**JOURNAL OF METEOROLOGY AND CLIMATE SCIENCE**
**J. Met & Clim. Sci. 22(1): 195-224 (June, 2023)**

# Agro-climatic zonation based on rainfall distribution over Ondo State, South-Western, Nigeria

**OMONIJO Akinyemi Gabriel *, [1], OLUTUMISE Adewale Isaac [2] and OLADITAN Titilaylo Olabimpe [3]**

1. Department of Water Resources Management and Agrometeorology, Federal University Oye-Ekiti (Ikole-Ekiti Campus) Ekiti State, Nigeria.

E-mail: akinyemi.omonijo@gmail.com

2. Department of Agricultural Economics and Extension, Adekunle Ajasin University, P.M.B.001, Akungba-Akoko, Ondo State, Nigeria.

E-mail: adewale.olutumise@aaua.edu.ng; firstwalefat@yahoo.com

3. Department of Crop, Soil and Pest Management, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria.

E-mail: to.oladitan@oaustech.edu.ng; ditanbimpe@gmail.com

* Corresponding Author: E-mail: akinyemi.omonijo@gmail.com; Tel: +2348036196217

**OMONIJO Akinyemi Gabriel *, [1], OLUTUMISE Adewale Isaac [2] and OLADITAN Titilaylo Olabimpe [3]**

**Abstract:**

The study focuses on the agro-climatic zonation based on rainfall distribution patterns using ArcGIS for mapping; it also employed frequency distribution to analyze rainfall data in Ondo State, Nigeria using rainfall data of 30 years' period (1991 – 2020). The result showed that rainfall amount is not a serious problem in plant growth in the humid tropics compare to the availability of soil moisture which is a major factor. The results of seasonal distribution patterns in accordance with the seasonal method employed in this study shows that January and February (dry months) recorded rainfall ranged from 3 mm to about 27 mm; the rainfall recorded ranged from about 95 mm to 130 mm in the months of March and April (Transition into wet season), while the recorded rainfall for the months of May to July (Wet season I) is about 190 mm and 275 mm. The rainfall recorded in the month of August (little dry season) is between 166 mm and about 208 mm. The rainfall data used in this study revealed month of August as little dry season contrary to results of some studies that shows that little dry season is now a July – August phenomenon, and not just August alone. The rainfall recorded ranged from about 203 mm to about 275 mm in the months of September and October (Wet season II), while that of November and December (Transition into dry season) is between 11 mm and about 40 mm. Although several studies have speculated that climate change will make weather and climate of some countries in Sub-Sahara Africa become unstable, the results show that little dry season popularly called "August Break" is anomalous. It shows clearly from this study that rain-fed agriculture is most viable in between Transition to Wet Season and Wet Season II. The recorded annual rainfall amounts ranged from about 1200 mm to 1600 mm in the northern side and between 1800 mm and about 2000 mm in the southern side of the study area. It is observed from the results of this study that rains do break after initial

rains. Therefore, it is important to advice farmers not to rush to plant crops such as maize with early rains because there is no assurance that the rains will not stop and this will lead to plants wither before steady rains.

**Keywords:** Rainfall, rain-fed agriculture, frequency distribution, seasonal distribution, agro-climatic zonation, mapping, Ondo State, Nigeria.

## 1.0 Introduction

Agro-climatic zonation is known as the process of delineating areas into homogeneous zones based on their agro-climatic attributes for the purpose of producing a particular crop. Zonation involves both classification and regionalization based on a set of agro-climatic criteria dictated by the climatic requirements of a given crop. Agro-climatic zonation is used to evaluate the crop production or yield potential of an area. In 1985, Nix defined agro-climatic zones in the Tropics using a combination of concepts of temperature and moisture criteria (Table 1).

Climate is the main determinant of what, when and where crops can be grown productively. For every tropical site, rainfall is the most important climatic determinant in rain-fed agriculture (Olivares, 2018).

The role of moisture in agricultural production is even more spectacular in the tropics because of relatively high temperatures that prevail throughout the year and the rates of evapotranspiration are constantly high (Siderius *et al.*, 2016). On the other hand, rainfall is highly seasonal over most parts of the tropics and varies in amounts from one year to another. Because temperatures are high enough throughout the year to ensure crop growth in the tropics with the notable exception of a few mountainous areas, the growing season in the tropics is determined by the availability

of rainfall to meet crop water requirements (Dauda *et al.*, 2014).

The usefulness of agro-climatic zonation is a rational selection of sites for crops or of crops for sites, that is, the process of delineating areas into homogeneous zones based on their agro-climatic attributes for the purpose of producing a particular crop (Taye *et al.*, 2019; van Wart *et al.*, 2013; Wani *et al.*, 2009). In other words, they enable farmers to make rational decisions on which crops to grow and which ones not to grow in a given agro-climatic zone or area based on the combination of temperature and moisture (rainfall) according to Nix (1985).

Since the beginning of recorded history on agriculture, farmers have always been interested in assessing the size of their future harvest in relation to what they have sown. On a wider scale, it has also influenced Governments wishing to make conservative food balance estimates for their countries (Chipanshi *et al.*, 1997; 1999).

In the past, there have been numerous attempts by several researchers to quantify crop climate relationships (Afolabi *et al.*, 2009; Ayoade, 2002; Joshi *et al.*, 2011; Kukal and Irmak, 2018). Yield fluctuations are often a consequence of weather fluctuations but it is unlikely that crop yield variations can be linked exclusively to one climatic parameter. Sometimes, crop yield may be attributed to one or two dominant parameters (Riebsame, 1989).

This study enables farmers to make an appropriate choice of farmland that is favourable to their desire crop with respect to climate variables in advance. It also helps in assessing the impacts of climate variations and climate change on crop yield. Knowledge of such impacts will form the basis for the choice of appropriate strategies for adaptation of agriculture in a given location to variations or changes in climate.

## 2.0 Materials and methods

### 2.1 Study area – Location, Size, Landform and Climate

Ondo State which is situated between longitudes 4°15′ E and 6°00′ E and latitudes 5°45′ N andn7°45′ N which is the north of the equator in the South-Western Nigeria (Figure 1). The State has 18 local government areas with a population of about 3,440,000 of which the rural population constitutes about 1.7 million and land area of 14,606 km2 (NPC 2006). It has three major landform characteristics. The coastal plains basically alluvium which occupy about 20 %; lowland and undulating plains constitute about 60 % of the land mass, while undulating lands with scattered rocks and hills occupy the remaining 20 % of the land area. It has the tropical wet-and-dry climate with a mean annual rainfall ranged between 1500 and 2000 mm. The mean annual maximum air temperature is about 34 °C, and a mean minimum air temperature, of about 20 °C (Adefolalu 1997). The climate of the area is also affected by inter-tropical discontinuity as a result of seasonal winds that blow from the north (North African anticyclone) and the one from the south (St. Helena anticyclone) during dry months. During the wet season, the climate is affected by Azores anticyclone from the north and St. Helena anticyclone from the south. Other factors that influence the climate of Ondo State are its location near the Atlantic Ocean and the existence of vegetation/ forest and mountains. The dry season is also characterized by Harmattan dust haze and hot and dry northerly winds that blow from the Sahara Desert over West Africa.

**OMONIJO Akinyemi Gabriel *, [1], OLUTUMISE Adewale Isaac [2] and OLADITAN Titilaylo Olabimpe [3]**

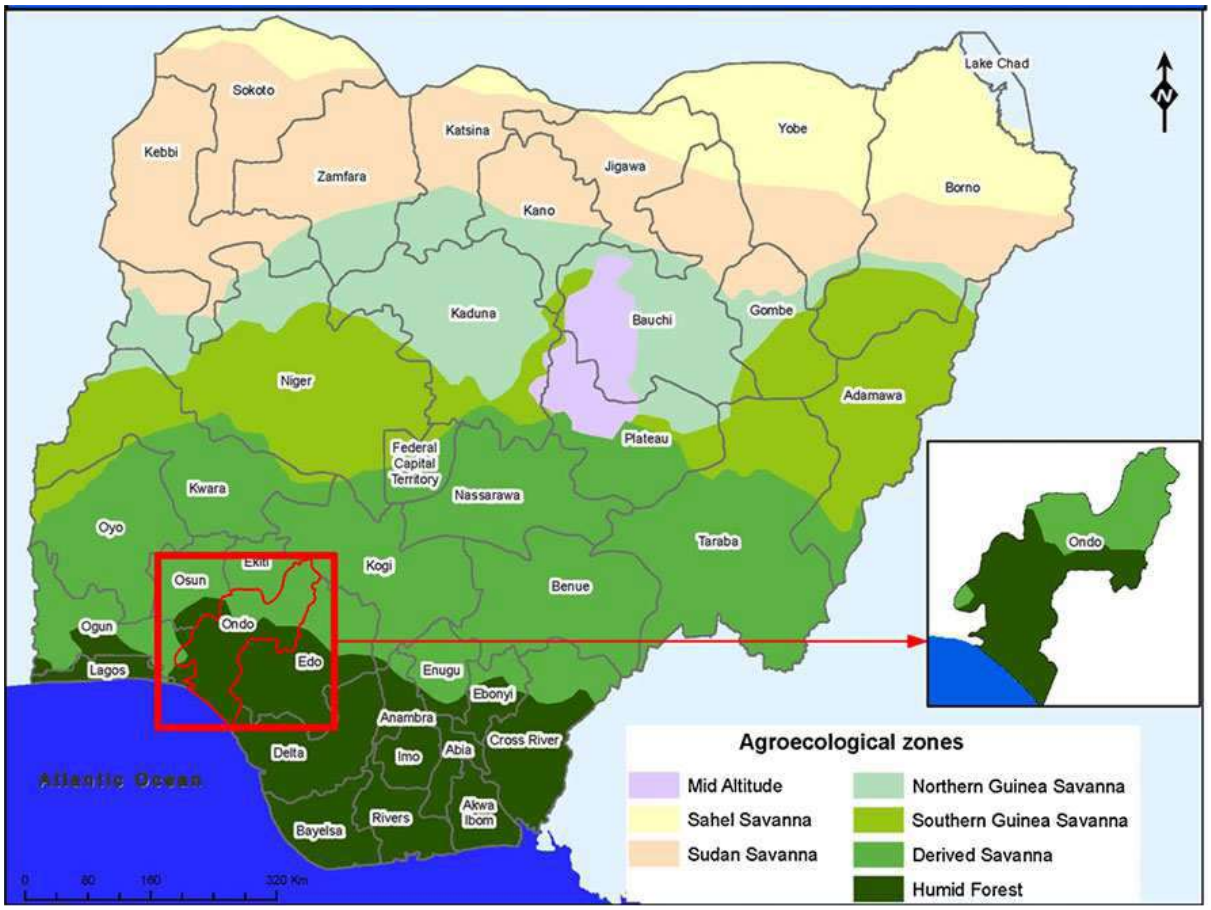


Fig.1: Map of Nigeria showing Ondo State, the study area (Source: IITA, 2022; International Institute of Tropical Agriculture, Ibadan)

**3.0**

**Data and analysis procedures**

The daily rainfall data used for this study for the period 1991 to 2020 were obtained from the Agro-climatological and Ecological Monitoring Unit, Akure, Ondo State, Nigeria. The use of rainfall data in this study was because rainfall is the most important climatic determinant in rain-fed agriculture in the tropical area. If the agrarian future of the study area, Ondo State is to be assured, the distribution of the amount of rainfall on month-to-month basis and other analysis employed in this study are critical in relation to rainfall spread in time which is a determinant in plant development and crop yield.

