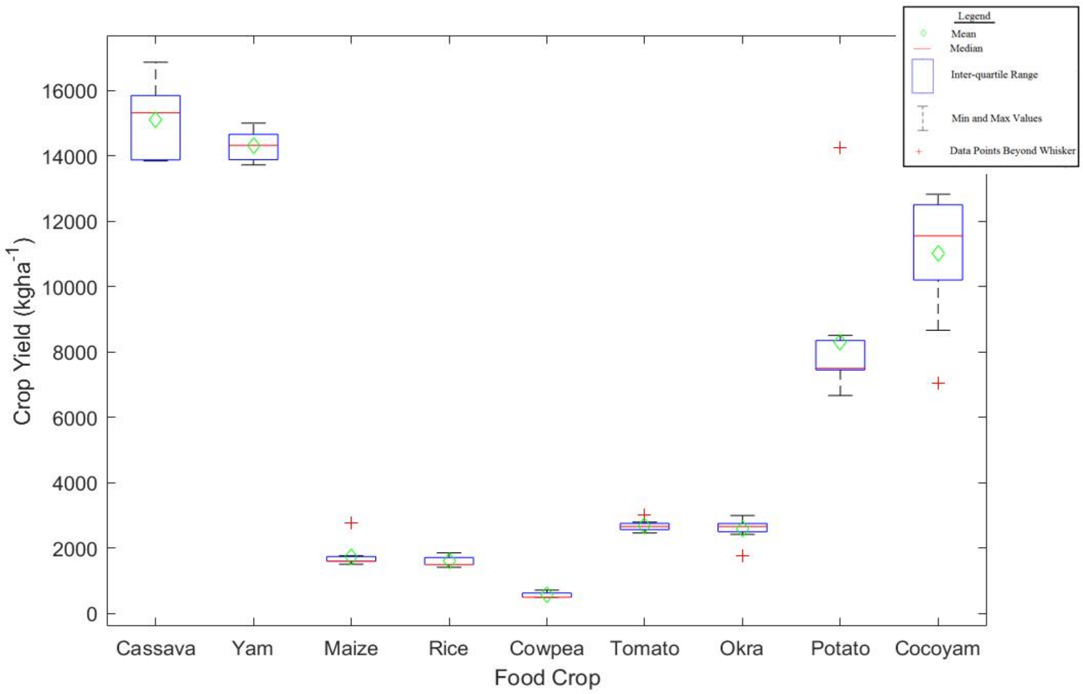


**Fig. 3. Box plot of annual mean major food crop yield in Osun State Nigeria from 1992 to 2016**

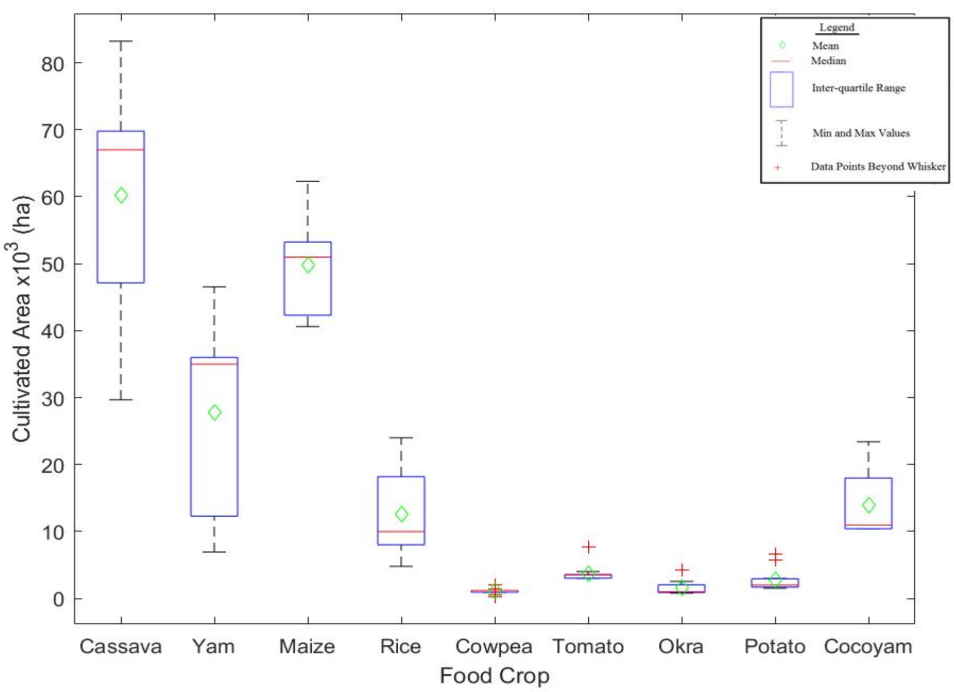


**Fig. 4. Box plot of annual mean area for major food crop cultivation in Osun State, Nigeria from 1992 to 2016**

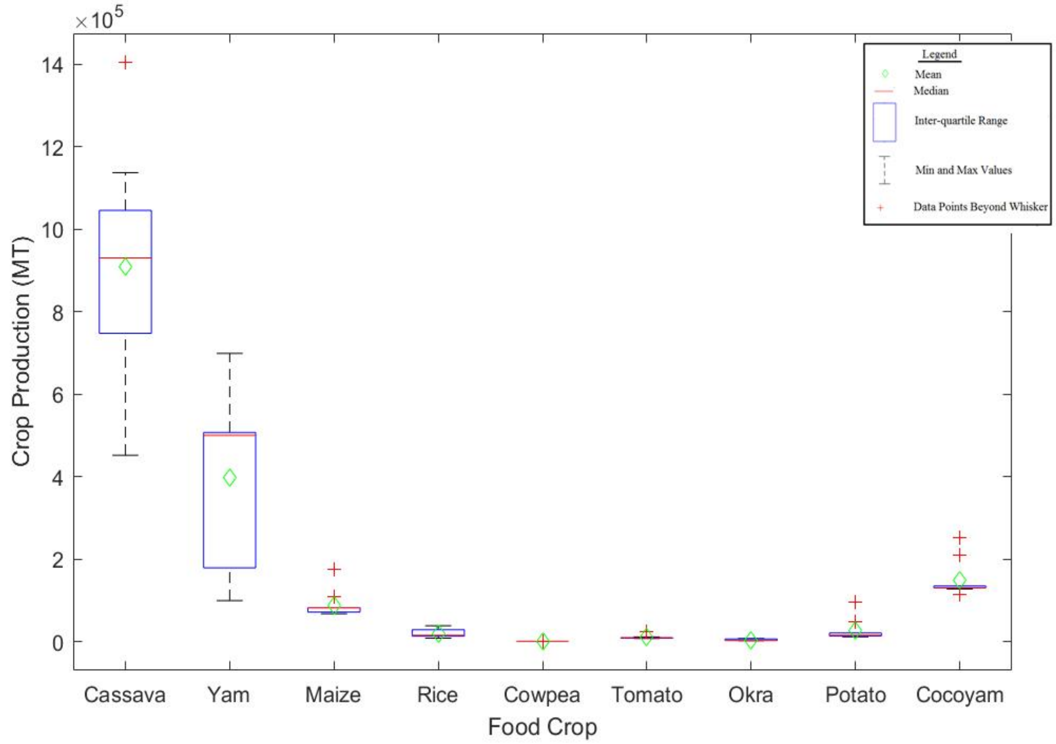


**Fig. 5. Box plot of annual mean food crop production in Osun State, Nigeria from 1992 to 2016**

## 3.2 Contribution of the State to National Production

The ratios of the crop production and cultivated area in the State to that of the national production are shown in Fig. 7. The national crop production and cultivated area as estimated by FMARD were generally below FAO estimates. The results indicated that (despite the fact that the land mass of the State is about 1% of the country), the State produced about 3.3 to 5.3% of the total country's cocoyam production (Fig. 7a) from 2.2 to 3.7% cultivated area (Fig. 7b). It produced 2.4 - 2.6% of national cassava from 1.2 -1.7% of national cultivated area; 1.5% of maize from 1.3-1.4% area; 0.9-1.8% of potato from 0.3-1.3% area; 0.6-0.7% of rice from 0.5-0.8% area; 0.6% of tomato from 1.3- 1.6% area; 0.4-0.5 of okra from 0.5% land; and 0.03-0.04% cowpea from 0.03-0.04% cultivated area.

