**SCHOLEDGE International Journal Of Multidisciplinary & Allied Studies**
ISSN 2394-336X, Vol.07, Issue 03 (2020)
Pg 74-90.
Paper URL: link.thescholedge.org/1214

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# Spatio-Temporal Analysis of the Rainfall Variability in the Derived Savannah Region of Nigeria, 1941 – 2010

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## Abstract

Studies have revealed evidence of rainfall variability and change in both trend and spatial patterns. Basic understanding of the long-term trend and spatial variation of rainfall distribution over a place for some periods of time would provide significant insight to the management and sustainable development of agriculture and other natural resources especially in a delicate environment like derived savannah. This study evaluates the spatial and temporal variability patterns of rainfall in the Derived Savannah region of Nigeria for the period between 1941 and 2010. The monthly rainfall data were acquired from the Nigerian Meteorological Services for six stations within and around the study area for the period. The data were standardized using a combination of standard deviation and mean, percentages of the coefficient of variation and temporal variability index were determined for each of the stations, which were interpolated using IDW techniques to generate surface maps so as to reveal the spatial and temporal patterns of rainfall. The study revealed that the mean annual rainfall increases at the rate of 1.20mm annually with a long term mean of 1,316mm and increasing in a north to south direction spatially. While the annual rainfall Coefficient of Variation (CV) varies between 8% and 38% and temporal variability indices range from -2.00 to 2.38 (i.e. from severely dry to extremely wet). The study shows there is a shift in Spatio-temporal distribution, pattern and trend due increased wetness and dryness in south and north respectively, there is a need for more climatic research in order to adopt appropriate adaptation and mitigation strategies.

## 1. Introduction

Recently, there has been increasing interest in the events of climatic variations and their implications on natural systems and human activities globally (1, 2, 3). The climatic variations termed variously as climate change and refer to change in the climate of a region for a comparable period of time, whether due to natural variability or as a result of anthropogenic activities such as landuse/landcover (LULC) changes, burning of fossil fuel, urbanization, and industrialization (4). When the fluctuations in climatic parameters such as temperature, precipitation, winds, clouds, and humidity revolve around their normal averages, the variations are regarded as normal. They are regarded as abnormal when they deviate significantly from their long time normal averages.

According to Mahoney *et al.* (5), historical records have shown evidence of climate variability and change. Basic understanding of the trend and variation of climatic parameters and atmospheric conditions over a place for some periods of time would provide significant insight into the management and sustainable development of natural resources. The climatic parameters, which include rainfall is an important component of the hydro-climatology and a key element of water or hydrologic cycle (6). The analysis of the historical antecedent and spatial patterns of rainfall provide better understanding its behaviour and may be of profound social and economic significance especially within the context of global warming, water, and energy cycles and the increasing demand for water due to population and economic growth (5, 6, 7).

Studies have shown the importance of rainfall as a major component and a key element of the climate system to the sustainability of the environment. For example, Mahé & Paturel (9) analyzed the connection between the Sahelian annual rainfall variability and runoff increase of Sahelian Rivers for the period, 1896 – 2006. The study revealed that the drought continues in the Sahelian despite the increase in the annual rainfall since the mid-1990s and this has induced hydrological change in the Sahelian region (9). Wang et al., studied the decadal variability of rainfall in the Sahel to demonstrate the significance of the knowledge of trend and variation of rainfall to vegetation dynamic and drought (10). In addition, Blanc and Perez revealed that the current water scarcity being witnessed in sub-Sahara Africa and the future water stress are consequent of the relationship between rainfall variability and demographic changes (11).

Also, historical studies in trend and variation of rainfall in different parts of the world show that there were both positive and negative trends at different time scales. For instance, Houghton *et al.* and Oguntunde *et al.* revealed that some areas exhibited a positive trend in the daily precipitation intensity and a tendency toward higher frequencies of heavy and extreme rainfall in the last few decades (12, 6). Furthermore, other studies indicated fluctuations in the annual rainfall trend, which suggested non-uniformity in both spatial and temporal patterns in some parts of Europe (13; 14). While, in USA positive trends were recorded for annual precipitation (6, 15, 16, 17).