The data analysis employed by Adefolalu (1997) for rainfall distribution patterns was adopted for this study as follows: mean monthly distribution, seasonal distribution and annual distribution. The seasonal distribution patterns were further analyzed into; January and February (dry months), March and April (Transition into wet season), May to July (Wet season I), August (Little dry season), September and October (Wet season II), November and December (Transition into dry season) as presented by Omonijo and Matzarakis (2011).

## 4.0 Results

### 4.1 Mean Monthly Rainfall and Seasonal Rainfall Distribution

The outcome of the monthly rainfall patterns in this study is not only to distribution in respect of plant development and crop yield but also to give an overview of the reliability of monthly and seasonal rainfall as a major factor for long time planning in the study area.

The classification of Griffrith (1972) and several studies on climate (Obasi *et al.*, 1978; Ojo *et al.*, 2001) indicate that a month with less than 60 mm of rainfall is a dry month in the tropics. The mean monthly amount of rainfall distribution patterns for

the months of January and February ranged from 1 mm to 43 mm which confirm that January and February are "Dry Months" (Figures 2 and 3). Rainfall is generally less than 5 mm in most places except for Irele Local Government Area (LGA) in the month of January while Ile-Oluji/Okeigbo, Ondo West, Ondo East, Idanre, Odigbo, Okitipupa, Irele and Ese-Odo Local Government Areas

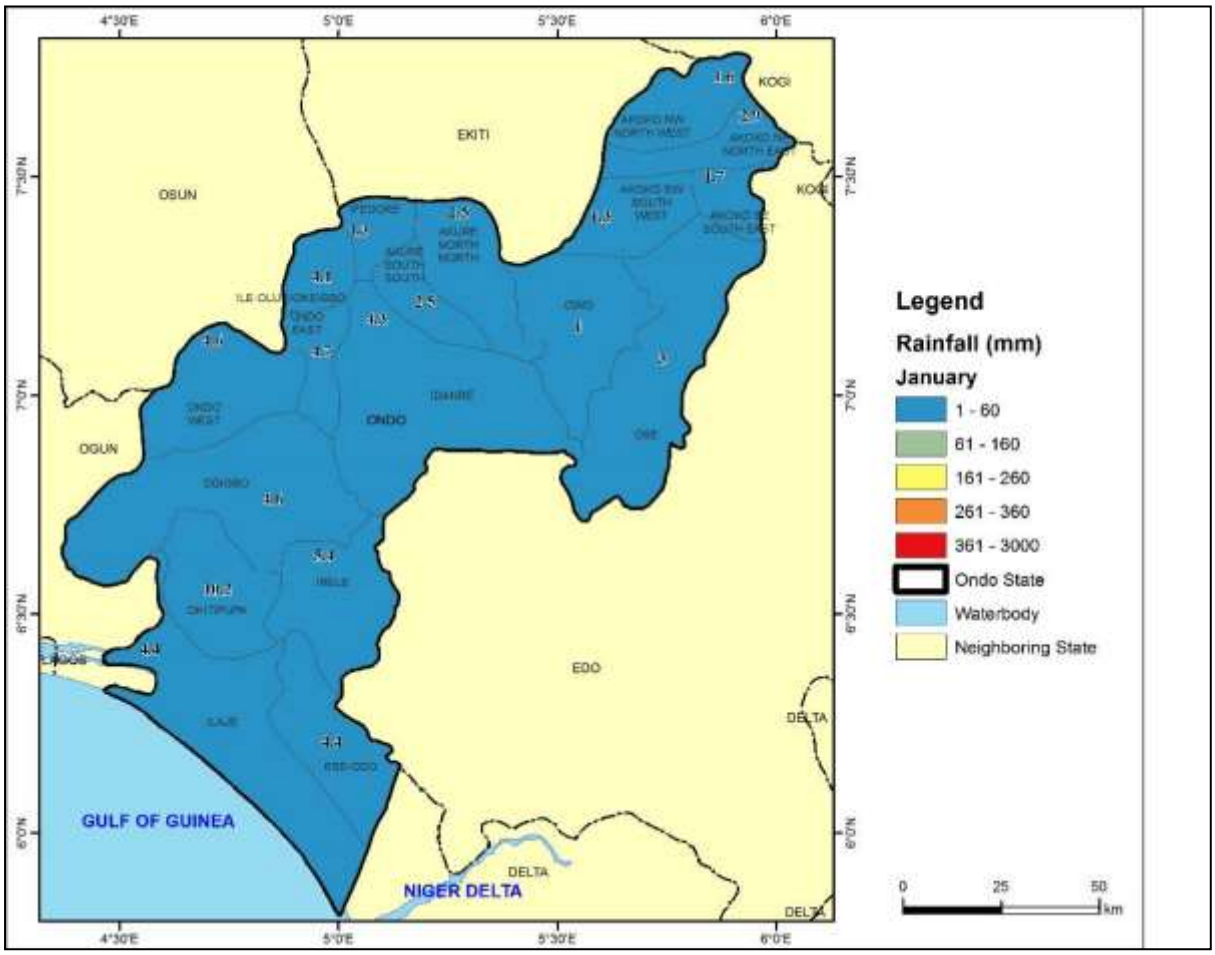


Fig. 2: Mean monthly rainfall in January (Map of Ondo State)

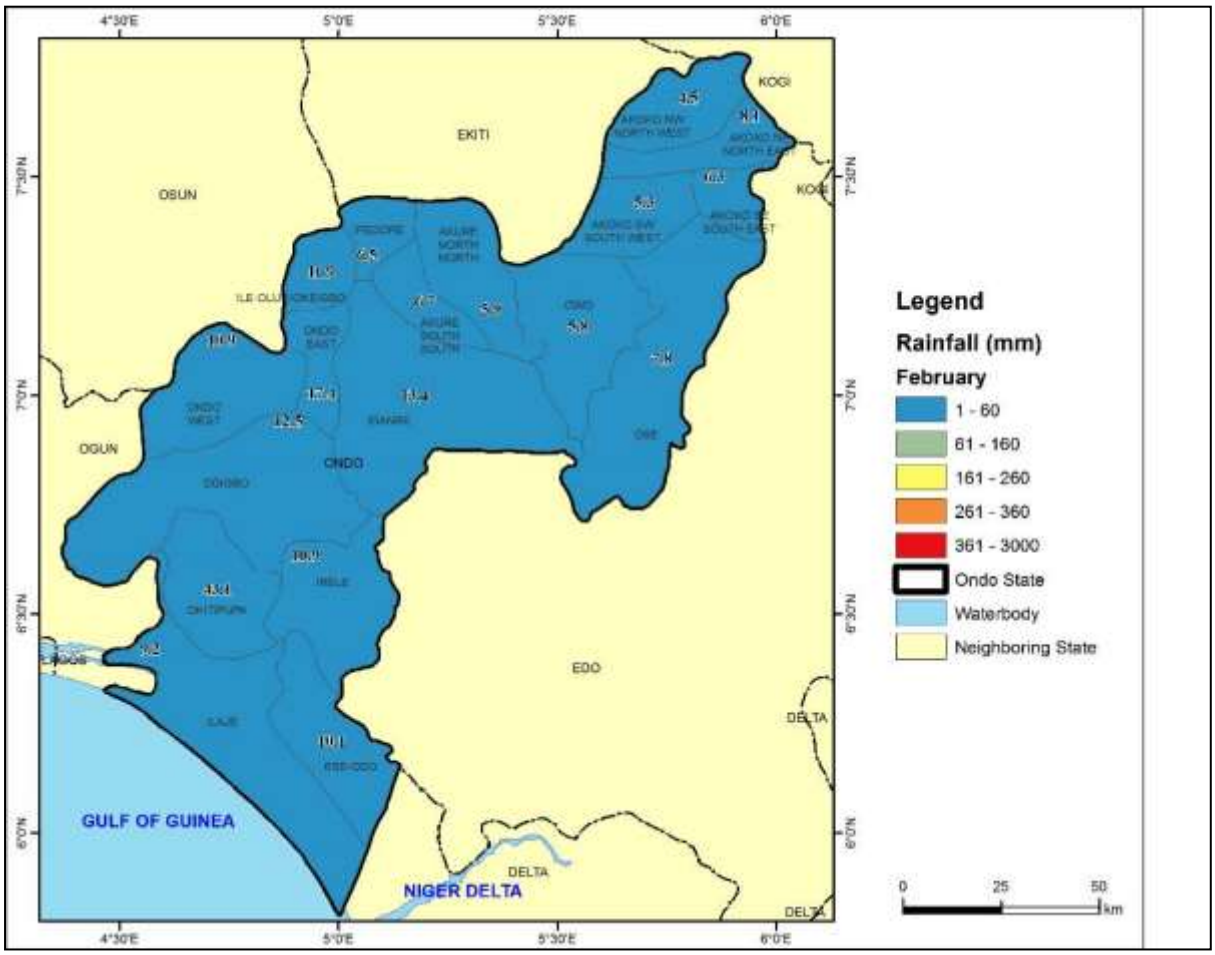


Fig. 3: Mean monthly rainfall in February (Map of Ondo State)

receives more than 10 mm of rainfall in the month of February. There is no location in the study area that show tendencies of rainfall amount near or above the threshold value of 60 mm.

