

# Extreme climatic conditions and effects on cropping activities at a farm settlement in southwestern Nigeria

**Adelowo A Adewoyin**

Obafemi Awolowo University Faculty of Science <https://orcid.org/0000-0001-5812-3079>

**Adebayo Oluwole Eludoyin**

[oaeludoyin@yahoo.com](mailto:oaeludoyin@yahoo.com)

Obafemi Awolowo University <https://orcid.org/0000-0003-0532-7689>

**Olusola Olumide-Ige Adetoro**

Obafemi Awolowo University Faculty of Science

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## Research Article

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# Abstract

Mitigating against the impact of extreme climatic conditions is a major concern for many communities in developing countries, especially in the sub-Saharan Africa. This study examined the occurrence of extreme climatic elements and coping strategies of smallholders in a farm community in Nigeria, as well as perception stakeholders in the area on the impact of extreme climatic conditions. Data used were responses of 24 purposively stakeholders and 35 years' daily rainfall, temperature and wind speed data. Results showed that area experienced rainfall fluctuations as well as temperature increase which were associated with poor germination, impaired of crops growth, alteration of quality harvests and lowered crop productivity in the area. Coping strategies varied with socio-economic differences among the farmers; with the relatively wealthy farmers practicing preventive methods while poor farmers embraced reactive strategies like changing methods of cultivation and praying. The study concluded that food security in the area as typical of many farm communities in the region, will benefit significantly from local knowledge of the farmers.

## 1. Introduction

Extreme climate conditions are a deviation from the norms (average climatic conditions), which are capable of upsetting numerous essential environmental parameters including interference to water balance and air temperature balance (Odekunle, 2004). Extreme climate conditions are phenomenon that may not been observed in an area for certain periods of time which may have occurred by climate change and climate variability. Extreme climate conditions can initiate dangerous conditions including floods, droughts, dry spell, typhoons and heavy snow. Although extreme climate condition may span for short period of time, but they can impact both environmental and agricultural processes significantly. In farming, situations like heavy rainfall within a limited period of time, dry spells within developing seasons when some crops require water to be available at field capacity and heavy downpours at periods when crops need a dry spell are termed extreme events (Maracchi et al., 2005). The events are typically unpredicted and non-seasonal but the damage can be enormous (IPCC, 2007). It is a universal problem, but with diverse levels of impacts and adaptation approaches across different societies (New *et al.*, 2006).

In Africa, extreme climate conditions are particularly susceptible due to poor technological development, low economic strength or high poverty level, climate awareness and education as well as financial and political will to reverse the vulnerability (Mirza, 2003). According to Hansen *et al.* (2001), extreme climate conditions have been attributed to occur as a result anthropogenic activity of human for better living at the expense of their impacts on the environment, extreme climate conditions have increased hazard on agricultural activities. Increase in the frequency and number of extreme conditions is usually linked to climate change due to greenhouse gases and aerosol anthropogenic emissions (Planton, 2008). Recently, extreme climate conditions have become an important issue for discussion among governments, especially as climate becomes an important subject of Sustainable Development Goal (SDG 13), awareness has increased its impact and variant coping strategies (Swart et al., 2003).

Agricultural production in the sub-Saharan Africa, which is mainly dependent on rainfall for wetness, may be rigorously compromised by fluctuations and extreme climatic conditions (Thompson et al., 2010). Fischer et al. (2005) argued that extreme climate conditions will cause loss of agricultural land, shortens growing seasons, lowers yields, and consequently cause food shortage. Extreme climate in the developing countries has also been linked with increase in the frequency and prevalence of certain climate delicate diseases, especially malaria, tuberculosis and diarrhea (Guernier et al., 2004). Boko et al., (2007) reported that extreme climate conditions may add more pressure to already threatened ecosystems in the region. Studies shown that in Nigeria agricultural activities suffer from extreme climate events (e.g., Ishaya and Abaje, 2008; Obioha, 2009; Enete and Amusa, 2010; Tambo and Abdoulaye, 2013; Ladan, 2014; Olagunju, 2015; Eludoyin et al., 2017;), only few studies have reported the fate of peasant farmers. Few of the exiting studies have reported generic results from cropping activities with community-based assessments, but further investigations have been deemed necessary from relatively less documented farm community like the present study area. The area represents farm community in the sub-Saharan Africa where plants are generally rain-fed; where consideration of weather and climate is of important concern, and where coping strategies to extreme weather conditions are reportedly low (Campbell et al., 2011).

Agriculture is an essential sector in the sub-Saharan Africa, where it employs over 80% of the population (Lobell *et al.*, 2008). The present research area, Iyanfoworogi is a typical rural community where over 85% of the populations are small-scale farmers (Adewumi and Ujoh, 2012), and most of the farming activities are rain-fed. Studies (e.g., Cooper et al., 2008; Mongi et al., 2010; Eludoyin et al., 2017), have claimed that farming activities in the many parts of Nigeria are susceptible to the influence of climate and weather vulnerability and many small-scale farmers have poor coping strategies. Many studies have also focused on government owned research centers, establishments and institutions (Adesina and Odekunle, 2011; Enete et al., 2011; Mustapha et al., 2012), all of which are non-representatives of the rural areas. The challenges faced by rural areas include poor coping strategies, low literate level and low crop production (Enete et al., 2011), and these may be exacerbated by extreme climatic events. Many of the rural community also lack established monitoring equipment that helps to monitor the existing climatic phenomenon and adequately predict the future. The present study area is hardly known despite its contribution to food security in the state, and this is the case of many resource centres in developing world, which according to the Friedman's core-periphery model are often characterized by degraded environment (Gu et al., 2001).

The time frame for this study is 34 years (1984 to 2018) based on availability of data. Selected Climatic data (Temperature, Rainfall and Windspeed) were daily records and was collected from the archive of Prediction of Worldwide Energy Resource (POWER) programme of the United States of America's National Aeronautics and Space Administration (NASA) data due to absence of ground-based meteorological station in the study area. The study site was chosen for the research work because it is accessible and it has good representation of the purposively selected crops (tree crops, tuber crops, leafy vegetable, and cereals) for the study. The overall aim was to examine the occurrence of extreme climate events, their impacts and people's coping strategies in rural community of the Southwestern Nigeria. Specific objectives of the study are to examine the occurrence of extreme climate events and their attributes over

the farm community, assess the impact of extreme events on crop productivity and coping strategies of the farmers with effects of the extreme events in the area.

## 2. Materials And Methods

### 2.1. Study Area

Iyanfoworogi, a farm community is situated in Ife East Local Government Area, Ile Ife, comprises of eight districts namely Adagba, Aganran, Agidi, Alagba, Aroko, Ayingun, Ladin, and Gidi-ogbo (Figure 1). It is typical rural areas with over 85% are small-scale farmers. The study area was preferred due to its accessibility. The farm products including tree crops (cocoa - *Theobroma cacao*, kola - *Cola acuminata*), tuber/root crop (yam - *Dioscorea rotundata*, cassava - *Manihot esculenta*), cereal crop (maize – *Zea mays*), leafy vegetable (okra - *Abelmoschus esculentus*, vegetables; *Talinum triangulare*, *Amaranthus hybridus*, *Basella alba*, which are the major crops in the study area. The study area exists within the tropical rainforest designated by Koppen's climate classification as 'Af'; characterized by small temperature range throughout the year and usually convectional storms as a result of its proximity to equatorial climate (Eludoyin et al., 2014).

The study area experiences *extreme* seasonal variation in monthly rainfall and also *major* seasonal variation in the apparent humidity. The normal hourly wind speed in the study area experiences *mild* seasonal variation over the course of the time. Iyanfoworogi area has average rainfall of 1,000 to 1,250 mm generally from March to October and a mean relative humidity of 75–100%. Iyanfoworogi farm community has a rising and falling landscape lie beneath by metamorphic rocks and characterized by two types of soils; deep clay soils on the upper hills and sandy soils on the lower portions, which support agriculture (Ajala and Olayiwola, 2013). The study area is one of the major collecting points for plantain, cocoa, palm oil and kernels, yams, cassava, maize, orange and kolanuts in southwestern Nigeria. The crops are cultivated for local markets and also transported by farm marketers to other neighborhood states. Iyanfoworogi inhabitants are primarily town-dwelling farmers and cocoa merchants who live averagely with minimum income of less than 1 US\$ per day per household, due to unhealthy economic condition of Nigeria as a country. Most of the farmers engage in cooperative societies association and trade by-batter to battle the impact of extreme climatic variations on their livelihood. Other economic activities of the Iyanfoworogi farm community includes fishing, livestock and poultry farming, hunting farming, small business enterprises and lime making. The dwellers also involved in iron-smelting which helps in the area of production of iron tools such as hoe and cutlass, which makes crop cultivation easier for farmers and helps in turn bring forth abundant harvests of food.