Similar to other parts of the world, rainfall trend and variability in Africa recorded negative anomalies both spatially temporal especially the drought in the Sub-Sahara Africa (18, 19; 20) For example, Oguntunde et al. and Ojo examined rainfall variations between 1901 and 1985 in West Africa and found no observable regular pattern in its trend and periodicity (6, 21). Furthermore, there are various studies on the analysis of rainfall trends and variability in Nigeria, some of the studies observed that rainfall patterns marked with fluctuations i.e. wet and dry periods that make it difficult to generalize especially the drought of 1970 decade. For instance, Olaniran analyzed the changing patterns of rain-days in Nigeria (22). Similarly, Olaniran rainfall anomaly patterns in dry and wet years over Nigeria (23). Bello studied the evidence of climate change based on rainfall records in Nigeria and asserted that there have been seasonal changes in the rainfall regime across the different ecoclimatic zones of Nigeria (24). In a similar vein, Oguntunde *et al.* assessed the rainfall trend in Nigeria between 1900 and 2000 and observed that Nigeria landscape was generally drying since the 1970s with the driest decades between 1970 and 1990 of the 20th century (6).

However, all these studies showed overwhelming interest in time scale, and relatively little effort was made to discover connections on different time and spatial scales. Therefore, this study seeks to assess the spatial and temporal variability patterns of rainfall in the Derived Savannah region of Nigeria for the period between 1941 and 2010. The derived savannah of Nigeria is a fragile ecoclimatic zone of which a little shift of days or delay in the onset of rainfall for the year might make the difference famine and good harvest for the region and general wellbeing of Nigeria populace.

## 2. The Study Area

The study area covers the Derived Savannah region of Nigeria spanning from longitude $4.25^0$ to $6.0^0$E and latitude $7.0^0$ to $8.75^0$N. It is about 37,751.91km$^2$ in the area and covers the present Ekiti State in its entirety and parts of Kwara, Ondo, Oyo, Osun, Kogi, and Edo States (Figure 1). As shown in figure 1 all the sixteen LGAs of Ekiti and about forty-one others in the remaining states, including Kwara (14LGAs), Ondo (13LGAs), Oyo (5LGAs), Kogi (4LGAs), Edo (3LGAs), Niger (1LGA) and Ogun (1LGA) are covered in the study area. The area covered in this study extends into the upper part of the forest ecological zone. This is to be able to capture the rainfall characteristics at the fringes of the ecological zone.

The annual mean rainfall decreases from about 1,600mm in the south to 1,200mm north around Ondo and Pategi respectively. The rainfall pattern is influenced by the orography as evident around the southwest of Effon ridges and other highlands within the region. Two-peak rains in derived savannah have a relatively short dry break in August. The low rainfall amounts between November and March account for the dry season in the area. While the annual mean is about $27.8^0$C and ranges 21.50C and $33.6^0$C for the minimum and maximum annual temperatures, respectively. The temperature anomaly shows a sinusoidal pattern even though the values are relatively high and uniform all year round. The highest values of temperature are usually recorded in February and March as a result of the dominance of Tropical continental (cT) airmass, while the lowest is in August when the tropical maritime prevails. The relief of the area is a relatively flat surface but dominated by the ridge system of Fold Mountains, particularly Efon ridge with elevation ranging from 500 – 900m above the sea level. Also, the area is well-drained by the Rivers Niger and its numerous tributaries which include Rivers Asa, Osun, Oro, and Aware. Some of these rivers have been dammed for irrigation and domestic water supply. The dams within the study area include Ero, Ejiba, Asa, Egbe, and Oba Dams as shown in figure 1.

The study area is populated mainly by the people of the Yoruba speaking tribe of Ekiti, Ondo, Osun, Kogi, Kwara, Oyo, and the Ogun States of Nigeria. The population is estimated at about 9.8million according to the 2006 census (25) and fairly distributed among the states covered. Osun has the largest with about 2,856,120 followed by

Ekiti and Ondo with 2,379,974 and 2,078,219 people respectively. Kwara has about 1.7million, while all the others have a total of 835,563. The average density is about 264 people per square kilometer.