The study of Adefolalu (1988) revealed that at the approach of the Thermal Equinox in the month of March, the prevailing hot conditions over the Atlantic Ocean result in high moisture content in the ambient air which, when advected by the southerly winds that veer into southwesterlies after crossing the equator into the coastal areas of the West Africa lead to formation of cumulus congestic clouds (usually referred to as CU-Towers). The resultant squally thunderstorms give scanty rainfall but very

strong and devastating gusty winds which signal the beginning of the rainy season with varying degrees of frequency and intensity in Southern States of Nigeria (Adefolalu, 1988).

The result from this study shows that mean rainfall amount in the months of March and April range from 59 mm to 160 mm (Figures 4 and 5). It is important to note that no LGA receives 200 mm of rainfall or any amount in excess of 200 mm. This suggest that even though the Wet Period (rainy season) has arrived, the adequate soil moisture surplus is not to be taken for granted because total evaporative losses will still be to the disadvantage of young and tender plants. The months of March and April are known for notorious storms in the study area. They constitutes the months of Transition from DRY to WET season. With the current reality of global climate change, it is therefore important that emphasis must be focused on the "Transition Months" as the most critical period in relation to annual cropping by farmers.

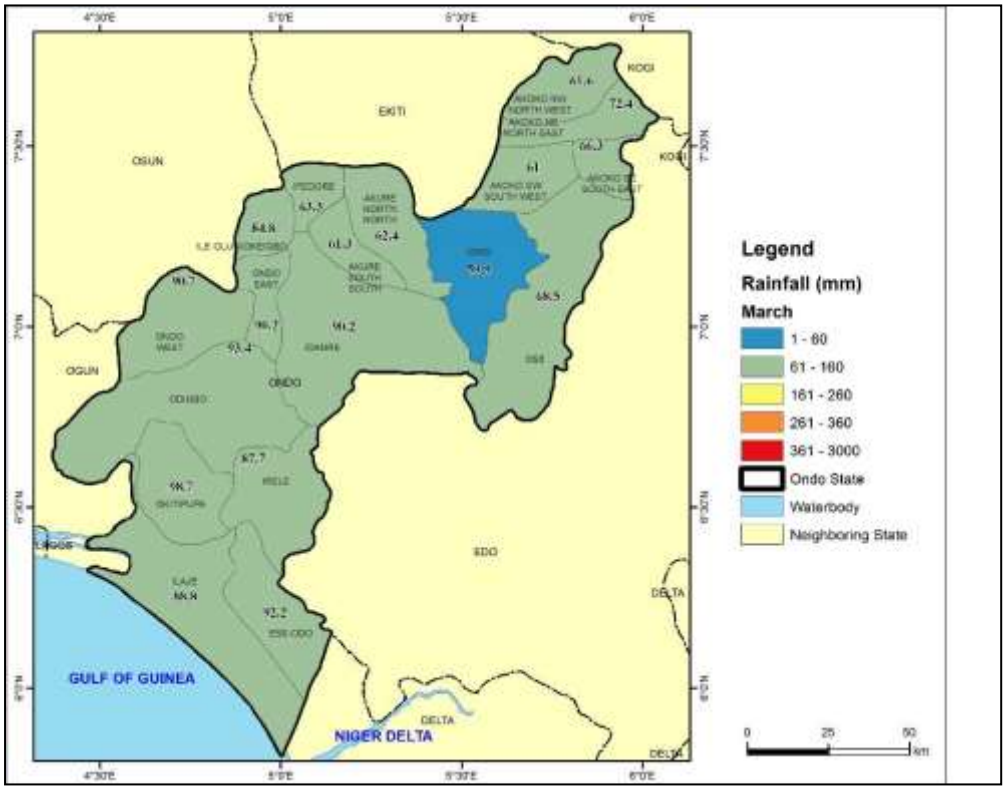

Fig. 4: Mean monthly rainfall in March (Map of Ondo State)

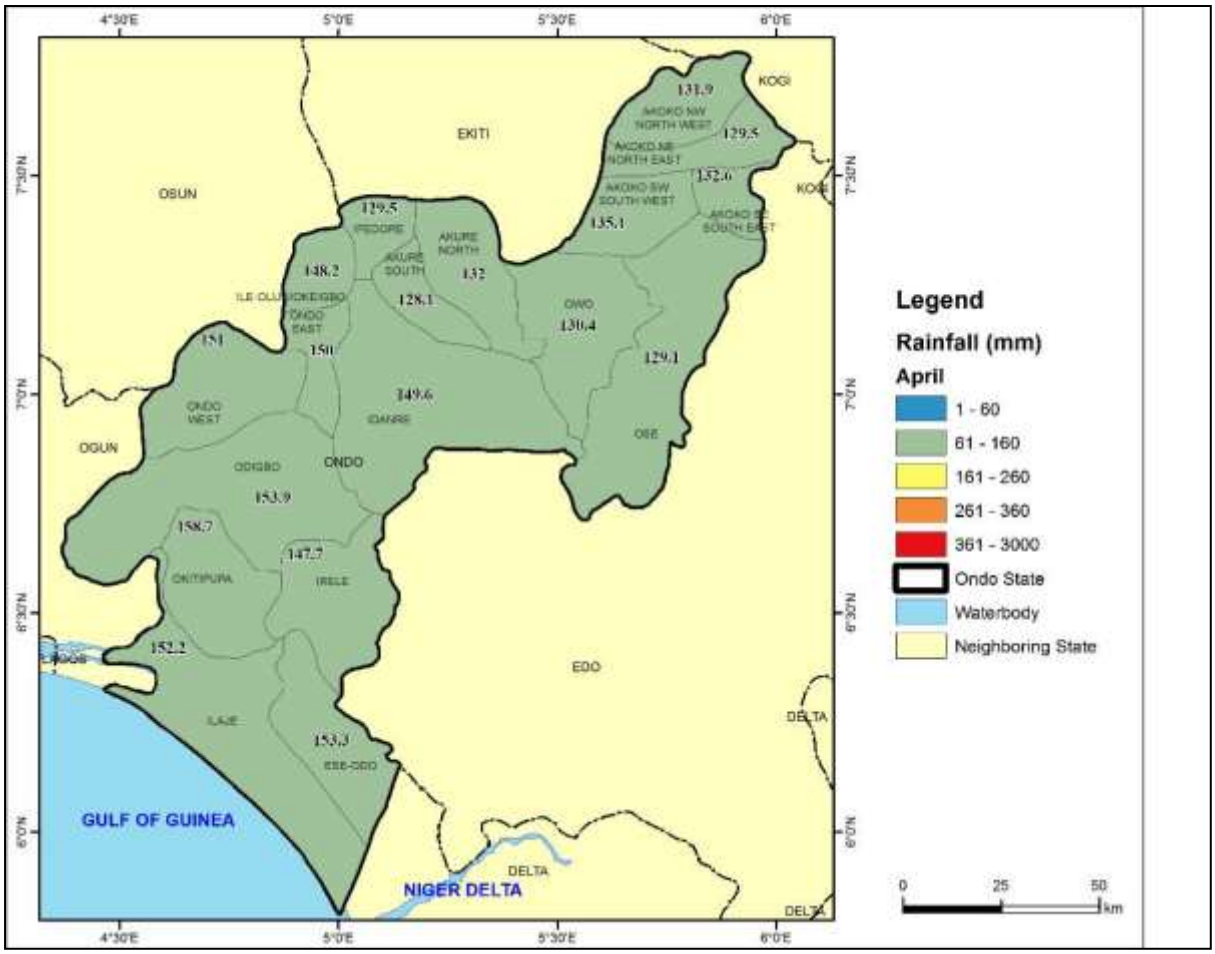


Fig. 5: Mean monthly rainfall in April (Map of Ondo State)

The analysis of rainfall in the months of May, June and July shows that the study area receives at least 160 mm and more in all the locations of the study area. Rainfall amount in excess of 200 mm was recorded in Okitipupa LGA only in the month of May; while Ile-Oluji/Okeigbo, Ondo West, Ondo East, Idanre, Odigbo, Okitipupa, Irele, Ese-Odo and Ilaje Local Government Areas recorded rainfall amount in excess of 200 mm in the month of June and all LGAs in the study area were credited with rainfall

amount in excess of 200 mm in the month of July (Figures 6, 7 and 8). This study supports the statement that the Wet Season in Nigeria is in two segments. Month of May to July is the "Wet Season – I" for both the