### 2.2. Data

Data were selected climatic elements and responses of farmers, farm products marketers and government agencies in the area. Climate variables were temperature, wind-speed and rainfall, whose daily records for 34 (1984 – 2018) years were obtained from the database of Prediction of Worldwide Energy Resource (POWER) programme of the United State of America's National Aeronautics and Space Administration

(NASA), because there is no ground-based meteorological station in the study area. Data on farm activities were collected from farmers who cultivated the components crop types (tree crop farmers, tuber/ root crop farmers, cereal farmers and leafy vegetable) in the area. Responses were sought for interview questions which were patterned along the extreme climatic cases that were revealed through the analysis of climate data. Information on impacts of extreme climatic events on the study area was obtained from the selected farmers, who were considered experienced enough to provide adequate information on the study area. The interview format was structured to allow for responses from the selected key informants inform of close-ended and open-ended questions. Information was sought on extreme climate events occurrence, their impacts at different stages of crop production (land preparation, planting, tendering, harvesting) and coping strategies. Also, eight major marketers mostly traders of agricultural products from the study area were selected. Government officers, mainly a management executive and a field officer of the Department of Rural and Extension Service of the Osun State Ministry of Agriculture were selected based on their knowledge on the trend of agricultural activities on the study area. In all 26 Key Informant was selected.

## **2.3. Data Analysis**

Data were first checked for consistency and suspects, especially in the climate data (such as those with negative value or '99', '09' etc.) were removed. Statistical Package for Social Sciences (SPSS) version 21 was used as the analysis tool to generate descriptive statistics like frequency, mean, percentage and standard deviation while boxplots analyzed to identify extreme cases of events. Simple linear regression analysis was used to test the magnitude of the relationship and influence among dependent variable (year/time) and independent variables (climatic variables). Wavelet analysis of signals in time – frequency space into small waves or bit signals (Frick *et al.*,1998) was used to characterize the variability in each of the selected parameters over the period of study. Wavelet analysis was achieved using Paleontological Software (PAST) version 4. Analysis of the responses of Key Informant was done with frequency distribution and Content analysis method.

## **3. Results And Discussion**

### ***3.1. General characteristics of climate***

The general distribution of the selected climatic characteristics over the community, a typical rural farm community, in the Southwestern Nigeria is presented in Table 1. From Table 1, average rainfall is 4.6 mm, and this is very variable across the months in a year (136.2%). The values of the coefficient of variance indicate high variability in rainfall across the months; but with above 100% values between November and April, and in August. High rainfall variability has significant implication for land preparation, planting and tendering of crops (Kyei-Mensah *et al.*, 2019). Also, peak rainfall values were higher in July-August-September (81.1mm, 95.5mm and 100.2mm, respectively) than the other months. The relatively high (95.5mm) peak rainfall value and high value of coefficient of variability (114%) suggest an occurrence of the little-dry season that typically occurs in August (August-break; Adejuwon and Odekunle, 2004).

Table 1  
Mean, variability and peak or range of rainfall, temperature and windspeed over the study area (1984 and 2018)

| Month     | Rainfall         |             | Peak<br>(mm/day) | Temperature |             | Windspeed               |      |             |                          |
|-----------|------------------|-------------|------------------|-------------|-------------|-------------------------|------|-------------|--------------------------|
|           | Mean<br>(mm/day) | (CV)<br>(%) |                  | Mean(°C)    | (CV)<br>(%) | Min<br>–<br>Max<br>(°C) | Mean | (CV)<br>(%) | Min<br>–<br>Max<br>(m/s) |
| January   | 0.46             | 323.91      | 19.80            | 24.16       | 6.75        | 19.10<br>–<br>27.40     | 1.60 | 29.38       | 0.60<br>–<br>3.20        |
| February  | 0.91             | 201.10      | 15.90            | 25.70       | 4.79        | 20.70<br>–<br>29.00     | 1.66 | 23.49       | 0.70<br>–<br>3.00        |
| March     | 2.47             | 141.30      | 34.10            | 26.17       | 3.17        | 22.50<br>–<br>28.90     | 1.77 | 19.77       | 0.90<br>–<br>2.80        |
| April     | 4.42             | 107.92      | 48.10            | 25.95       | 2.70        | 23.70<br>–<br>29.10     | 1.79 | 18.44       | 0.80<br>–<br>3.20        |
| May       | 5.67             | 84.66       | 41.80            | 25.43       | 2.71        | 23.20<br>–<br>28.20     | 1.64 | 18.90       | 0.60<br>–<br>2.70        |
| June      | 7.89             | 87.58       | 55.60            | 24.57       | 2.60        | 22.10<br>–<br>26.30     | 1.71 | 19.88       | 0.70 -<br>2.90           |
| July      | 8.21             | 97.93       | 81.10            | 23.79       | 2.86        | 21.40<br>–<br>26.00     | 1.97 | 19.29       | 0.90<br>–<br>3.00        |
| August    | 7.19             | 114.88      | 95.50            | 23.64       | 2.50        | 21.00<br>–<br>25.20     | 2.01 | 20.40       | 0.90<br>–<br>3.40        |
| September | 9.24             | 84.74       | 100.20           | 24.12       | 2.65        | 21.80<br>–<br>26.00     | 1.61 | 24.84       | 0.70<br>–<br>2.90        |
| October   | 6.38             | 92.01       | 54.60            | 24.68       | 2.63        | 22.50<br>–<br>26.50     | 1.31 | 21.37       | 0.60<br>–<br>3.30        |
| November  | 1.47             | 145.58      | 14.50            | 24.91       | 3.21        | 20.90<br>–<br>26.80     | 1.22 | 20.49       | 0.50<br>–<br>2.30        |

\*Coefficient of Variance (CV)

| Month                         | Rainfall         |             | Temperature      |          |             | Windspeed               |                     |                          |                   |
|-------------------------------|------------------|-------------|------------------|----------|-------------|-------------------------|---------------------|--------------------------|-------------------|
|                               | Mean<br>(mm/day) | (CV)<br>(%) | Peak<br>(mm/day) | Mean(°C) | (CV)<br>(%) | Min<br>–<br>Max<br>(°C) | Mean<br>(CV)<br>(%) | Min<br>–<br>Max<br>(m/s) |                   |
| December                      | 0.53             | 350.94      | 25.30            | 24.06    | 5.20        | 19.60<br>–<br>26.70     | 1.65                | 26.06                    | 0.50<br>–<br>3.40 |
| Overall<br>(Annual)           | 4.58             | 136.2       | 100.20           | 24.76    | 5.05        | 19.10<br>–<br>29.10     | 1.65                | 26.06                    | 0.50<br>–<br>3.40 |
| *Coefficient of Variance (CV) |                  |             |                  |          |             |                         |                     |                          |                   |

In addition, average temperature recorded at the community varied between 23.6°C and 26.17°C; with August recording the lowest average temperature while the average peak occurred in March (Table. 1). There was generally low temperature variability (2.5% – 6.8%), as expected for regions in the tropics. Studies show that areas within tropical areas are characterized with low temperature range (McGregor and Nieuwolt, 1998), probably due to latitudinal influences. In general, rainfall generally increased from its onset in March/April, gradually until it peaked in September (Figure 2a). Figure 2a also reveals annual fluctuations within the study period, providing tendency for occurrence of extreme events. Temperatures, on the other hand fluctuated appear more rapidly in December – March (which correspond to dry season period in the study area), than in other months (wet season) (Figure 2b).

Results of trend analysis also showed that rainfall tends to exhibit complex trend within the study area, fluctuating and appearing to increase in some months while it reduced in others; while the trend was negative in March-August and October, it was positive for most of the dry months (November – February) and September. The low value (less than 1%) of the coefficient determination ( $R^2$ ) obtained in the regression analysis suggest that the change in rainfall does not significantly correspond to change in year (Table 2a). For the mean temperature, most of the months (except January) experienced relative significant (p-value  $\geq 0.05$ ) increase, with the low coefficient of determination ( $R^2$ ) suggesting that factors other than change in date exert greater influence on air temperature (Table 2b). Studies (e.g., Akinbode, et al., 2008; Akpodiogaga-a and Odjugo, 2010; Oguntunde et al, 2012; Eludoyin et al, 2014) have shown that altitude, prevailing trade winds, land use activities, vegetation and proximity to water bodies are important factors that influence temperature changes in southwestern Nigeria.