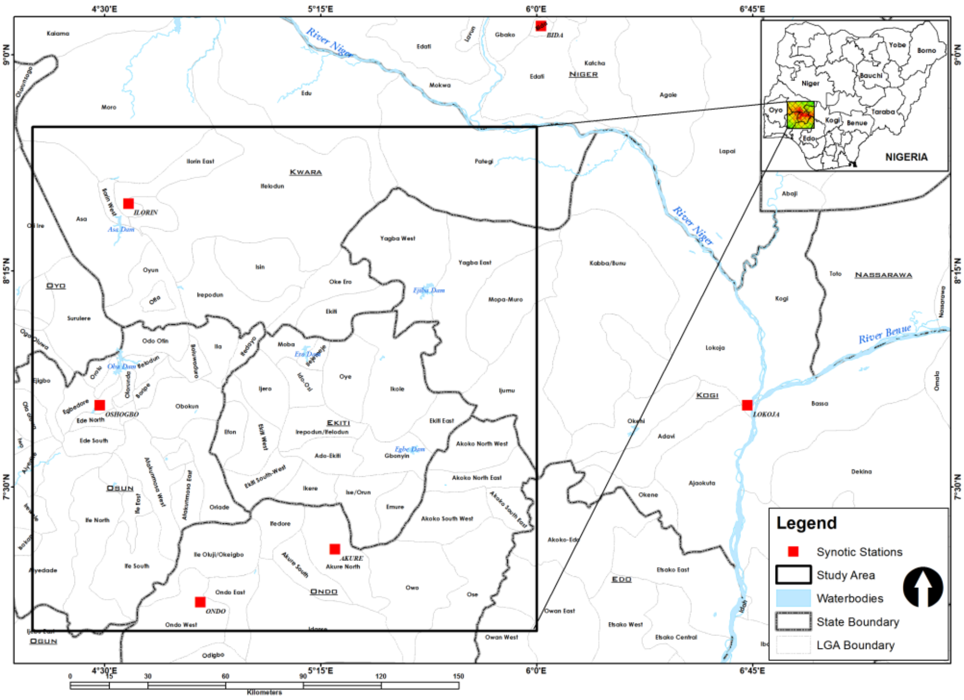


**Figure 1:** The Study Area *(Author, 2015)*

## 3. Dataset and methods

### *3.1 Sources of data*

The observed monthly rainfall data for the period between 1941 and 2010 were acquired from the Nigerian Meteorological Services (NIMET), Lagos for six stations (i.e. Ilorin, Bida, Lokoja, Akure, Ondo, and Oshogbo) within and around the study area. However, there were data gaps in the time series data from NIMET. For instance, rainfall data were not recorded for the Oshogbo station between 1948 and 1957, Ondo for 1941 and Akure between 1941 and 1979. The Akure station actually started operations in 1980. The period between 1941 and 2010 was adopted for this study in order to account and accommodate for the standard climatic period, which simply defines climate as the average weather or atmospheric conditions of a place for a period between 35 and 40 years (26) and 50 – 60years or more being optimal and preferred for Standardized Precipitation Index (SPI) (27). Nevertheless, the issue of data gaps was resolved by statistically regressing the years with a gap against the data of the same period from the nearest station having a similar correlation with the stations with the data gaps. Consequently, the missing years were determined using trend line equations.

### *3.2 Analysis – Methods*

***(i) Statistical techniques*** - The Monthly Rainfall (1941–2010) data were summarized using the statistical tools of measures of central tendency and dispersion. The monthly mean, annual mean and standard deviation were computed for the parameters considered in all the stations and standardized using a combination of standard deviation and mean. Also, percentages of the coefficient of variation for each of the stations were computed from the standard deviation of annual mean divided by the mean of annual mean and multiplied by 100. The rainfall variability index was determined from the standardize departure of the monthly rainfall in order to separate the climate into wet and dry periods. Single figures were derived for the anomaly, coefficient of variation, and variability index for each of the stations that were used to create surface maps. Consequently, the rainfall anomaly and variability index were determined using the following formulae:

$$Z = \frac{X-\mu}{\sigma} \qquad \text{---------- (eqn.1)}$$

$$CV = \frac{\sigma}{\mu} * 100 \qquad \text{---------- (eqn. 2)}$$

$$\delta i = (Pi - \mu)/\sigma \qquad \text{--------- (eqn. 3)}$$

$$\sigma = \sqrt{\frac{\Sigma(xi-\mu)}{n-1}} \qquad \text{---------- (eqn. 4)}$$

*Where, Z = Anomalies (standardization); CV = Coefficient of Variation; X = Value of climatic variables;* $\delta_i$ *= Variability index for year (i);* $p_i$ *= annual value of the climate parameter for year (i);* $\sigma$ *= Standard deviation and* $\mu$ *= Mean (28; 6).*

***(ii) Interpolation Technique*** – This research adopts the Inverse Distance Weighted (IDW) model to create the surface maps for the rainfall parameters. The IDW model was used because of the coarse nature or distance between synoptic stations within the study area. The IDW predicted very well in a situation where the influences of phenomena or observations diminish in their contributions with distances. Also, the IDW model always interpolates values of observations within the range of data values, so that the approximate values may not contain peaks and valleys. Therefore, the IDW involves dividing each of the observations by its distance from the target point raised to a power (α) (29). Thus:

$$Zj = kj \sum_{i=1}^{n} \left(\frac{1}{dij^{\alpha}}\right) zi \qquad \text{......... (Eqn. 5)}$$