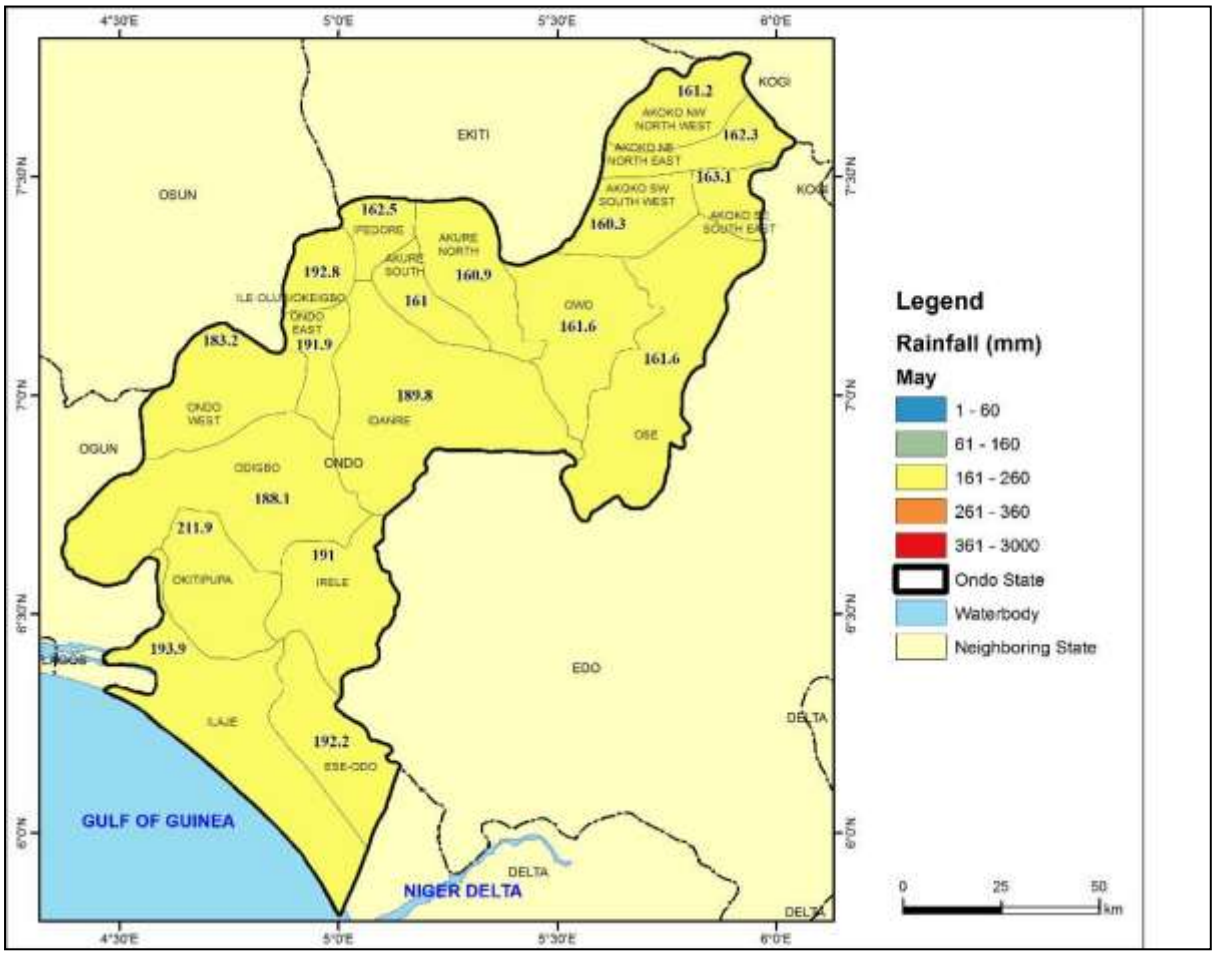


Fig. 6: Mean monthly rainfall in May (Map of Ondo State)

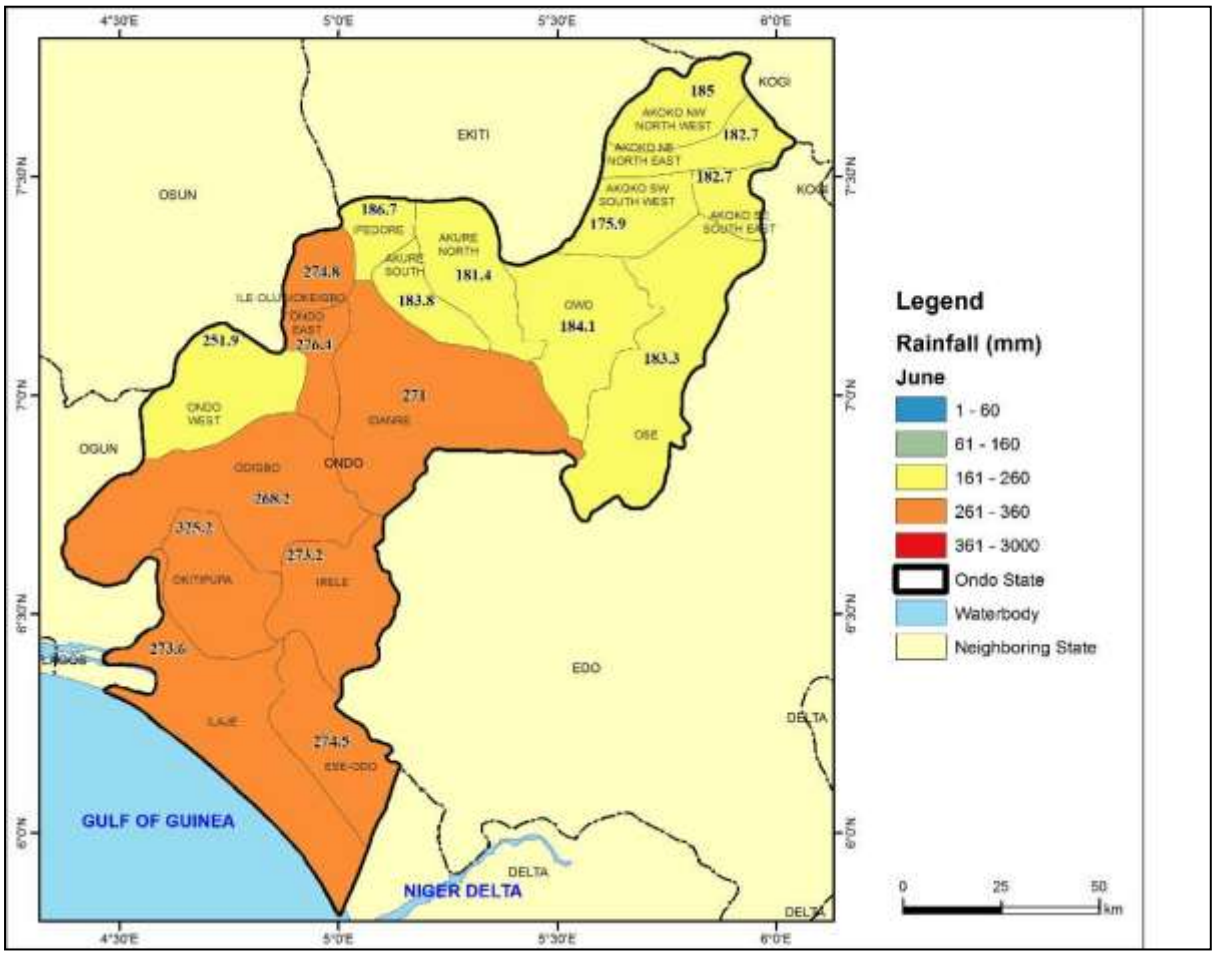


Fig. 7: Mean monthly rainfall in June (Map of Ondo State)

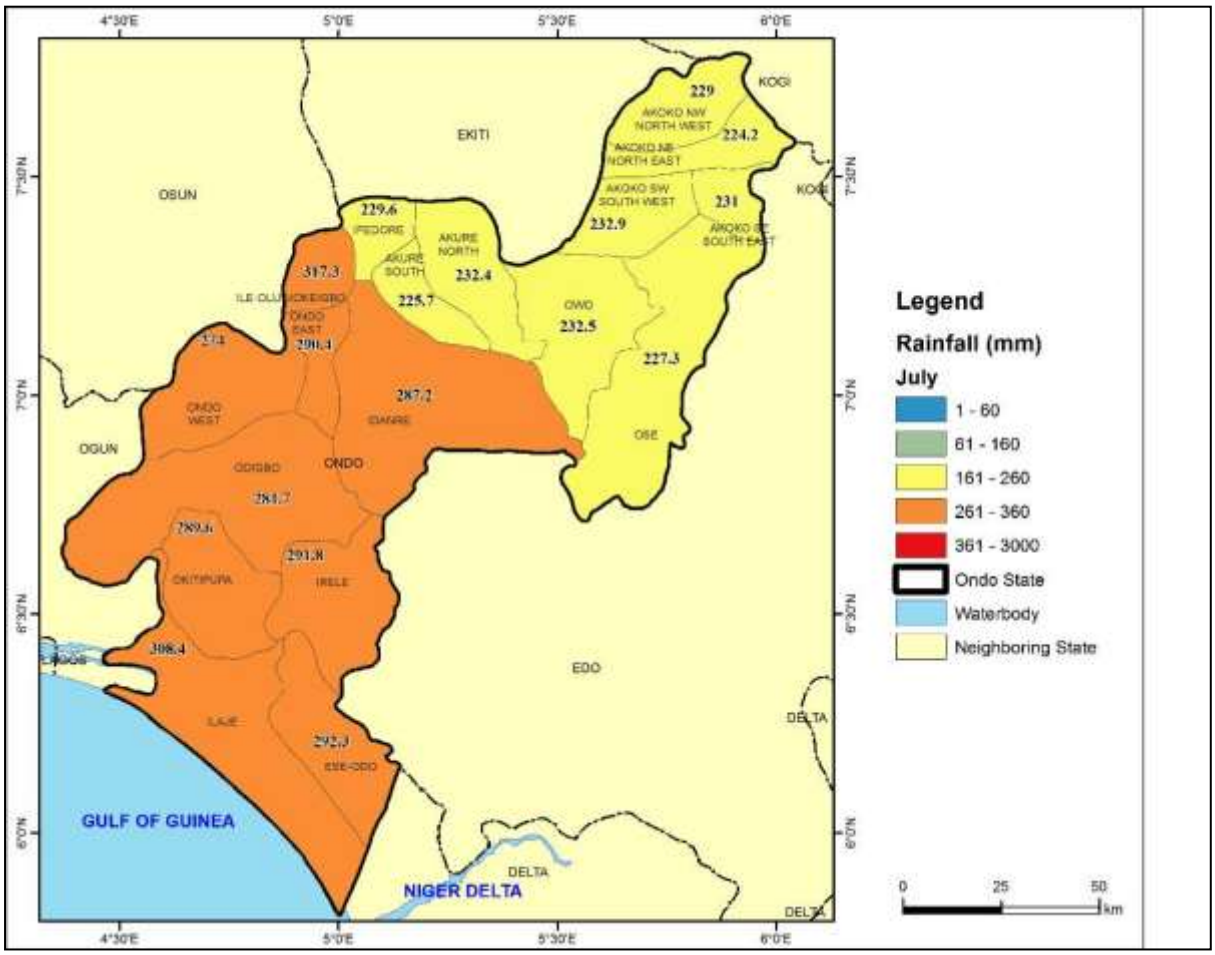


Fig. 8: Mean monthly rainfall in July (Map of Ondo State)

amount of rainfall and spatial distribution. The above pattern is maintained in June and July which constitute the wettest months with 200 mm to 300 mm in the study area.