Table 2  
a: Trend of change in Rainfall (mm)

| Month                                                                      | Constant (a) | Slope (b) | R <sup>2</sup> | P-value |
|----------------------------------------------------------------------------|--------------|-----------|----------------|---------|
| January                                                                    | -27.70       | 0.014     | 0.01           | 0.002*  |
| February                                                                   | -33.67       | 0.017     | 0.01           | 0.003*  |
| March                                                                      | 55.21        | -0.026    | 0.01           | 0.012*  |
| April                                                                      | 86.51        | -0.041    | 0.01           | 0.005*  |
| May                                                                        | 14.24        | -0.004    | 0.001          | 0.767   |
| June                                                                       | 23.94        | -0.008    | 0.00           | 0.704   |
| July                                                                       | 12.05        | -0.002    | 0.00           | 0.937   |
| August                                                                     | 79.48        | -0.036    | 0.002          | 0.146   |
| September                                                                  | -25.27       | 0.017     | 0.00           | 0.472   |
| October                                                                    | 32.79        | -0.013    | 0.001          | 0.455   |
| November                                                                   | -102.28      | 0.052     | 0.06           | 0.000*  |
| December                                                                   | 8.24         | 0.004     | 0.001          | 0.432   |
| Overall (Annual)                                                           | - 27.70      | 0.014     | 0.01           | 0.002*  |
| Linear trend is significant at $p \leq 0.05$ for the asterisked (*) values |              |           |                |         |
| Coefficient of determination (R <sup>2</sup> )                             |              |           |                |         |

Table 2  
b Trend of change in Temperature (°C)

| Month                                                                     | Constant (a) | Slope (b) | R <sup>2</sup> | P-value |
|---------------------------------------------------------------------------|--------------|-----------|----------------|---------|
| January                                                                   | 28.90        | -0.002    | 0.00           | 0.613   |
| February                                                                  | 10.52        | 0.008     | 0.01           | 0.05*   |
| March                                                                     | 10.28        | 0.008     | 0.01           | 0.002*  |
| April                                                                     | 11.08        | 0.007     | 0.01           | 0.001*  |
| May                                                                       | - 0.56       | 0.013     | 0.04           | 0.000*  |
| June                                                                      | - 2.87       | 0.014     | 0.05           | 0.000*  |
| July                                                                      | - 32.87      | 0.028     | 0.18           | 0.000*  |
| August                                                                    | - 19.75      | 0.022     | 0.14           | 0.000*  |
| September                                                                 | - 19.34      | 0.022     | 0.12           | 0.000*  |
| October                                                                   | - 17.30      | 0.021     | 0.11           | 0.000*  |
| November                                                                  | - 22.30      | 0.024     | 0.09           | 0.000*  |
| December                                                                  | - 27.42      | 0.026     | 0.04           | 0.000*  |
| Overall (Annual)                                                          | 28.94        | 0.002     | 0.00           | 0.626   |
| Linear trend is significant at $p \leq 0.05$ for the asterisked (*) value |              |           |                |         |
| Coefficient of determination (R <sup>2</sup> )                            |              |           |                |         |

Table 2  
b Trend of change in Temperature (°C)

| Month                                                                     | Constant (a) | Slope (b) | R <sup>2</sup> | P-value |
|---------------------------------------------------------------------------|--------------|-----------|----------------|---------|
| January                                                                   | 28.90        | -0.002    | 0.00           | 0.613   |
| February                                                                  | 10.52        | 0.008     | 0.01           | 0.05*   |
| March                                                                     | 10.28        | 0.008     | 0.01           | 0.002*  |
| April                                                                     | 11.08        | 0.007     | 0.01           | 0.001*  |
| May                                                                       | - 0.56       | 0.013     | 0.04           | 0.000*  |
| June                                                                      | - 2.87       | 0.014     | 0.05           | 0.000*  |
| July                                                                      | - 32.87      | 0.028     | 0.18           | 0.000*  |
| August                                                                    | - 19.75      | 0.022     | 0.14           | 0.000*  |
| September                                                                 | - 19.34      | 0.022     | 0.12           | 0.000*  |
| October                                                                   | - 17.30      | 0.021     | 0.11           | 0.000*  |
| November                                                                  | - 22.30      | 0.024     | 0.09           | 0.000*  |
| December                                                                  | - 27.42      | 0.026     | 0.04           | 0.000*  |
| Overall (Annual)                                                          | 28.94        | 0.002     | 0.00           | 0.626   |
| Linear trend is significant at $p \leq 0.05$ for the asterisked (*) value |              |           |                |         |
| Coefficient of determination (R <sup>2</sup> )                            |              |           |                |         |

In terms of wind, average windspeed varied from  $1.22 \text{ ms}^{-1}$  to  $2.01 \text{ ms}^{-1}$ , in November and August, respectively. It varied between 18.44% and 29.8% in all the months but the peak occurred in January (see Table 1). The values of windspeed in the region is classified within the 'Light air' ( $0.5 - 1.5 \text{ ms}^{-1}$ ), 'Light breeze' ( $1.6 - 3.3 \text{ ms}^{-1}$ ) and 'Gentle breeze' ( $3.4 - 5.5 \text{ ms}^{-1}$ ) range of Beaufort Wind Force Scale. According to the Beaufort Wind Force Scale, the 'gentle breeze' causes leaves and small twigs to be in constant motion, and as such plants with fibrous roots and light stems are likely to fall during the wind movements. Patterns of changes in windspeed over the study period suggest that windspeed has declined between 1984 and 2018 in all the months, except January (Figure 2c). The results of linear regression analysis that shows the estimates of the level of change indicate significant increase in January while the other months (excluding November and December) experienced significant decrease over the years (Table 2c). In terms of coefficient of determination, the results predict the importance of local variables, which were not determined in this study. Meanwhile, studies show that breakers of windspeed often include vegetation, especially trees or tree crops, increase in built-up or intentional use of wind breakers, such as wind fences (Jawaheer *et al.*, 2019; Sfestos, 2000). In general, the selected climatic variables were weakly correlated; (temperature correlated inversely and weakly with windspeed ( $r = -0.29$ ) and rainfall ( $r = -0.20$ ), and correlation between rainfall and windspeed was also weak but direct ( $r = 0.18$ ).

## **3.2. *Extreme climate conditions***

### **3.2.1. Rainfall**

Extreme climatic conditions in the study area were analyzed using box plots, wavelet transform plots and graphical depiction of days with less than 0.2 mm (frequency of dry day), days with more than 20 mm of rainfall and frequency of days with more than 40 mm of rainfall in 24 hours. The boxplots showed evidences of extreme rainfall event occurring at any time (month) of the year, given the outliers in Figure 3a. The months of July, August and September, particularly showed outliers in excess of rainfall peaks throughout the year, suggesting that the study area may be vulnerable to the effects of excess wetness in these periods. Years 1988, 1997, 2006, 2008 and 2018 were the periods of the July-September outliers. Figures 3b-c, which show the frequency of days with a minimum of 20mm, and 40mm, respectively, reveal that the occurrence of heavy rainfall fluctuated within the study period (1984-2018). The fluctuation suggests difficulty for accurate prediction of the heavy rain period, and such may have dire consequences for cropping activities. For example, while April became drier since 2012, and May since 2017, the months of June- September became wetter (Figure 3b). Also, August and September have experienced 1-2 episodes of above 40 mm rainfall in 2017 and 2018, at variance to what the experience was in some years earlier (Figure 3c). In general, the results of the wavelet transform plot (Figure 3d) shows an unclear band of consistent change in low signal (blue colour) at the upper limit, that are likely to be associated with noise; missing data is not suggested as there were none. The red band in the middle indicates high disturbance in signals, correlating with relative uniformity in rainfall in the mid-period of the year. Also, the different shapes in the patterns observed in the wavelet result suggest irregular temporal pattern in rainfall across the study period. These irregular patterns are consequent of daily, monthly and annual variability in rainfall. Consequently, the results suggest significant variability in both the average and extreme rainfall events in the study area; a condition that may pose challenges in the understanding of climate condition by farmers who depend only on past experience.

### **3.2.2. Air temperature**

In terms of air temperature (Figure 4a), variability occurred more in December and January than the rest of the months, probably due to the prevalence of Harmattan, which typically dominates the dry season in these months. The Harmattan is a cold dust-laden wind from the Sahara Desert, brought by the Tropical Continental (cT) airmass, that accompanies the hot dry season between December and March (Eludoyin et al., 2014). The air temperature relatively declined from April before rising in September. In general, extreme air temperature condition in the study area is expectedly low (lower than that of the rainfall), as low temperature variability is an important characteristic of areas in the tropics (Jauregui, 1991).

The wavelet transform plot shows two clear distributions of the signals; the upper with low signal disturbance (blue) and the lower part with high disturbance (red band), suggesting relative uniformity in temperature in most part of the time (Figure 4b). Unlike rainfall, the patterns shown in the wavelet results were more regular and predictable, indicating lesser daily, monthly/ seasonal and annual variabilities in temperature than rainfall. The relative uniformity in the air temperature however varied over the months;

plots showing the frequency of dry days (days with less than 0.2mm) across the study period showed irregular fluctuations over the years (Figure 4c). Expectedly, the dry season months (December – March) recorded more peaks of dry days than the other months. Also, whereas the number of dry days has reduced in most of the months, they (dry days) have increased in March, April, May, July and August (Table 3).