*Where,* $\mathbf{Zj}$ *= Predicted Value;* $\mathbf{d}_{ij}$ *=distance between the known value and predicted value;* $\mathbf{z}_i$ *= the known value and* $\mathbf{k}_j$ *= an adjustment to ensure that the weights add up to 1(29).*

Subsequently, the surface maps generated were used to determine the spatial distribution and pattern of rainfall anomaly, coefficient of variability, and variability index.

## 4. Results and discussions

### *4.1 Rainfall Characteristics and trend*

The study revealed that the mean annual rainfall increases at the rate of 1.20mm annually with a long term mean of 1,316mm as presented in figure 2 for the period between 1941 and 2010. The derived savannah records a positive trend of rainfall anomaly, increasing annually at a rate of 0.007mm. The study area receives the lowest and highest of 951mm and 1,688mm in 1946 and 1991 respectively, which represent about 28% and 28% below and above the mean annual rainfall respectively as illustrated in figure 3. While the annual rainfall Coefficient of Variation (CV) varies between 8% and 38%, which recorded in 1966 and 2009 as could be seen in figure 4.

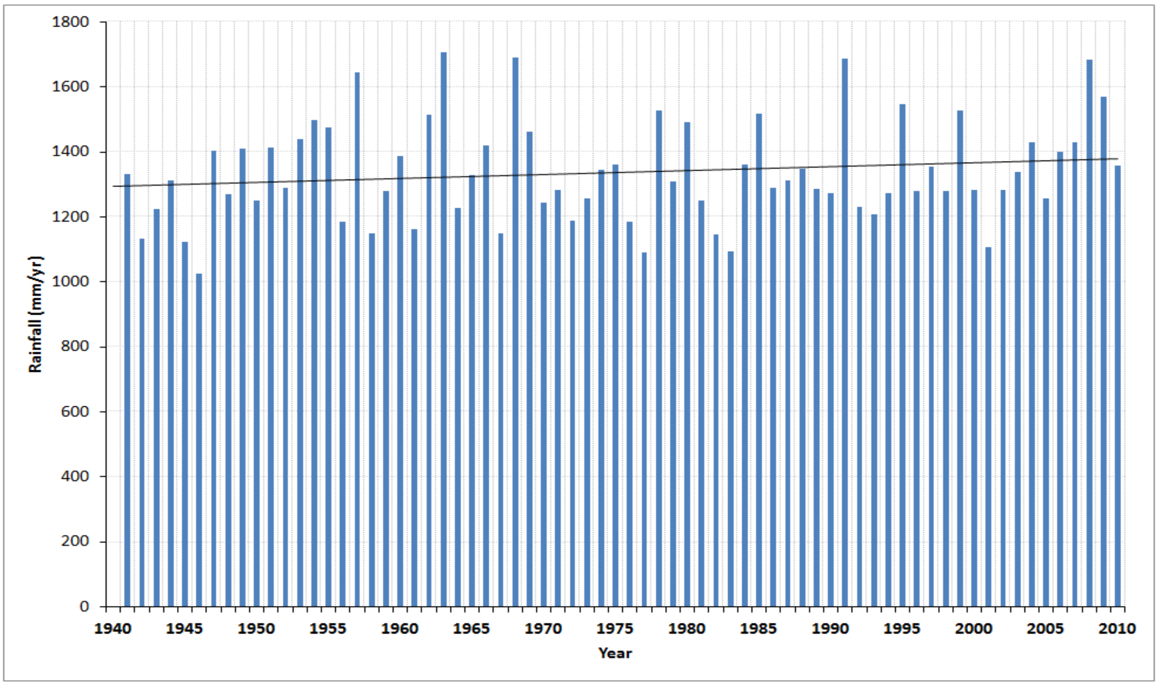
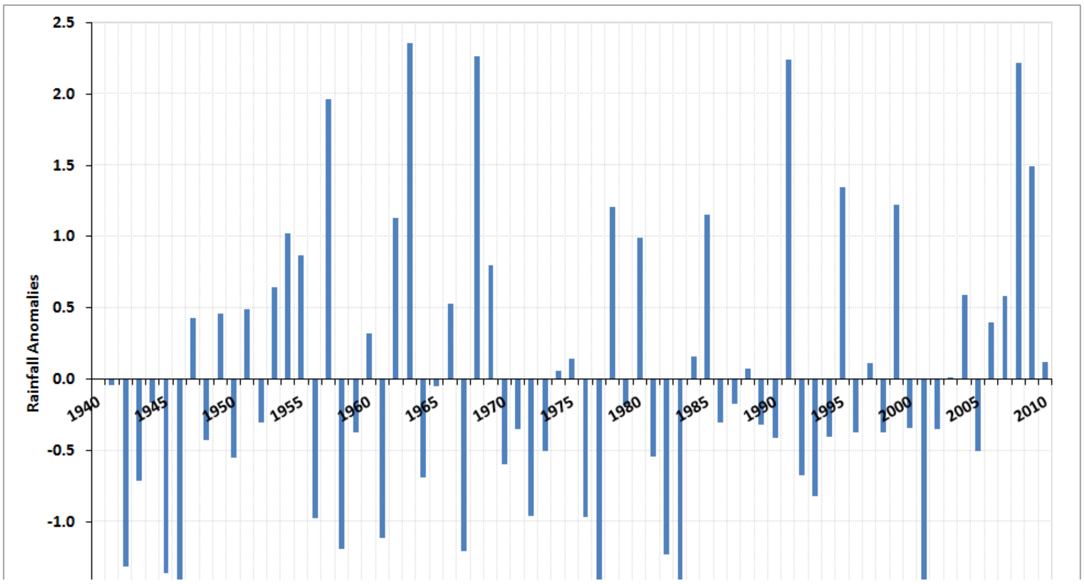