The month of August has long been recognized as a period of relative decline rainfall which, made it to be referred to as "Little Dry Season" (Omonijo and Matzarakis, 2011). During this period of "little dry season", the study area receives rainfall ranged from 166 mm to 208 mm (Figure 9). The amount of rainfall in the period called "little dry season" is the least among the months of June to October in the study period. The observations from the results of this study indicate that the first wet period terminates in August when there is decline in rainfall amount; this month

indicates the end of the first annual cropping period under rain-fed

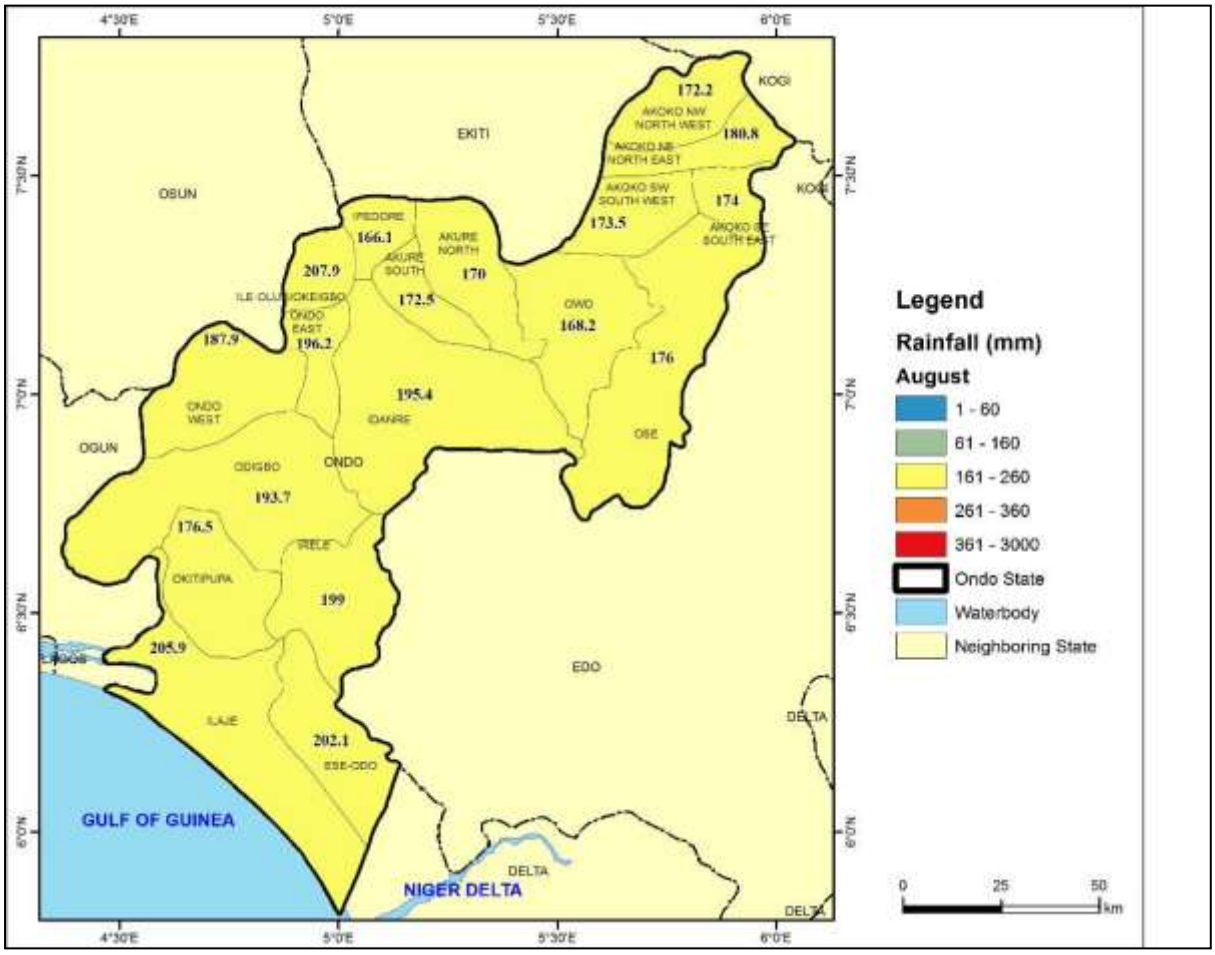


Fig. 9: Mean monthly rainfall in August (Map of Ondo State)

agriculture. The study of Adefolalu (1973 and 1990) showed that August dry spell is variable in both spatial and temporal distributions. However, the above result by Adefolalu (1973 and 1990) can only be ascertained by continued monitoring for agricultural planning in the study area if sustainable development is to be assured.

Rainfall during the months of September and October is between 160 mm and 285 mm (Figures 10 and 11). There are spatial distributions of rainfall in the months of

September and October which is known as "Wet Season II". Apart from the relatively uninterrupted precipitation from the months of May through October, the evaporative power normally declines steadily from June to August due to higher cloud cover and cooler soil conditions.

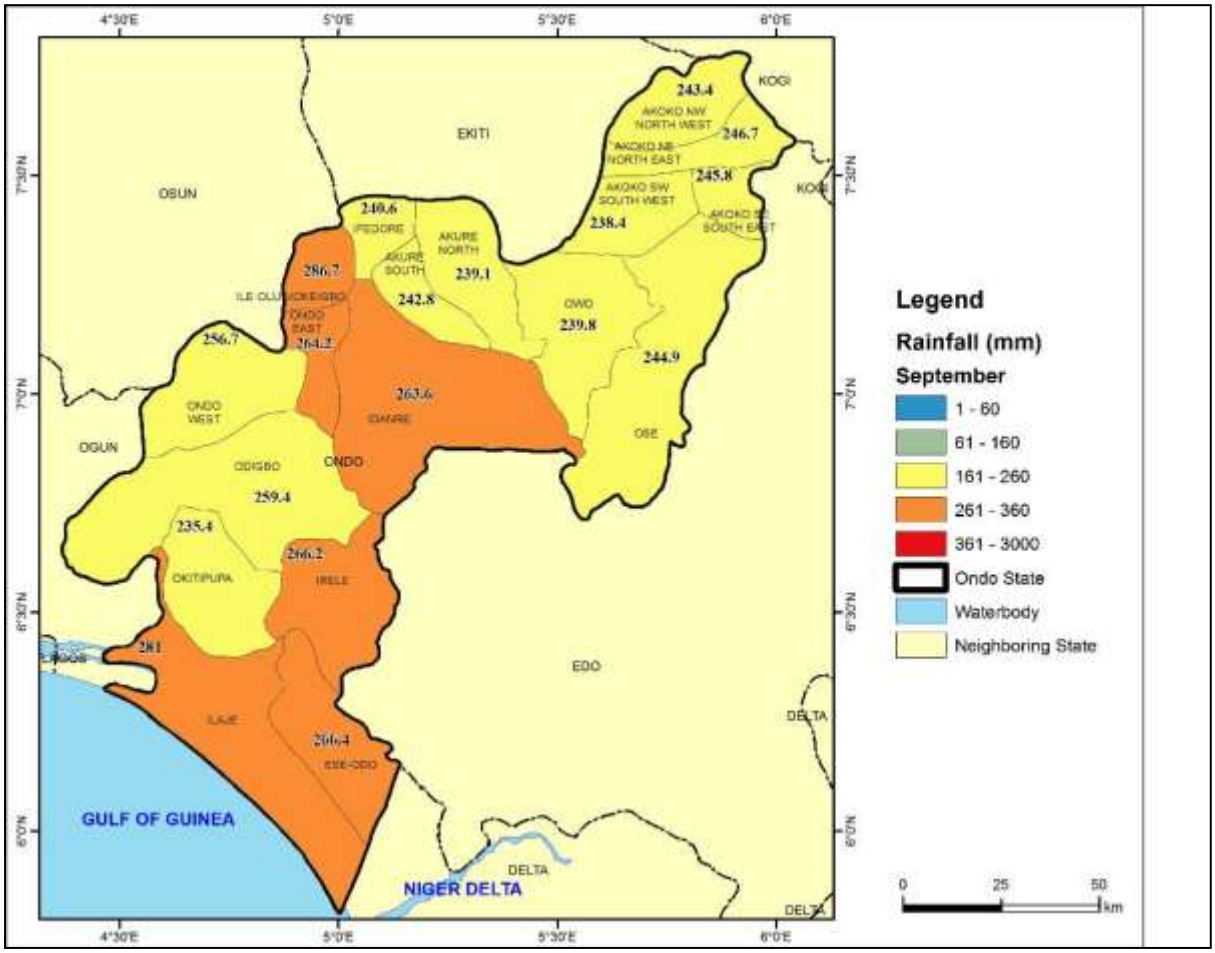


Fig. 10: Mean monthly rainfall in September (Map of Ondo State)