Table 3  
Trend (linear regression;  $a \pm bx$ ) of dry day frequency

| Month     | Regression equation | Coefficient of Determination |
|-----------|---------------------|------------------------------|
| January   | 29.866 - 0.056x     | 0.0403                       |
| February  | 25.56 - 0.093x      | 0.0655                       |
| March     | 18.012 + 0.0311x    | 0.0026                       |
| April     | 9.7395 + 0.0748x    | 0.0177                       |
| May       | 4.3277 + 0.077x     | 0.027                        |
| June      | 3.684 - 0.0459x     | 0.0234                       |
| July      | 3.2303 + 0.0412x    | 0.0108                       |
| August    | 5.0706 + 0.0532x    | 0.0117                       |
| September | 2.3529 - 0.0434x    | 0.0568                       |
| October   | 9.8 - 0.2x          | 0.2133                       |
| November  | 26.531 - 0.2501x    | 0.2838                       |
| December  | 29.393 - 0.0552x    | 0.0198                       |

### 3.2.3. Wind speed

Wind speed generally occurred at relative extreme in 1988, 1991, 1998 and 2015, and the extreme cases occurred more in December, January, April and August (Figure 5a) The mean values were however not prominently different, and comparison with Beaufort Scale does not suggest an extreme windy day in the area. The peak windspeed is in the category of 'Gentle Breeze', and this has only occurred in August and October (Figure 5b). Figure 5b also reveals varying monthly variations in the pattern of windspeed across the months. Windspeed generally become more rapid in January, February and August.

## 3.3. Characterization of farms and farmlands

### 3.3.1. Demography and socio-economic characteristics of farmers

Farmers in the study area are mostly small-scale farmers; and selected participants in this study are largely adults (aged 30 – 67 years), majority of who are male (68.8%); 18.7% are chiefs in the study area

(about eight villages and the administrative community, Iyanfoworogi farm community). Half (50%) of the participants were born in the village, and with the rest participants have been involved in cropping activities for between five and forty years (Table 4a). Table 4 also showed that all the participants have acquired a form of formal education (at least primary education) and often make use of hired labour or family help, except those who largely cultivate leafy vegetables. Female dominated cultivation of leafy vegetable while tree cropping was largely controlled by male farmers; both male and female farmers were involved in tuber and cereal cropping. All the farmers work on full-time, and each of the eight villages produce crops worth between 5 – 198 million naira (US \$13071 - US \$510309 at December, 2020), annually. In general, the farmers are not stack illiterates as many literatures depicted farmers in many parts of sub-Saharan Africa (Brooks et al., 2013; King and Palmer, 2010; UNESCO, 2004; Lockheed et al., 1980). The farmers were sufficiently intelligent to understand climate conditions, and impacts on their farm activities in the area.

Table 4  
Characteristics of the farmers in Iyanfoworogi farm community

| Characteristics                              | Crop types                    |                               |                     |                     |
|----------------------------------------------|-------------------------------|-------------------------------|---------------------|---------------------|
|                                              | Tree crops                    | Tuber                         | Leafy vegetable     | Cereals             |
| Age group of people involved                 | 30-67                         | 30- 65                        | 30- 65              | 30-65               |
| Educational Status                           | Primary, Secondary & Tertiary | Primary, Secondary & Tertiary | Primary & Secondary | Primary & Secondary |
| Gender                                       | Male                          | Male & Female                 | Female              | Male & Female       |
| Dominant crops                               | Cocoa                         | Cassava                       | Green vegetable     | Maize               |
| Labour type                                  | Hired/Family                  | Hired/Family                  | Family              | Hired/Family        |
| Length of residence (years)                  | 30 – 60                       | 15 – 60                       | 5 – 40 years        | 5 – 50 years        |
| Average annual income (in Naira) per village | 198,000,000                   | 20,000,000                    | 5,000, 000          | 40,000,000          |
| Farming time                                 | Full-time                     | Full-time                     | Full-time           | Full-time           |

### 3.3.2. Characteristics of the farm

Selected cropping activities at Iyanfoworogi Farm community are characterized with comparable farm size, land tenure system, cropping method and farm input (Figure 4b). Tree crops occupied 1 – 4 ha of land that was acquired through lease, purchase or inheritance. Tuber and cereal crops farms occupied 1-2 ha but while most farms used for tuber were either leased, purchased or inherited, that used for cereals cropping were less likely to have been leased/hired. The importance as attached to a type of crop may

influence type of land allocated to it. For example, perennial crops, especially tree crops are likely to be cultivated on owned (e.g., inherited or purchase) piece of land than leased piece of land while a hired piece of land is more likely to accommodate short-term (biennial, annual or biannual) crops like tuber and leafy vegetables. It is, nonetheless, surprising that land tenure system for cereals (which is essentially an annual or biannual crop) farms were not dominantly hired/leased. Leafy vegetable farms were generally small, and understandably occupied more leased/hired piece of land, probably because they are essentially short-term farming and are largely operated by non-indigenes, female, young people or as a part of other major cropping activities. With respect to cropping methods, dominant method is the mixed cropping system, although few tree crops farmers engage in mono-farming. Mixed cropping or multiple cropping or multi-cropping is the usual practice of growing two or more crops in the same piece of land during one planting season (Abhisek, 2020). In the study area, mixed cropping was practiced, partly for raising income from the farms. In addition, mixed cropping is practiced in the tuber crops farms, mainly to serve as wind breakers, and reduce the impact of wind erosion, among others, or as a precautionary loss supplement as in the case of a 65-year-old key informant who recounted that:

*'Weather nowadays is unpredictable. I engaged in mixed farming to have maximum gain and so as not to have the experienced I had in the past. Before, I practiced mono-cropping, cultivating mainly cocoa, until 2006 when was heavy rains of July/August nearly caused me to lose my entire cocoa farm. It was an unforgotten year for me, and even to survive it was terrible for me and my family. Since then I have been engaging in mixed farming for survival so that if such bad climate incidence happens again I will not loss all. It was this type of situation that turned me to a mixed crop farmer.'*

Seventy-five (75%) of the farmers apply fertilizers and pesticides to their farms for improved yield. Fertilizers are often applied March – April and June – August in the farms. Also, 43.8% of the farmers also used pesticides to treat the infestation of pests and related diseases in March – April, and 56.3% apply pesticides in June – August.

### **3.4. Effects of extreme weather conditions**

Analysis of the perception of selected key informants on the effects of extreme weather conditions is provided in Figures 7(a-c), for rainfall, temperature and wind extremes, respectively. All the key informants perceived that excess (heavy) rainfall, early and late rainfall onset and cessation, as well as irregular rainfall occurrence are extreme rainfall conditions (Figure 7a), and that dry spell, low and high temperature as well as perception of increased temperature is known temperature extreme conditions (Figure 7b). Windy condition such as is also considered an extreme meteorological event in the study area. Most of the farmers and marketers complained of a general shortfall due to the identified extreme weather conditions. Responses from the farm community show a reasonable level of consideration for weather/climate by the farmers. For instance, a male key informant (aged 63 years old) responded to a question requesting if and why they consider weather thus:

*I study the trend of weather condition and I always prepare ahead, I have been in this farming business for close to 50 years now so I don't joke with weather condition. I know the best weather period for each crop,*

*because I don't have any other work, so I must study the trend of weather very well, though in year 2018 a lot of farmers in this community complained about bad weather conditions, but my son, I have a very high yield output as that of year 2016 and 2017'.*

Opinion of key informant indicates that a thorough understanding of the weather condition and capacity to predict the climate is essential for farmers in the area. Conversely, other key informants, who lost 'massively' to a flood event in 2018, appeared to consider a spiritual involvement in the weather conditions. For instance, one of them argued that the hope on miracles to sustain their productivity under extreme climate conditions.

### **3.5. Perception on coping strategies**

Specific extreme climate conditions, the impact and corresponding coping/adaptive strategies, identified in the study area, are presented in Table 5. Reported extreme climate conditions include drought, increased heat condition, and delayed or late rainfall. Drought, experienced in terms of loss of yield and land degradation was adapted to by planting of drought resistant varieties of crops, including cassava, banana and cocoyam. Sixty-five percent of the key informants engaged in planting drought resistance plants to avoid absolute loss in case of drought condition, and 35% only prayed according to their faith. In terms increased heat condition, seeds and seedlings are typically destroyed by heat, leading to poor yield. The farmers also responded to the condition of increased heat the same way they did as for drought resistant crops. However, banana, cocoyam as well as trees such as teak and palm trees are used as 'protective' or 'cover' crops whose broad leaves are used shed the planned crops, including cocoa seedlings. Also, some of the farmers cut leaves of banana and other leafy short trees to protect their cocoa seedlings and young cocoa farms. Furthermore, leafy vegetable farmers usually cultivate around flood plains but they also complained of the destructive impact of mining activities on the floodplains, especially along River Owena.