## 3.3 Impacts of Climate Variations on Crop Yields

The adjusted R-squared, $R^2$, values in Table 1 implied that about 90% (0.898) of variations in tomato, 65% of yam and 64% of cocoyam and 48% of cowpea were influenced by climatic factors, which strongly justified the contributions of climate to variations in their yields at $p < 0.1$. These results suggested that temperature and rainfall extremes could have significant effects on the yields of these major crops. However, contributions of climatic factors to the variations in the yields of rice, maize, cassava, potato and okra were found to be insignificant and varied between 0.1 and 35%. This could be an indication that non-climatic factors could have significant effects on their yields.

Table 2 presents the matrix of correlation coefficients between the crop yield and the climate parameters. The results suggest that relationship between climatic conditions and yield at $p < 0.05$ differ among the crop types. For example, positive relationships were established between rainfall and yam ($r = +0.51$) but negative for cowpea ($r = -0.42$) both significant at $p < 0.05$. This implies that increase in rainfall favours the yield of yam but detrimental to cowpea. This is so for cowpea because the rainfall ranged between 1052 and 1694 mm/year in the study area which is slightly above the optimum rainfall range of 500 to 1200 mm/year for the crop growth and development [36]. This result supports the drive for alternative water supply (irrigation) to enhance full utilization of the State's potential for yam production.

Furthermore, increase in minimum temperature was suggested to favour the yield of tomato and cocoyam (*r* = +0.86), yam (*r* = +0.74) and okra (*r* = +0.53) while it was detrimental to cowpea (*r* = -0.73). Negative but significant relationship was obtained between maximum temperature and cassava (*r* = -0.44), cowpea (*r* = -0.42) and potato (*r* = -0.34) but positive for tomato (*r* = +0.56), cocoyam (*r* = +0.54) and okra (*r* = +0.31). These are indications that future rise in maximum temperature may hamper production of cassava, cowpea and potato but suggested to favour cocoyam, tomato and okra. This is in agreement with literature that extremes of warm conditions could be detrimental to crop growth, development and yield [13,19]. Relative humidity correlated positively and significantly with only cassava (*r* = +0.48). This suggest that the observed annual decrease in relative humidity during the study period was not sufficient enough to reduce the yield of cassava due to other non-climatic factors that enhance its production such as improved varieties, fertilization, better control and management of pests and diseases, and planting of drought resistant and quality seeds among others. Nevertheless, there is no significant correlation between rice and maize yields and climate variables. This is because rice production in the State is greatly supported by wetland farming system. Similarly, this could be an indication that the climatic conditions particularly during the growing season is within the maize crop tolerance. In addition, low correlation values with climate variables implies that variation in crop yields may largely depend on combinations of number of interacting factors which are of both climatic and non-climatic components [37].

The results of the synchronization between the crop yield anomalies and climate are shown in Fig. 8. Synchronization (or agreement) were generally greater than 50% between rainfall and most of the crop yields except for, cowpea, potato and okra (Fig. 8a). This confirms the general view that crop production in Africa is substantially rain dependent [13,24]. Similarly, high synchronization were obtained with minimum temperature and relative humidity but low (less than 50%) with yields of cowpea and potato. However, maximum temperature were generally less synchronized with the yields of most crops except cocoyam, tomato and okra (Fig. 8c). The results of both correlation and synchronization support the assertion that crop production in the area is substantially climate dependent. In agreement with literature [13,18,19,20,29], the signals from these study indicated that climate impact on yield differed among the crop types. It suggests that crop yields vary significantly with changes in climatic conditions provided other non-climatic factors that could influence crop growth and development remain favourable and unchanged.

**Table 1. Equations of linear trend (at p < 0.05) of crop yields, cultivated area and production and results of regression analysis of yields with climate variables in Osun State, Nigeria from 1992 to 2016**