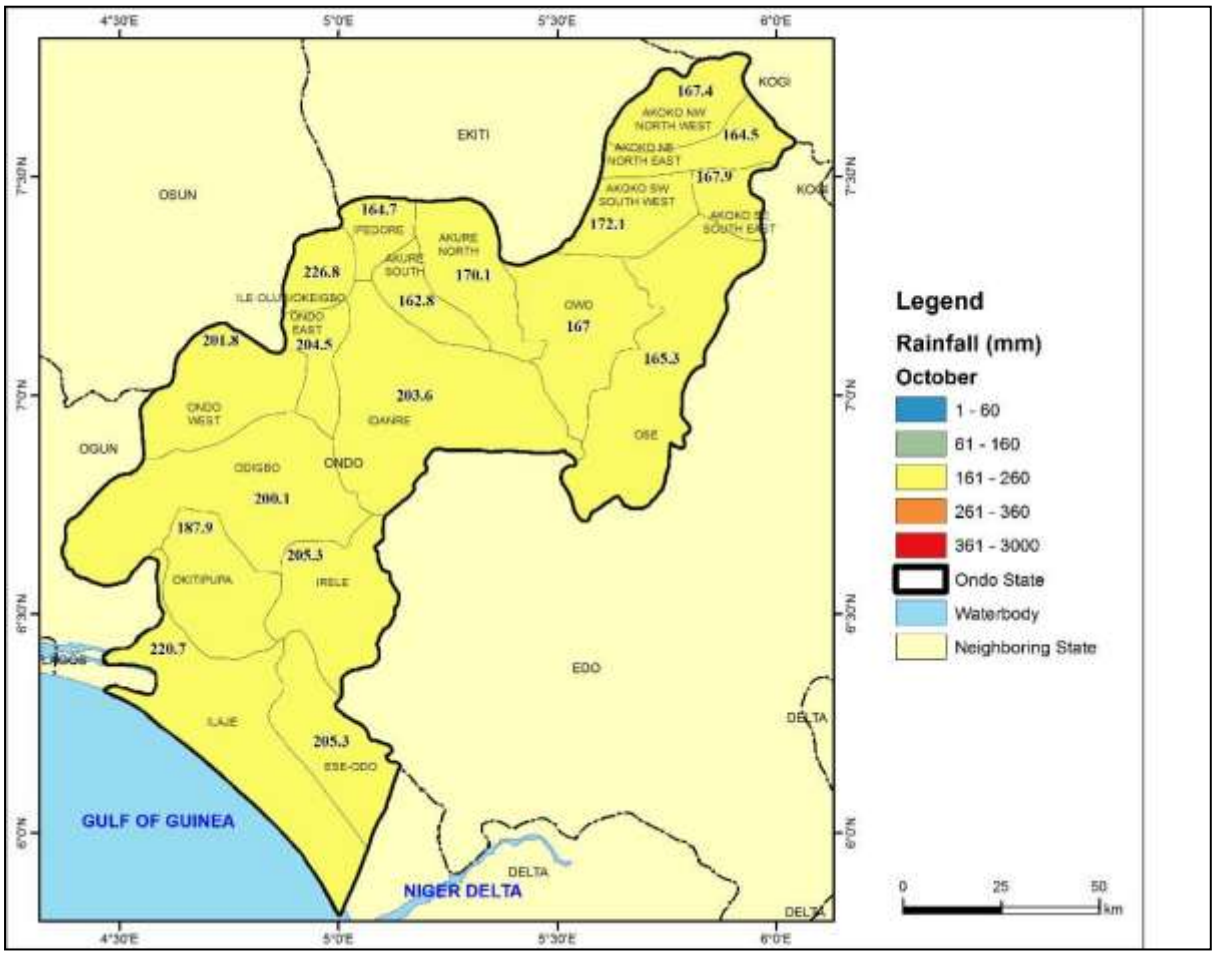


Fig. 11: Mean monthly rainfall in October (Map of Ondo State)

Thus, soil moisture conditions that are more favourable will commence from the month of May and reaching a peak in the month of August. The month of August, which is the month of lowest surface temperatures according to Adefolalu (1985) and Omonijo and Matzarakis (2011) is expected to remain adequate for plants through October and into November.

The months of November and December is referred to as "Transition months into Dry Season". Declination in the amount of rainfall received in the months of November and December is similar with the beginning of the dry season. However, the above can only be true regarding meteorological and not agricultural terms. This is because the cessation of

precipitation does not indicate deficit soil moisture conditions. It is important for farmers that engage in late season planting to take cognizance of this very important characteristic, especially in all year round cropping regime that will enhance food production in the study area. The amount of rainfall received in the study area under the study period is less than 100 mm in both November and December (Figures 12 and 13).

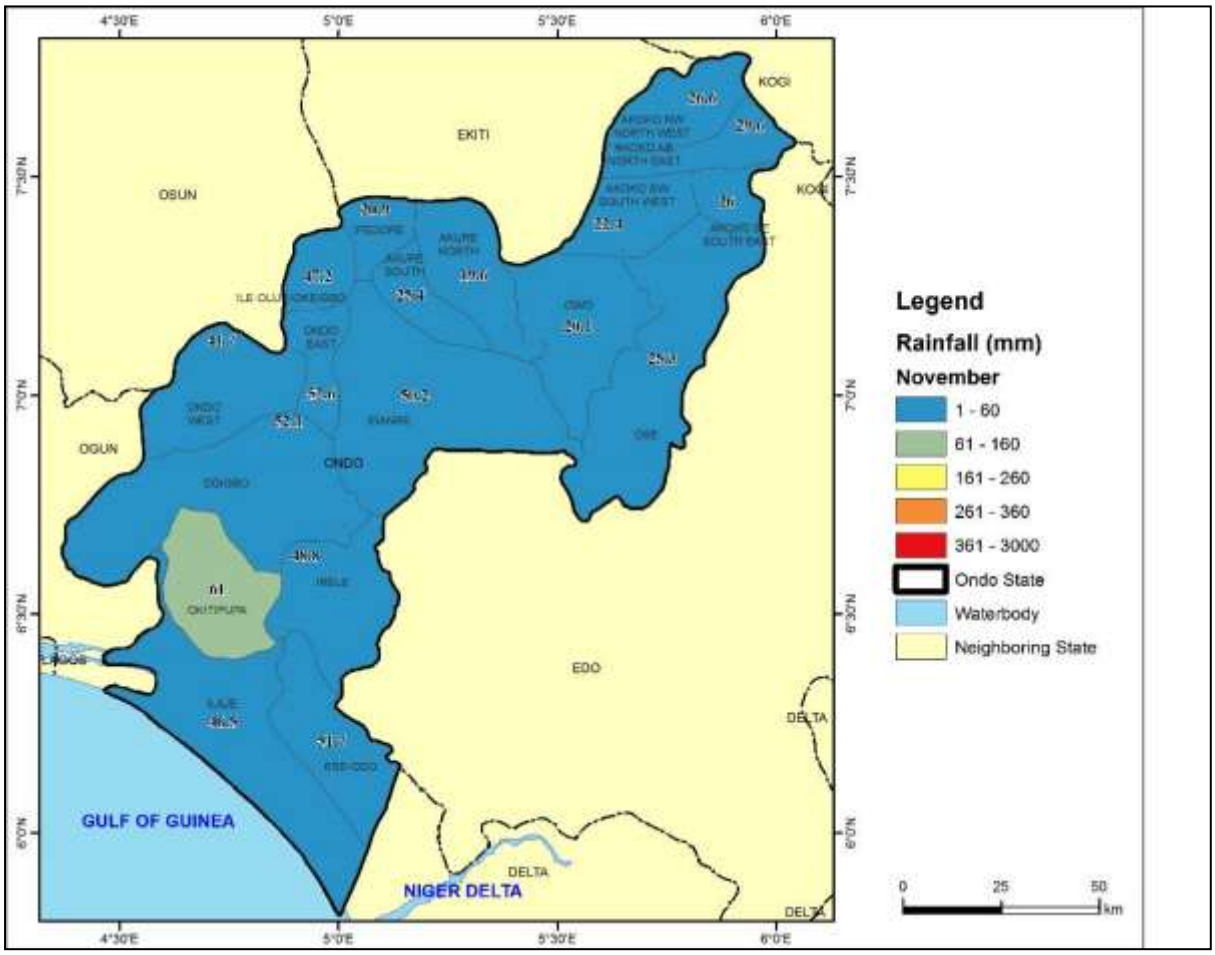


Fig. 12: Mean monthly rainfall in November (Map of Ondo State)

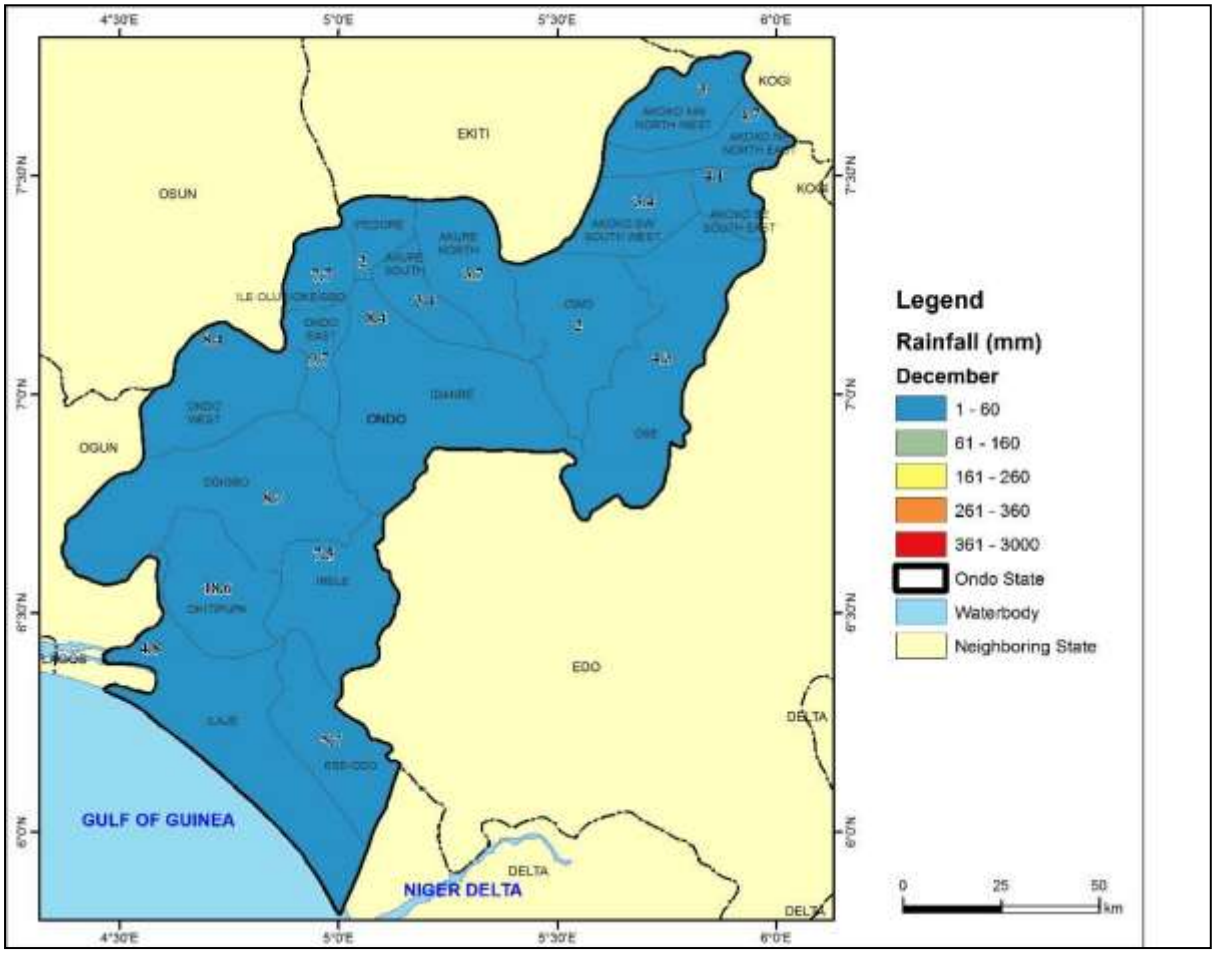


Fig. 13: Mean monthly rainfall in December (Map of Ondo State)

It is understandable from this study that cropping may be possible in the two months of the dry season without additional water from other sources. Furthermore, it may be difficult to have any successful dry season planting of seasonal crops that fail to yield to maturity within two to three months beyond October and November without irrigation.