**Table 5: Extreme weather conditions and coping/adaptive/responsive strategies among farmers**

| Extreme weather condition  | Effects                                                                                                                                                                                                                         | Coping/Adaptive/Responsive Strategies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Drought                    | <ul style="list-style-type: none"> <li>• Loss of yield</li> <li>• Land degradation</li> </ul>                                                                                                                                   | <ul style="list-style-type: none"> <li>• Planting of drought resistant varieties of crops, e.g. cassava, banana and cocoyam</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Increased heat/temperature | <ul style="list-style-type: none"> <li>• Loss of seed</li> <li>• Loss of yield</li> </ul>                                                                                                                                       | <ul style="list-style-type: none"> <li>• Cultivation and use of cover crops: A farmer describe this as 'planting of banana and cocoyam as cover crops before the intended crops (maize and cassava) are cultivated. The broad leaves of the cover crops to shed (protect) the maize and cocoa seedlings from the scotching sun (heat) during hot weather and drought'.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Excess rainfall            | <ul style="list-style-type: none"> <li>• Floods</li> <li>• Pests and diseases</li> <li>• Loss of crop yields</li> <li>• Soil erosion</li> <li>• Land degradation</li> <li>• Problems with transporting farm products</li> </ul> | <ul style="list-style-type: none"> <li>• Mixed cropping to reduce the burden of loss; multiple crops are cultivated rather than a single cropping. For example, cassava, maize, cocoa, palm tree, banana and vegetables with cocoa</li> <li>• Prayers; seeking divine intervention</li> <li>• Cropping rotation: Farmers replace infested crop with other crops e.g. replacing maize with cassava in following planting season to overcome pest/disease infestation, which usually occur after flood</li> <li>• Shifting cultivation strategies: Practiced when land is available to overcome pest/disease infestation</li> <li>• Use (spraying of crops) of chemical pesticides</li> <li>• Use of motorcycles and labourers as replacement for vehicles (buses and cars) during flood</li> </ul> |
| Delayed/Late rainfall      | <ul style="list-style-type: none"> <li>• Loss of crop yield</li> <li>• Loss of crop input during faulty planning season</li> </ul>                                                                                              | <ul style="list-style-type: none"> <li>• Working on experienced based-forecast of delayed/late rainfall; experience indicates 3-4 years for recurrence period. During expected period crop planting is reduced ('scaled-down') by farmers to reduce loss. Warning signals include fluctuation in Harmattan</li> <li>• Change of occupation: some farmers left crop cultivation to get involved in trading (buying and selling) of farm produce</li> </ul>                                                                                                                                                                                                                                                                                                                                         |

Excess rainfall in the study area was associated with floods, increased prevalence of pests and diseases, loss of crop yields, soil erosion and land degradation. Farmers' adaptive or coping strategies include mixed cropping, crop rotation, shifting cultivation and many of the respondents claimed to offer prayers. About 65% of the key informants engaged in mixed farming and cultivation of multiple crops to reduce the burden of loss to the extreme climatic condition or its effects. In addition, popular pesticides used in by the farmers include Black pod, Red force, blue bot, Ridomine, Ultimax, Gamale 20, Rocket and AK 47. Furthermore, delayed or late rainfall was linked to loss of crop yield due to faulty planting period. Coping strategies for delayed or late rainfall, include reducing the strength of planting (scaling down on crops'), changing planting date due to unpredicted climate/weather change; 85% of key informants predicted a cycle of '3-4' years of unfavourable climate. In the period of the 'unfavourable weather condition', the

farmers claimed to increase their use of pesticides and fertilizers, and this often raise the cost of farming. Only about 15% of the farmers whose farmland were around the River Owena floodplain are less affected by the 'change' in weather condition and consequently do not often alter the 'normal' planting season, but adapt by machine-facilitated-irrigation-spray from the river. In general, capacity to respond to any of the identified strategies were based on farmer's experience and socio-economic status; the few wealthy farmers tend to respond better by increasing the purchase of fertilizers, pumping machines, pesticides, etc. Also, transportation network which is vulnerable to flood conditions often requires communal efforts during the flooding season.

Many of the Key informants also revealed that their past experience of delayed/late rainfall has enhanced their preparedness for any of the present and future occurrences. They largely proclaimed to seek divine intervention for preparedness for and coping with the effects of the extreme climatic effects, while decrying the non-performance of the government sector. They alleged total negligence by the government, despite their contribution to the State's economy. When the key informant from the government department of Extension Office was asked, their response suggested that the representatives rarely visit the farm community for fear of intimidation, poor support and poor understanding of the government plans for the farm community.

## 4. Conclusion

Cropping activities (including farming and marketing) in the study area are affected by extreme climate condition and climate variability. It is difficult to project future climatic events based on the experience of farmers alone due to the extreme climate events. Cropping activities are limited by extreme climate scenarios and poor coping strategies in the area. The poor coping strategies appear to have been exacerbated by disconnect with appropriate government agency. Consequently, the study recommends creation of platform for awareness of extreme climatic events, their impacts and enhanced coping strategies among the residents, especially in the rural community, where majority have low socio-economic status. The study also recommends improved relationship between actors in cropping activities and relevant government agency (Rural Extension workers). At present, evidence from this study revealed sore relationship, and thus has greater impacts on farming activities in the study region. Lastly, improved road links with farm communities is recommended. This will improve the capacity of the people to handle the consequences of extreme events.

## Declarations

### **Ethics approval and consent to participate**

**Ethical approval:** Approval to conduct social surveys was obtained through the Obafemi Awolowo University, Ile-Ife, Nigeria

**Consent to participate:** All the participating authors agree to participate in the research.

**Consent for publication:** All the participating authors agree to participate to publish the manuscript in this preferred journal.

**Funding:** The research was not funded by any governmental or non-governmental institution.

**Data availability:** Data are available in repository with the Obafemi Awolowo University, Ile-Ife, Nigeria.

**Competing of interest:** There is no competing interest by the authors.

**Authors' contributions:** AOE designed the research as a supervisor with OOA as co-supervisor while AAA was a research student. AOE guided AAA in the analysis and interpretation of the data while OOA read through and edited the initial draft. All authors read and approved the final manuscript.