| Crop name | Linear trend equation | | | Regression of yield (with climate variables) | | |
|---|---|---|---|---|---|---|
| | **Yield** | **Area** | **Production** | ***p*-value** | **$R^2$** | **Adjusted $R^2$** |
| Cassava | Y=248.78X - 4835 | Y=-0.28X + 621 | Y=13106X – 3*10$^{-7}$ | 0.289 | 0.420 | 0.130 |
| Yam | Y=72.03X - 1301 | Y=-0.54X + 111 | Y=-4624.36X + 9664 | 0.006 | 0.768 | 0.651 |
| Maize | Y=49.83X - 9814 | Y=0.35X - 646 | Y=4556.91X - 9044 | 0.894 | 0.136 | 0.297 |
| Rice | Y=38.50X - 7557 | Y=-0.47X + 952 | Y=-7.98X + 3608 | 0.948 | 0.098 | 0.354 |
| Cowpea | Y=27.12X - 5374 | Y=0.1X - 197 | Y=98.8X - 1972 | 0.062 | 0.679 | 0.478 |
| Okra | Y=37.61X - 7270 | Y=0.24X - 471 | Y=817.3X - 1628 | 0.550 | 0.421 | 0.061 |
| Tomato | Y=-43.34X + 8941 | Y=0.28X - 556 | Y=595.55X - 1190 | 0.000 | 0.932 | 0.898 |
| Sweet Potato | Y=557.16X - 1108 | Y=0.28X - 561 | Y=4563.88X - 9.1199 | 0.321 | 0.466 | 0.132 |
| Cocoyam | Y=83.79X - 1570 | Y=0.43X - 847 | Y=7935.1X - 2*10$^{-7}$ | 0.007 | 0.758 | 0.637 |

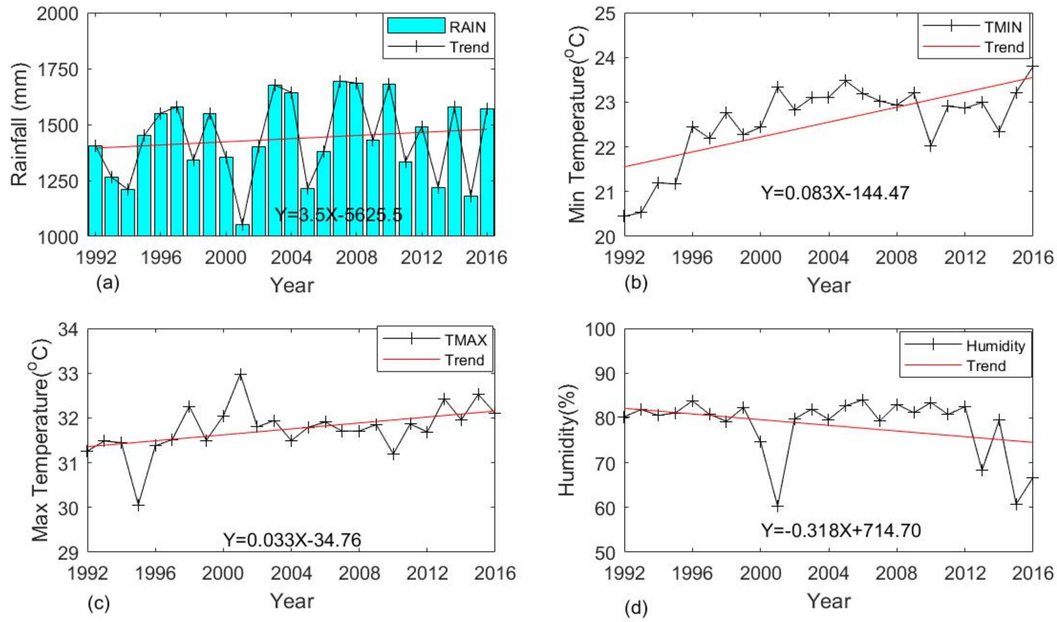


**Fig. 6. Inter-annual variation and trend in the mean climatology from 1992 to 2016 over Osun State, Nigeria: (a) rainfall, (b) minimum temperature, (c) maximum temperature and (d) relative humidity**