### 4.2 Seasonality Patterns and Annual Rainfall Distribution

The mean monthly rainfall reflects on reliability within the two cropping periods before and after August. The dry season shows that rain-fed agriculture is not viable in Ondo State during the months of November to March. Generally, rainfall amount is below 100 mm in all the Local Government Areas of Ondo State.

Seasonal rainfall distribution in 18 LGAs of Ondo State, Nigeria is presented in Table 2. Based on the results of seasonal rainfall distribution in Table 1, rain-fed agriculture is most viable in between Transition to Wet Season and Wet Season II. During the Wet (rainy) Season, the bulk of the annual rainfall amount is received. The highest value of annual rainfall amount is about 1700 mm while the lowest annual rainfall amount is about 1300 mm during Rainy Season in the study area.

The annual rainfall pattern (Figure 14) shows that amounts range from about 1200 mm to 1600 mm in the northern side of Ondo State, Nigeria. In the southern side of the study area, the amount of annual rainfall is between 1800 mm and about 2000 mm. In view of the annual rainfall pattern, crops that are hitherto restricted to certain geographical belts on the basis of latitude alone can be properly developed if there is proper planning in areas that were previously considered unviable.

Table 1: Agroclimatic Zones of the Tropics (Source: Nix, 1985)

| Main Zone Belt | Perihumid | Humid | Subhumid | Semihumid | Transitional | Semiarid | Arid | Periarid |
|---|---|---|---|---|---|---|---|---|
| **Tropical Alpine Zone** | Glacier & Mountain Swamps | | Cattle – sheep zone | | | Sheep zone | | High altitude desserts |
| **Upper Highland Zone** | | Sheep & dairy zone | Pyrethrum & wheat | Wheat & barley zone | Upper Highland ranching zone | Upper Highland Nomadism zone | | |
| **Lower Highland Zone** | | Tea–dairy zone | Wheat/maize & pyrethrum zone | Wheat/maize & barley zone | Cattle, sheep & barley zone | Lower Highland ranching zone | Lower Highland Nomadism zone | |
| **Upper Midland Zone** | | Coffee Tea zone | Main coffee zone | Marginal coffee zone | Sunflower maize zone | Livestock-sorghum zone | Upper Midland ranching zone | Upper Midland Nomadism zone |
| **Lower Midland Zone** | | Lower Midland Sugarcane zone | Marginal Sugarcane zone | Lower Midland Cotton zone | Marginal Cotton zone | Lower Midland<br>Livestock<br>Millet zone | Lower Midland ranching zone | Lower Midland Nomadism zone |
| **Lowland & Inner Lowland Zones** | | Rice-Taro zone | Lowland Cotton zone | Lowland Cotton zone | Groundnut zone | Lowland ranching zone | Lowland ranching zone | Lowland Nomadism zone |
| **Coastal Lowland** | | Cocoa & Oil palm zone | Lowland Sugarcane zone | Cocoa<br>Cassava zone | Cashew nut<br>Cassava zone | Lowland<br>Livestock<br>Millet zone | Lowland ranching zone | Lowland Nomadism zone |

Table 2: Seasonal rainfall (mm) distribution in 18 LGAs of Ondo State, Nigeria (1991-2020)

| LGA\Season | Dry months (Jan & Feb) | Transition to Wet Season (Mar & Apr) | Wet Season I (May to July) | Little Dry Season (August) | Wet Season II (Sept & Oct) | Transition to Dry Season (Nov & Dec) |
|---|---|---|---|---|---|---|
| Akoko North West | 3.1 | 96.8 | 191.7 | 172.2 | 205.4 | 14.8 |
| Akoko North East | 5.5 | 101.0 | 189.7 | 180.8 | 205.6 | 17.2 |
| Akoko South East | 4.0 | 99.4 | 192.3 | 174.0 | 206.8 | 15.0 |
| Akoko South West | 3.3 | 98.1 | 189.7 | 173.5 | 205.3 | 12.9 |
| Ose | 5.4 | 98.8 | 190.7 | 176.0 | 205.1 | 14.8 |
| Owo | 3.4 | 95.1 | 192.7 | 168.2 | 203.4 | 11.0 |
| Akure North | 3.7 | 97.2 | 191.6 | 170.0 | 204.6 | 11.7 |
| Akure South | 4.6 | 94.7 | 190.2 | 172.5 | 202.8 | 14.4 |
| Ifedore | 3.9 | 96.4 | 192.9 | 166.1 | 202.6 | 11.4 |
| Ile-Oluji/Okeigbo | 8.0 | 116.5 | 261.6 | 207.9 | 256.8 | 27.5 |
| Ondo West | 7.8 | 120.8 | 236.4 | 187.9 | 229.2 | 25.1 |
| Ondo East | 11.1 | 120.1 | 252.9 | 196.2 | 234.3 | 31.2 |
| Idanre | 8.9 | 119.9 | 249.3 | 195.4 | 233.6 | 29.3 |
| Odigbo | 8.6 | 123.7 | 246.0 | 193.7 | 229.7 | 30.4 |
| Okitipupa | 26.7 | 128.7 | 275.6 | 176.5 | 211.7 | 39.8 |
| Irele | 8.1 | 117.7 | 252.0 | 199.0 | 235.7 | 28.1 |
| Ese-Odo | 7.2 | 122.7 | 253.0 | 202.1 | 235.8 | 28.7 |
| Ilaje | 6.8 | 120.5 | 258.6 | 205.9 | 250.8 | 25.7 |

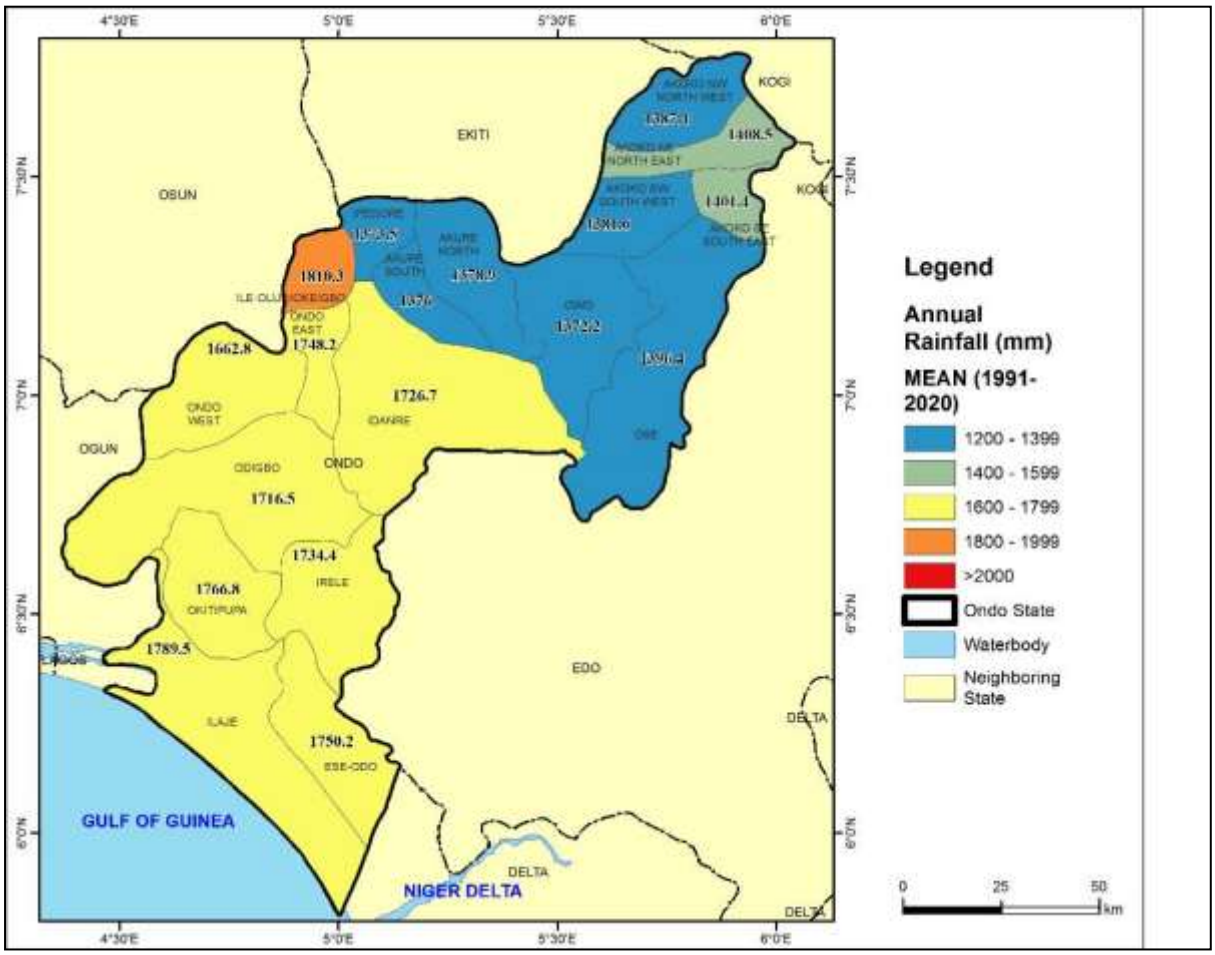


Fig. 14: Mean annual rainfall in 1991 – 2020 (Map of Ondo State)

**5.0**

**Discussion**

The variability of climate is reflected by the decline of total rainfall. There are other characteristics of precipitation effectiveness that tend to give a better definition of the kind of variation which seems to have impacted negatively on the agricultural economy of Nigeria. Due to importance of rainfall to agriculture in the tropics, Ochei and Oluleye (2017) stated that Mesoscale Convective Systems (MCSs) form an important component of meteorology in West Africa, and in particular, contribute substantially to

precipitation totals. In addition to the above, the study of Ochei *et al*. (2015) revealed that thunderstorm frequency is associated with rainfall over Nigeria.