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## Figures

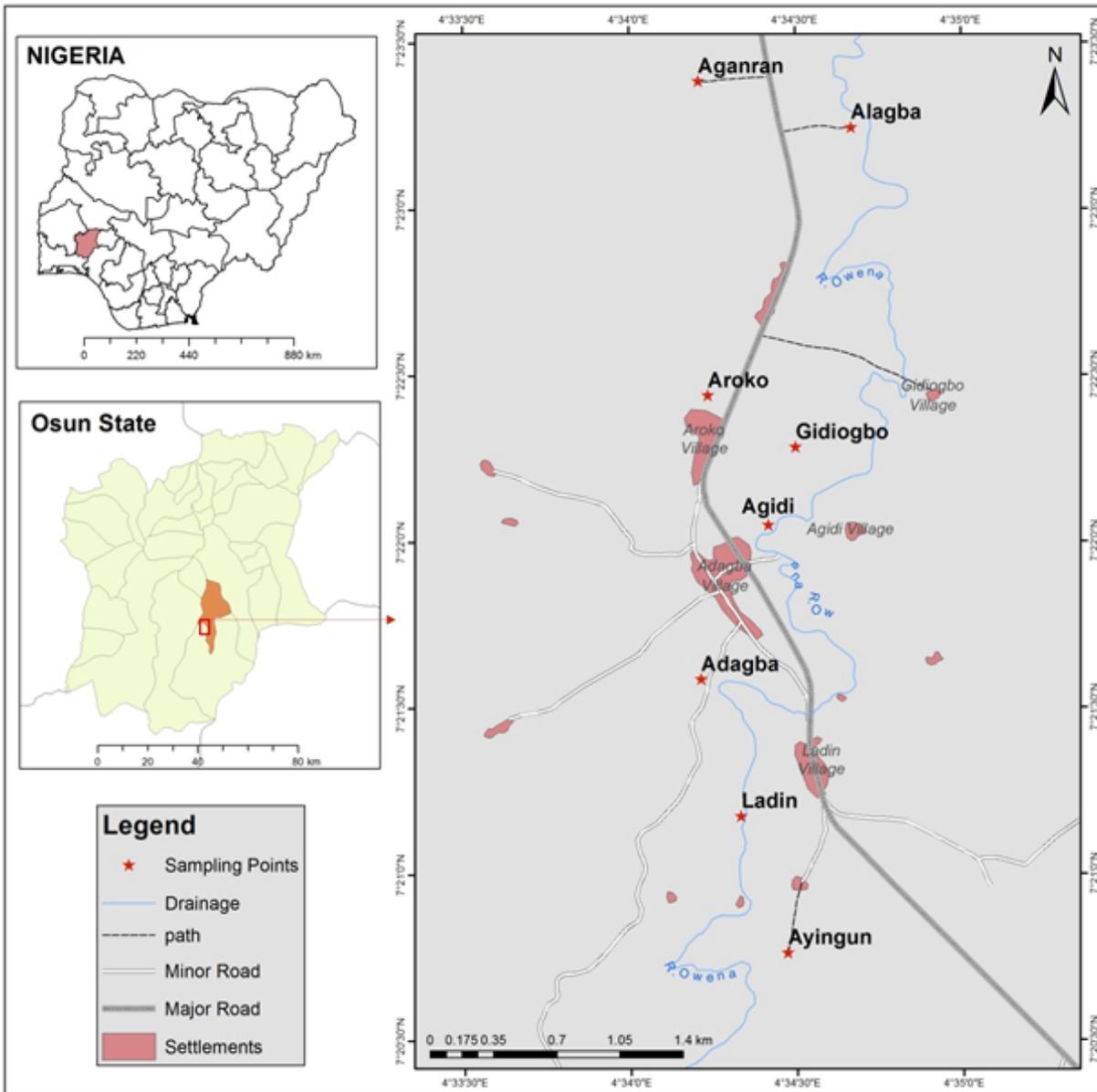
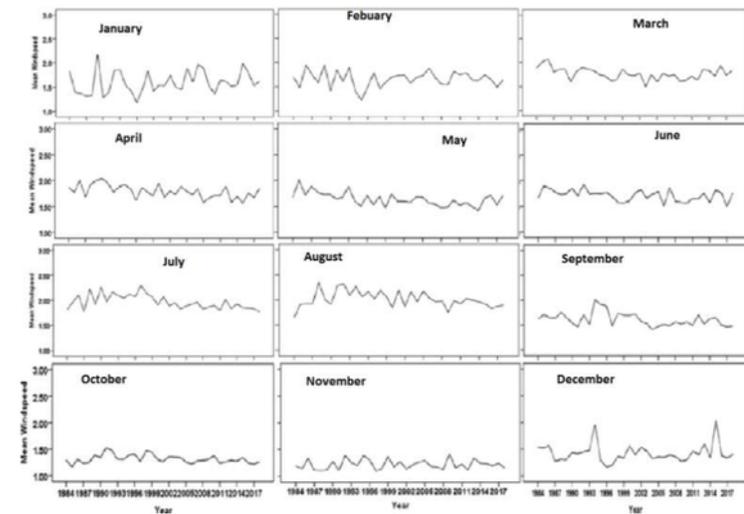
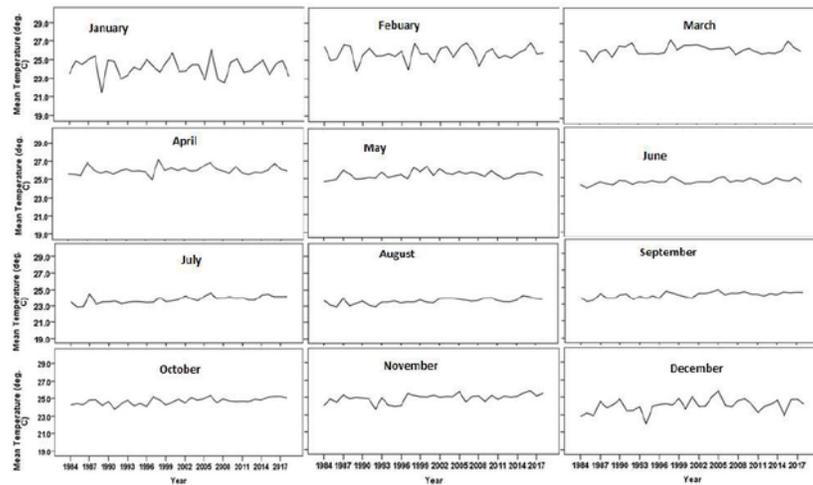
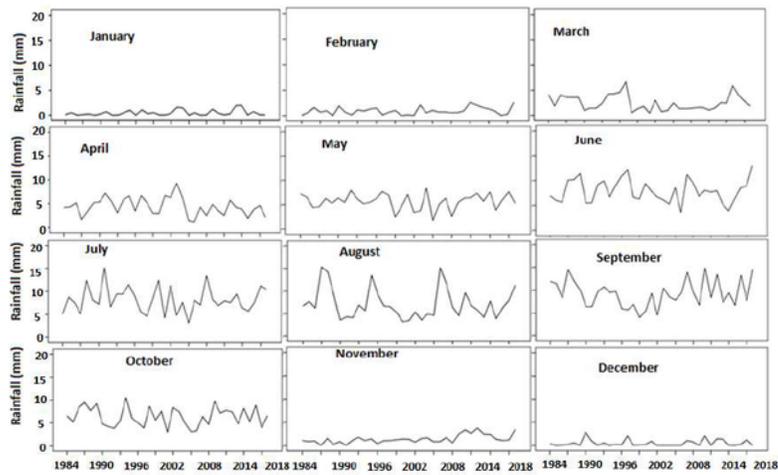


Figure 1

The study area, Iyanfoworogi farm community in southwestern Nigeria

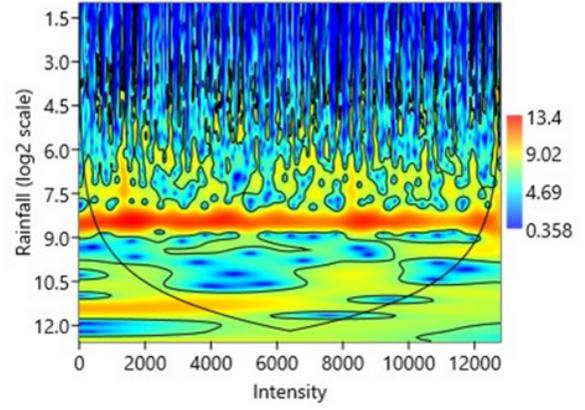
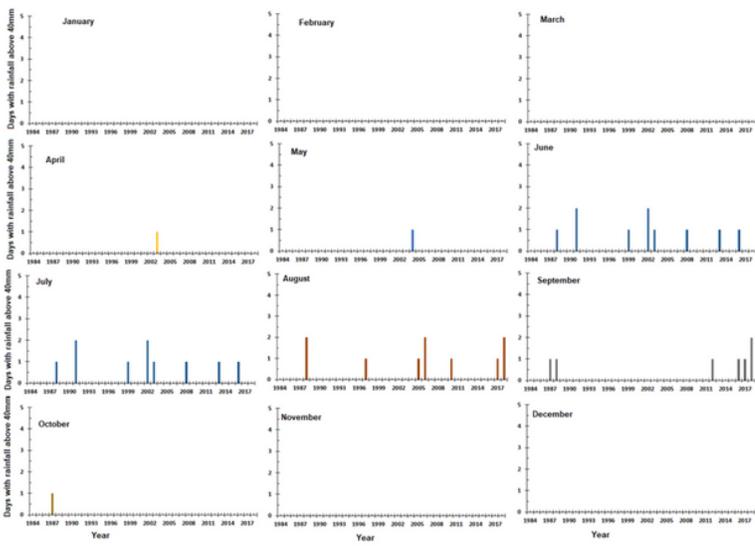
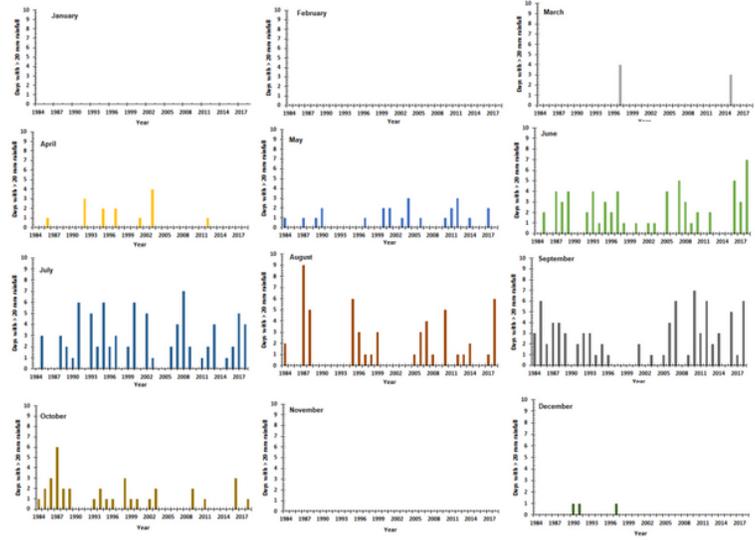
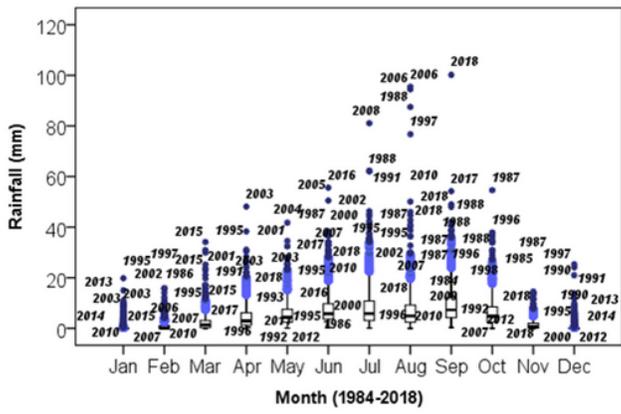