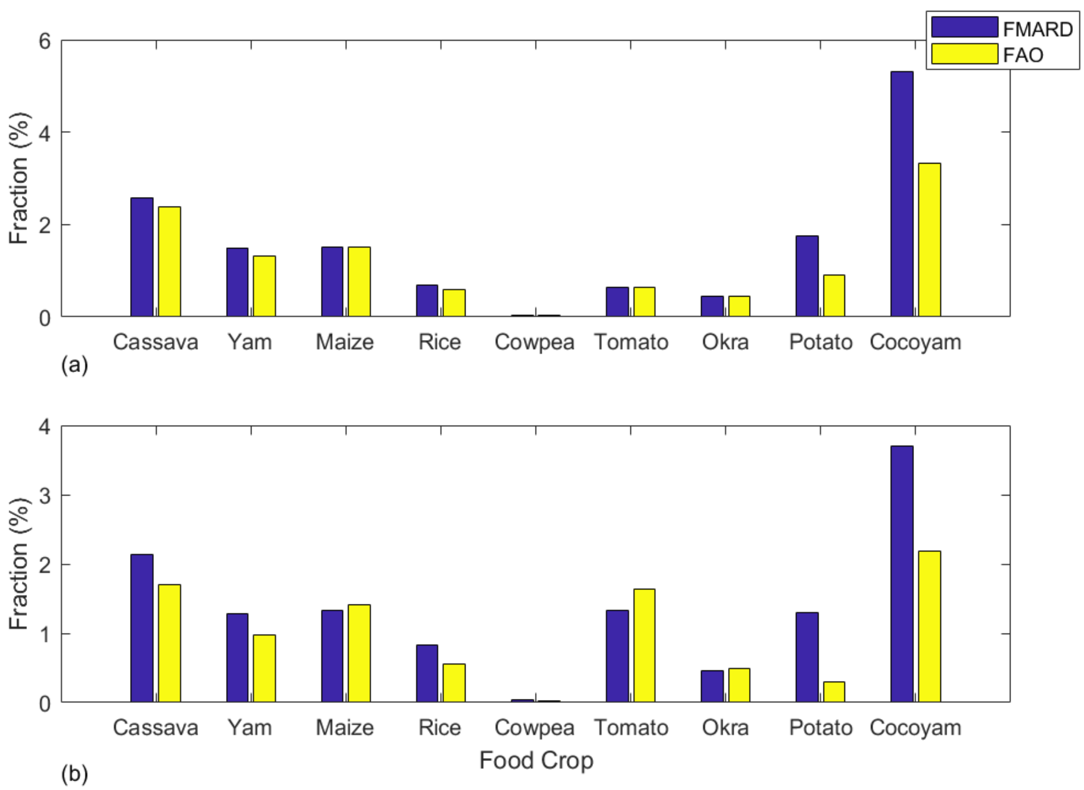


**Fig. 7. Ratio of crop (a) production and (b) cultivated area in Osun State to the FMARD and FAO estimated values for Nigeria from 1992 to 2016**

**Table 2. Matrix of correlation coefficient between the crop yields and climate parameters in Osun State, Nigeria from 1992 to 2016**

| Crop Name | | Yield | Rain | Tmax | Tmin | Humid | Crop name | | Yield | Rain | Tmax | Tmin | Humid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cassava | Yield | 1.000* | 0.270 | -0.442* | 0.008 | 0.481* | Yam | Yield | 1.000* | 0.511* | 0.132 | 0.739* | 0.112 |
| | Rain | | 1.000* | -0.340* | 0.157 | 0.527* | | Rain | | 1.000* | -0.340* | 0.157 | 0.527* |
| | Tmax | | | 1.000* | 0.609* | -0.607* | | Tmax | | | 1.000* | 0.609* | -0.607* |
| | Tmin | | | | 1.000* | -0.197 | | Tmin | | | | 1.000* | -0.197 |
| | Humid | | | | | 1.000* | | Humid | | | | | 1.000* |
| Maize | Yield | 1.000* | 0.024 | 0.084 | 0.275 | 0.111 | Rice | Yield | 1.000* | 0.154 | -0.019 | -0.133 | 0.089 |
| | Rain | | 1.000 | -0.340* | 0.157 | 0.527* | | Rain | | 1.000* | -0.340 | 0.157 | 0.527* |
| | Tmax | | | 1.000* | 0.609* | -0.607* | | Tmax | | | 1.000* | 0.609 | -0.607 |
| | Tmin | | | | 1.000* | -0.197 | | Tmin | | | | 1.000* | -0.197 |
| | Humid | | | | | 1.000* | | Humid | | | | | 1.000* |
| Tomato | Yield | 1.000* | 0.292 | 0.555* | 0.864* | -0.041 | Cocoyam | Yield | 1.000* | 0.048 | 0.536* | 0.861* | -0.194 |
| | Rain | | 1.000* | -0.340 | 0.157 | 0.527* | | Rain | | 1.000* | -0.340* | 0.157 | 0.527* |
| | Tmax | | | 1.000* | 0.609* | -0.607* | | Tmax | | | 1.000* | 0.609* | -0.607* |
| | Tmin | | | | 1.000* | -0.197 | | Tmin | | | | 1.000* | -0.197 |
| | Humid | | | | | 1.000* | | Humid | | | | | 1.000* |
| Cowpea | Yield | 1.000* | -0.411* | -0.420* | -0.727* | 0.200 | Potato | Yield | 1.000* | 0.172 | -0.368* | -0.271 | 0.288 |
| | Rain | | 1.000* | -0.332 | 0.224 | 0.625* | | Rain | | 1.000* | -0.387* | 0.005 | 0.574* |
| | Tmax | | | 1.000* | 0.644* | -0.625* | | Tmax | | | 1.000* | 0.714* | -0.609* |
| | Tmin | | | | 1.000* | -0.256 | | Tmin | | | | 1.000* | -0.194 |
| | Humid | | | | | 1.000* | | Humid | | | | | 1.000* |
| Okra | Yield | 1.000* | -0.282 | 0.308* | 0.534* | -0.123 | | | | | | | |
| | Rain | | 1.000* | -0.751* | -0.418* | 0.635* | | | | | | | |
| | Tmax | | | 1.000* | 0.526* | -0.855* | | | | | | | |
| | Tmin | | | | 1.000* | -0.221 | | | | | | | |
| | Humid | | | | | 1.000* | | | | | | | |