In agriculture, it is not the quantity of the amount of rainfall that matters, but how much of it is available to dissolve soil nutrients that plants require from the soil. Whenever the amount of quantity of water in the soil is adequate, there is a good degree of certainty that plants will obtain adequate nutrients for good growth and possible high yield. However, when plants have no access to these nutrients, there is likely to be failure. The above situation may arise when precipitation distribution both in time and space is abnormal. For example, late onset (that is, beginning) of the rains may lead to problem even when the total rainfall received during the entire season is normal or above average. Similarly, untimely cessation, (that is, the rains stop untimely or before the usual or proper period) may constitutes a major problem for farmers. The worst situation is to be expected when onset is delayed and cessation is premature or advanced. The situation will lead to a shortened rainy season that may curtail the Length of Growing Season (LRS).

Regarding the onset of the rains, the planting season may be divided into three sections namely: early, normal and late/ delayed onset periods. When the rains commence before the normal period, it is said to be early and delayed when it begins after the normal dates. Cessation means the effective termination date of the rainy season. It does not imply the last day rain fell, but when the steady rainfall can no more be assured. Untimely cessation is the critical aspect for maturity of plants just as delayed onset is critical for plant growth. Thus, there is possibility of crop failures under purely rain-fed agriculture for cereal crops that are harvested two times during the normal planting season. Delayed onset will affect plants more seriously than

untimely cessation since the period of growth regardless of the year is long enough for annual crops. Both delayed onset and untimely cassation will lead to the same end results. In the first case, plants will have stunted growth while in the latter case; maturity of crops will be affected. In both cases, yield will be reduced. The average Length of Rainy Season is between 7 and 8 months in the study area.

Going by the data used for this study in Ondo State, Nigeria, the short break during any particular rainy season known as "little dry season" or popularly called "August Break" is anomalous as first proposed by Adefolalu (1972) and supported by Ochei *et al.* (2015). This feature may likely due to the global climate change because several studies have speculated climate fluctuations in some countries in Sub-Sahara Africa due to climate change (Riebsame, 1989; Ojo et al. 2001). In the study area, the short break during the course of the rains or planting period is critical because plants which have not developed to the extent that can withstand such breaks may wilt and become unproductive.

## 6. 0 Summary, conclusion and recommendations

This study analyzed rainfall distribution patterns using ArcGIS for mapping in order to establish proper agro-climatic zonation in Ondo State, Nigeria. Findings from this study show that rainfall in the months of January and February is less than 60 mm in all the Local Government Areas in Ondo State. In the months of March and April, rainfall ranged from 61 mm to 160 mm in all the 18 LGAs of the study area, while the months of May, June and July recorded rainfall between 161 mm and 260 mm in 16 LGAs and rainfall between 261 mm and 360 mm in 2 LGAs of Ile-Oluji/Okeigbo and Okitipupa LGAs. The study observed that rainfall ranged from 161 mm to 260 mm in the month of August (little dry season) in all the 18 LGAs in Ondo State.

The study revealed that rainfall is between 161 mm and 260 mm in the months of September and October while the months of November and December recorded rainfall of less than 60 mm within the study period in Ondo State. The study also discovered that "August Break" known as "little dry season" is anomalous as first proposed by Adefolalu (1972) and supported by Ochei *et al.* (2015). This scenario may likely be associated with the global climate change. The magnitudes of climate variability and change as well as the rates of the change and their regional variations are fundamental in assessing the projected impacts of climate variability and change on agriculture.

Another important finding of this study revealed that knowledge of the microclimate of crops can assist in creating a better environment for the growth of crops. The results of this study are invaluable for policy-making decisions, especially for planning short- and long-term agricultural farming intervention strategies aimed at preventing and minimizing the constraint pose by rainfall.

Based on the findings of this study, the most important advice for farmers is not to rush into sowing seedlings of crops like maize with early rains because there is no assurance of adequate soil moisture that will enhance sustainable growth and development of plants before steady rains. This study suggests that it will be necessary for government to educate farmers that are rains dependent (majority of farmers in Ondo State) on how to manage the effects of rainfall on various crops planted on their farmland. This knowledge will help to save farmers from crops loss, particularly farmers that lack adequate knowledge of climate variability and change.

**Funding**

No funding available for his work.

**Acknowledgments**

We acknowledge the gesture of the colleagues of the first author and staff of the Department of Meteorology and Climate Science, Federal University of Technology, Akure, Nigeria that accommodated him in their research laboratory during this period of research and Dr. Akinluyi Festus of the Federal University of Technology, Akure, Nigeria for mapping. We equally appreciate Agroclimatological and Ecological Monitoring Unit, Akure, Ondo State, Nigeria for providing the data for this study.

**References**

Adefolalu, D. O. (1997): Hydro-Ecozone mapping of Ondo/Ekiti State, Nigeria, Ondo State Project Final Report, p.141 plus Appendices. Adefolalu, D. O. (1995): Agro-climatological and ecological zones study of Ondo State,

Nigeria. Final report, phase III. Prepared by Federal University of Technology, Minna vol. 2. Niger State, Nigeria. Adefolalu, D. O. (1990): Desertification studies. In: Vaughan, R. A. (Ed.), Microwave Remote Sensing for Models; Kluwer Academy Publishers, 273-324.

Adefolalu, D. O. (1973): On the mid-summer drought in Nigeria. Nigeria Quarterly Meteorology Magazine, 3(4).

Adefolalu, D. O. (1972): "On the mean Equivalent Potential temperature of the tropical Atmosphere and the 'Little Dry season' of West Africa", Niger. Q. Meteorol. Mag. 2 (1): 15 – 40. Afolabi, L. A., Omonijo, A. G. and Aderibigbe, A. T. B. (2009): Effects of Rainfall Patterns

on Soil Moisture, Soil Temperature and Plant Growth in Humid Forest Zone, Nigeria, Am.- Eurasian J. Sustain. Agric., 3(3): 413-4178 Ayoade, J. O. (2002): Introduction to Agroclimatology. Vantage Publishers Limited, Ibadan, Nigeria

Chipanshi, A. C. et al. (1999): Large-scale simulation of wheat yields in a semi-arid environment using a crop growth model. Agric. Systems, 59:57-66

 

Chipanshi, A. C. et al. (1997): Early production of spring wheat yields in Saskatchewan from current and historical weather data using the CERES – Wheat model. Agric and Forest Meteorology, p. 84, 223-232.

Dauda, A. K., Adesiji, G. B. et al. (2014): Awareness of Climate Change and Indigenous coping strategies of women crop farmers in KogiState, Nigeria. Journal of Tropical Agriculture, Food, Environment and Extension, 13(1): 1-7; http://dx.doi.org/10.4314/as.v13i1.1

Griffith, J. F. (1972): Nigeria in World Survey of Climatology (Landsberg, Ed.), Elvesier, 10: 167-186.

IITA (2022): International Institute of Tropical Agriculture, Ibadan, Nigeria.

Joshi, N. P., Maharjan, K. L. and Piya, L. (2011): Effect of Climate Variables on Yield of Major Food-crops in Nepal – A Time-series Analysis. Journal of Contemporary India Studies: Space and Society, Hiroshima University, 1: 19-26.

Kukal, M. S. and Irmak, S. (2018): Climate-Driven Crop Yield and Yield Variability and Climate Change Impacts on the U.S. Great Plains Agricultural Production. Scientific Reports, 8: 3450-3467; doi:10.1038/s41598-018-21848-2

Nix, A. A. (1985): Agriculture. In: Kates, R. W., et al. (Eds.), Climate Impact Assessment; John Wiley and Sons, Chichester.

NPC, (2006): Nigeria Population Census Report. National Population Commission, Abuja, Nigeria.

Obasi, G. O. P., Adefolalu, D. O. et al. (1978): Maps of mean Onset and Cessation dates of the rains in Nigeria. Nigeria Meteorology Department Published Series.

Ochei, M. C. and Oluleye, A. (2017): Climate Variability impact on the frequency of occurrence of mesoscale convective systems in Northern Nigeria. Climatology and Weather Forecasting, 5 (3): 1 – 13.

Ochei, M. C., Orisakwe, I. and Oluleye, A. (2015): Spatial, seasonal and inter-seasonal variations of thunderstorm frequency over Nigeria. African Journal of Environmental Science and Technology, 9 (12): 810 – 833.

Ojo, O., Ojo, K. and Oni, F. (2001): Fundamental of Physical and Dynamic Climatology. SEDEC Publishers (O. O. Ojo & Co.), Lagos, Nigeria.

Olivares, B. O. (2018): Tropical rainfall conditions in rainfed agriculture in Carabobo, Venezuela. La Granja: Journal of Life Science, 27(1): 84-100; http://doi.org./10.17163/lgr,n27.2018.07.

Omonijo, A.G. and Matzarakis, A. (2011): Climate and bioclimate analysis of Ondo State, Nigeria. Meteorol. Z. 20 (5), 531–539. Riebsame, W. E. (1989): Assessing the social implications of climate fluctuations: A Guide to Climate Impact Studies, UNEP, Nairobi, Kenya. Siderius, C., Van Walsum, P. E. V. et al. (2016): The role of rainfed agriculture in securing food production in the Nile Basin. Journal of Environmental Science and Policy, 61: 14-23; http://dx.doi.org/10.1016/j.envsci.2016.03.007.

Taye, M., Simane, B. et al. (2019): Rainfall Variability across the Agro-Climatic Zones of a Tropical Highland: The case of the Jema Watershed, Northwestern Ethiopia. Journal of Environment, 6(11): 118-128; https://doi.org/10.3390/environments6110118.

van Wart, J., van Bussel, L. G. J. et al. (2013): Use of agro-climatic zones to upscale simulated crop yield potential. Journal of Field Crops, 143: 44-55; http://dx.doi.org/10.1016.j.fcr.2012.11.023. Wani, S. P., Sreedevi, T. K. et al. (2009): Rainfed Agriculture – Past Trends and Future Prospects. In: Wani, S. P. (Eds.), Rainfed Agriculture: Unlocking the Potential, CAB International.