**Figure 2**

a: Variability in average monthly rainfall over the study area

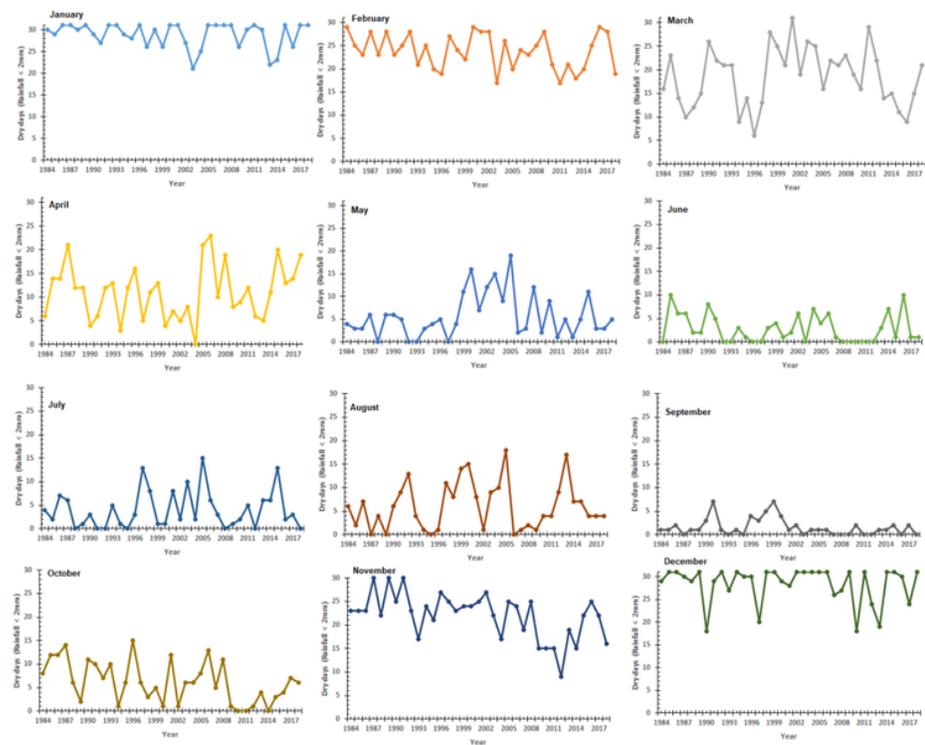
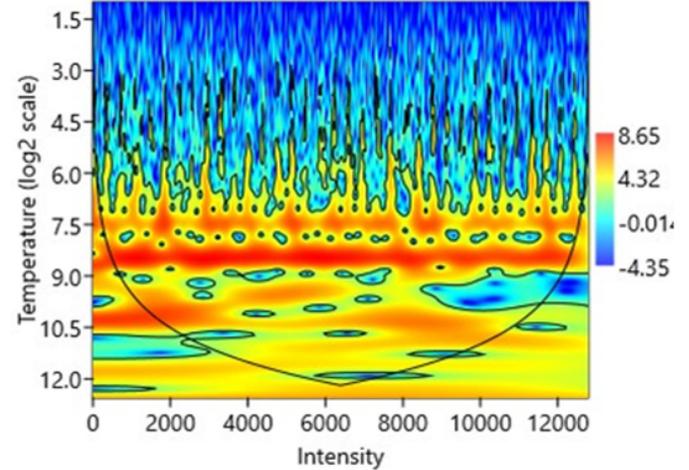
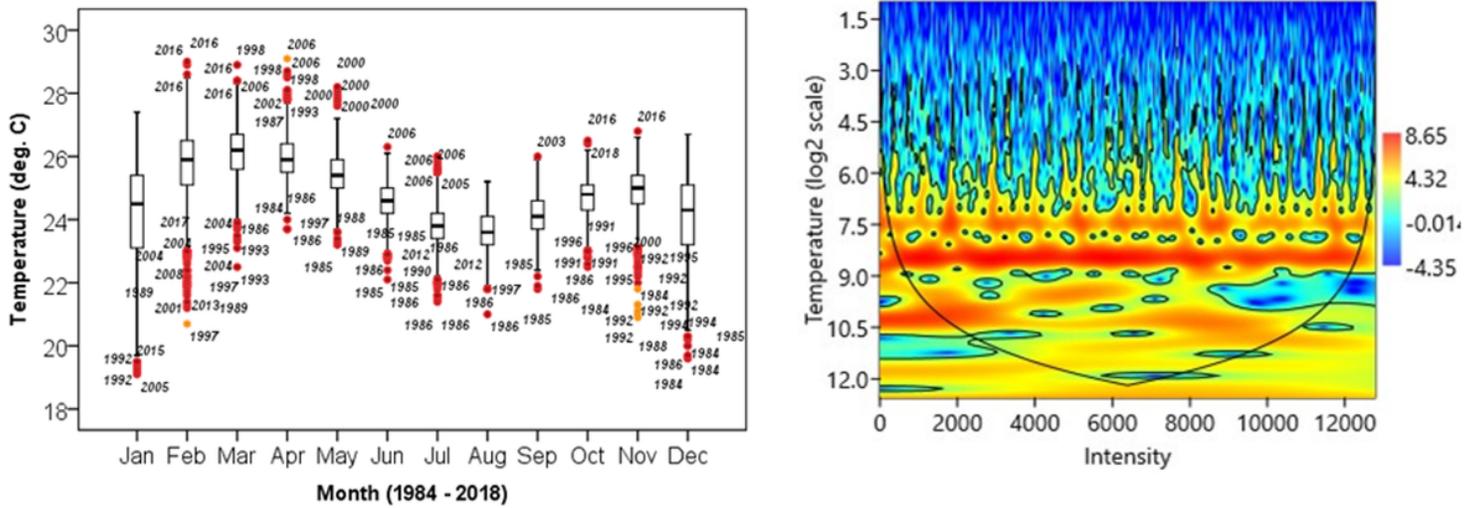
b: Variability in average monthly temperature

c: Variability in average monthly wind speed



**Figure 3**

- a. Boxplots showing the period of extreme rainfall events (outliers) in the study period
- b. Distribution of days with more than 20 mm of rainfall
- c. Distribution of days with more than 40 mm of rainfall
- d. Wavelet transform of rainfall (daily record; 1984-2018) over the study area



**Figure 4**

- a. Boxplots showing the period of extreme temperature events (outliers)
- b. Wavelet transform of air temperature (daily record; 1984-2018)
- c. Distribution of dry days with less than 0.2 mm rainfall