*(* significant at $p < 0.05$; RAIN = rainfall; TMAX = maximum temperature; TMIN =minimum temperature; HUMID = relative humidity)*

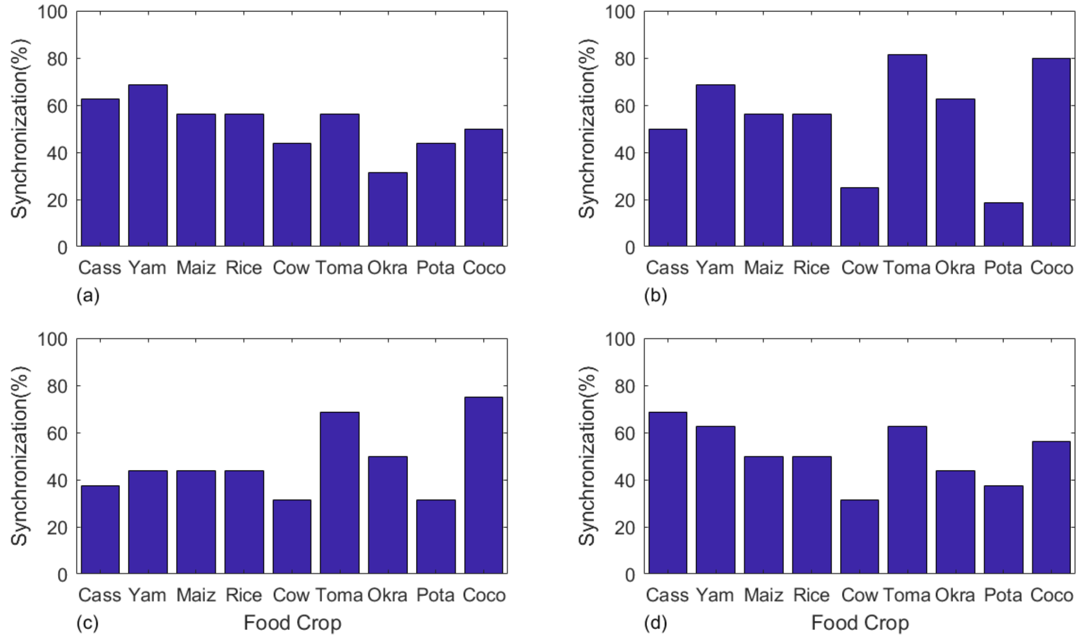


**Fig. 8. Synchronization between inter-annual variabilities in mean climatology and crop yields over Osun State, Nigeria (1992-2016): (a) rainfall, (b) minimum temperature, (c) maximum temperature and (d) relative humidity (*Cass=cassava; Yam = yam; Maiz = maize, Rice = rice; Cow= cowpea; Toma = tomato; Okra = okra; Pota = potato; and Coco = cocoyam*)**