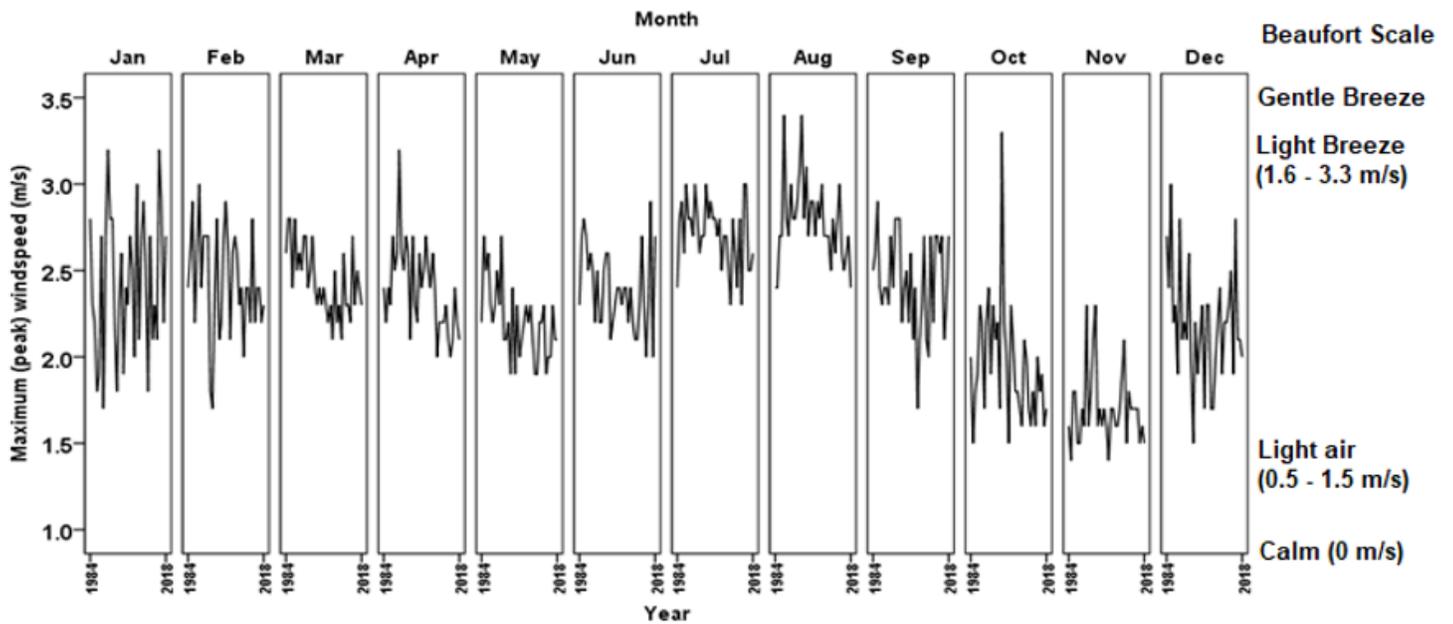
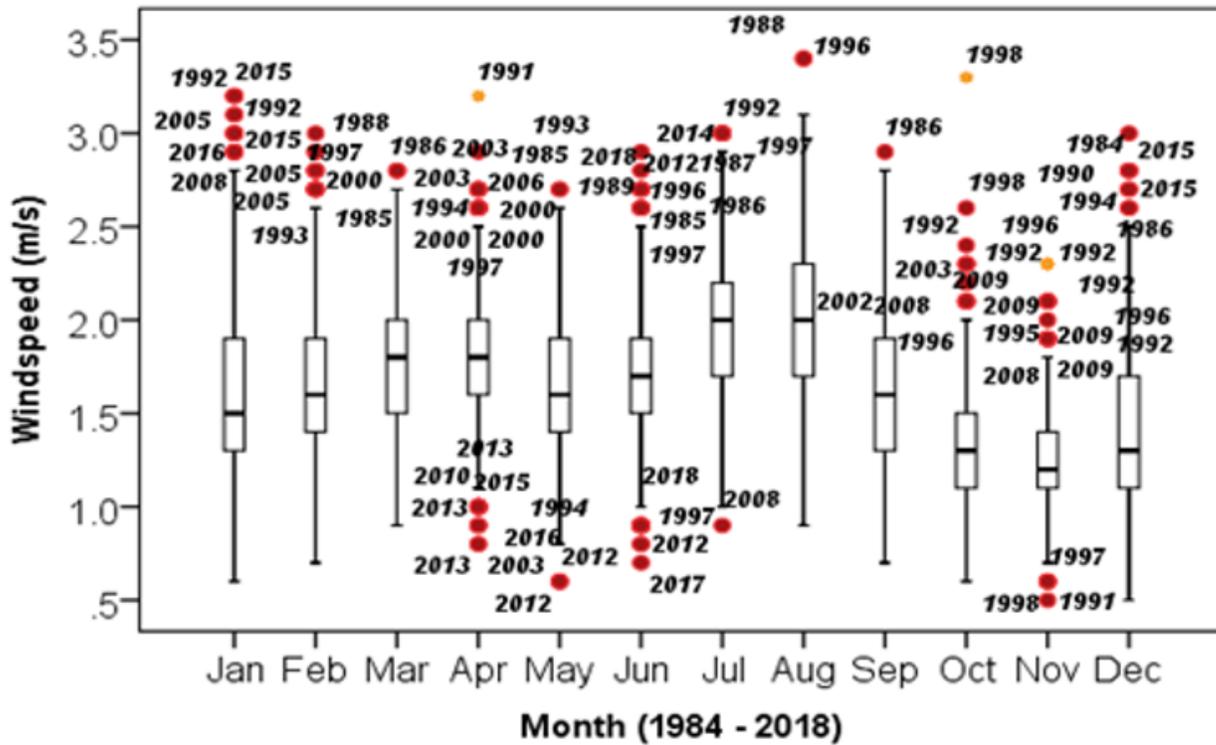


Figure 5

- a. Boxplots showing the period of extreme wind events (outliers) in the study area
- b. Pattern of daily windspeed at different month within the study period

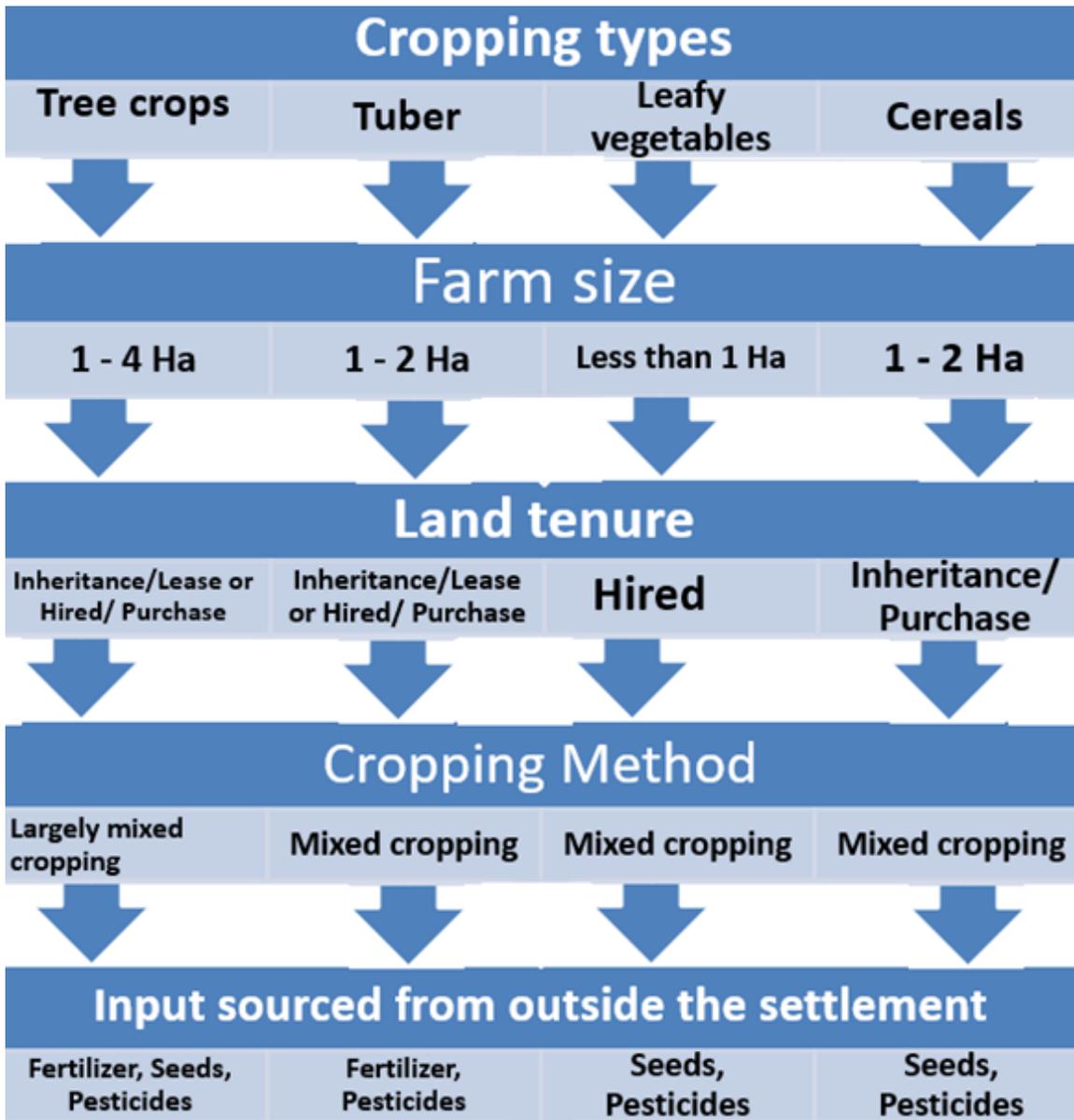


Figure 6

Characteristics of cropping systems in Iyanfoworogi Farm Community

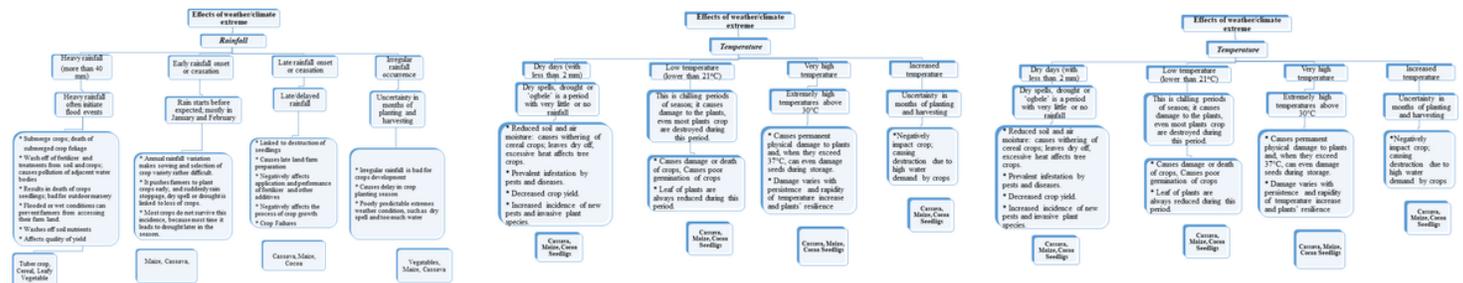


Figure 7

a: Perception on extreme temperature events and effect on cropping activities

b: Perception on extreme rainfall events and effect on cropping activities

c: Perception on extreme wind events and effect on cropping activities

## Supplementary Files

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