## 4. CONCLUSION

This study has examined the recent trend of climate and production of 9 commonly cultivated food crop (cassava, yam, maize, cocoyam, sweet potato, rice, tomato, okra and cowpea/beans) from 1992 to 2016 in Osun State, southwestern Nigeria. This was with a view to assessing the contributions of the State to the total national food production and the impacts of climate variations on the crop yields. To achieve this objective, the State and national crop data from both the Federal Ministry of Agriculture and Rural Development (FMARD), Abuja and the United Nations Food and Agriculture Organization (FAO) as well as station observation of rainfall, relative humidity, minimum and maximum temperatures from the Nigerian Meteorological Agency (NIMET), Abuja were used.

It was shown that cassava production was on top in the State with $9\times 10^5$ MT, followed by yam ($4\times 10^5$ MT), cocoyam ($1.5\times 10^5$ MT), maize ($0.9\times 10^5$ MT), potato ($0.26\times 10^5$ MT), rice ($0.20\times 10^5$ MT), tomato ($0.1\times 10^5$ MT), okra ($0.04\times 10^5$ MT) and cowpea ($0.006\times 10^5$ MT). It More than 85% of the agricultural land area in the State was used for the cultivation of cassava (34%), maize (28%), yam (16%) and cocoyam (8%). The inter-annual variability in crop yield, cultivated area and production were much higher for both cassava and yam and least for cowpea. The results indicated that the state-to-national crop production ratio of 3.3 - 5.3% for cocoyam was the highest and 0.03-0.04% for cowpea was the least. It was found that, rainfall increased by 87.5 mm, minimum and maximum temperatures by 0.8 and 2$^{o}$C respectively while relative humidity decreased by 8.0% during the 25-year study period. There were decreasing trends in only the yield of tomato (43 kg ha$^{-1}$ per year) and cultivated area for cassava (280 ha/year, yam (540 ha/year) and rice (470 ha/year). Consequently, production of yam and rice decreased by 4624 and 8 MT respectively. These suggest that decrease in annual crop production is largely dependent on a combination of substantial reduction in yield due to climatic factor and cultivated area due to social-economic factors.

Thus, the study speculates that future agricultural supportive strategies for smallholder farmers towards increasing potential land area used for cropping will enhance food crop production in the State. Results established varying relationship between climatic conditions and crop yields at $p < 0.05$ and suggested that about 48 to 90% of variations in the yields of tomato, yam, cocoyam and cowpea were strongly influenced by climatic factors. Positive significant relationship was established between rainfall and yam ($r = +0.51$) but negative for cowpea ($r = -0.42$). This implies that increase in rainfall could favours the yield of yam but detrimental to cowpea. These support the drive for alternative water supply or irrigation to enhance full utilization of the State's potential for yam production and suggest unfavourable rainfall regime for cowpea in the State where rainfall ranged between 1052 and 1694 mm/year contrary to optimum rainfall range of 500 to 1200 mm/year for the crop growth and development [36].

In agreement with literature [13,19,20], there were indications that future rise in maximum temperature may hamper production of cassava, cowpea and potato but suggested to favour cocoyam, tomato and okra. Very low and insignificant correlation between rice and maize yields and climate variables is suggestive of the fact that rice production in the State is greatly supported by wetland farming system while the prevailing climatic conditions could be said to be within the maize crop tolerance. In addition, low correlation values with climate variables implies that variation in crop yields may largely depend on combinations of number of interacting factors which are of both climatic and non-climatic components [37]. Results support the assertion that crop production in Africa is substantially climate dependent provided other non-climatic factors that could influence crop growth and development remain favourable and unchanged.

## ACKNOWLEDGEMENTS

The authors are greatly indebted to the Federal Ministry of Agriculture and Rural Development (FMARD), Abuja; the Food and Agriculture Organization of the United Nations (FAO); and the Nigerian Meteorological Agency (NIMET), Abuja for providing the agricultural and climate data used for this study. Our appreciation also goes to the Tertiary Education Trust Fund (TETFUND) Office, Abuja, Nigeria for their financial support.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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