**Figure 2:** The characteristics and trend annual rainfall (1941 – 2010)

The seasonal rainfall pattern within the study area as presented in figure 5 exhibits double maxima during the period with the highest rainfall of 228mm recorded in the month of September.



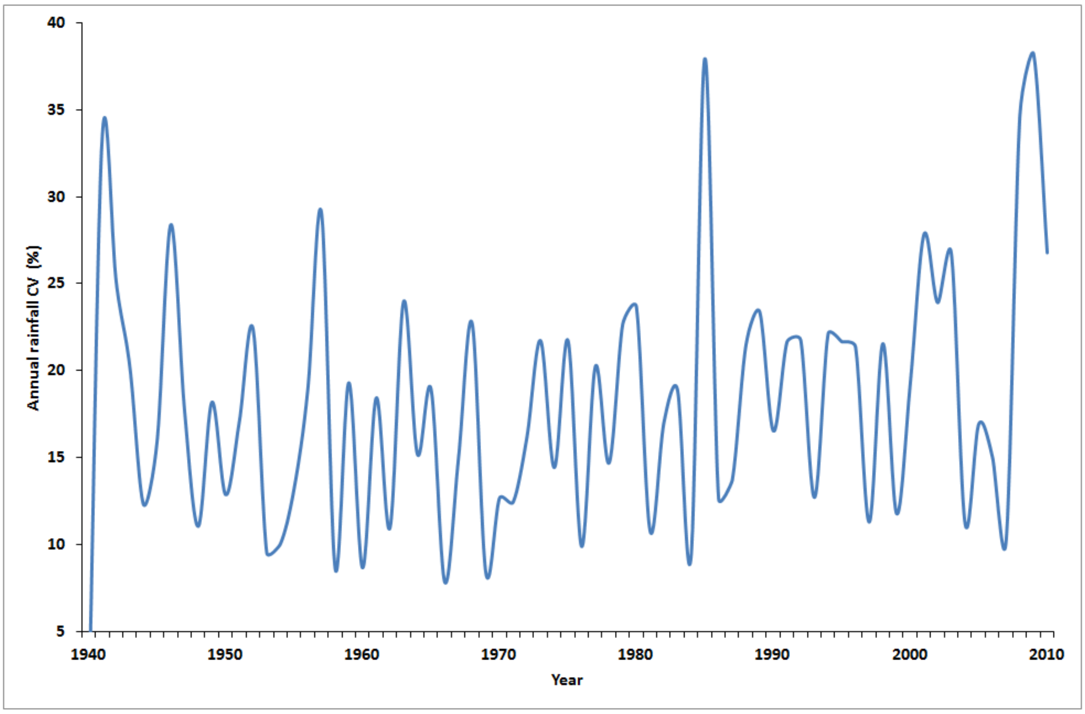


**Figure 4:** The coefficient of variation of annual rainfall (1941 – 2010)

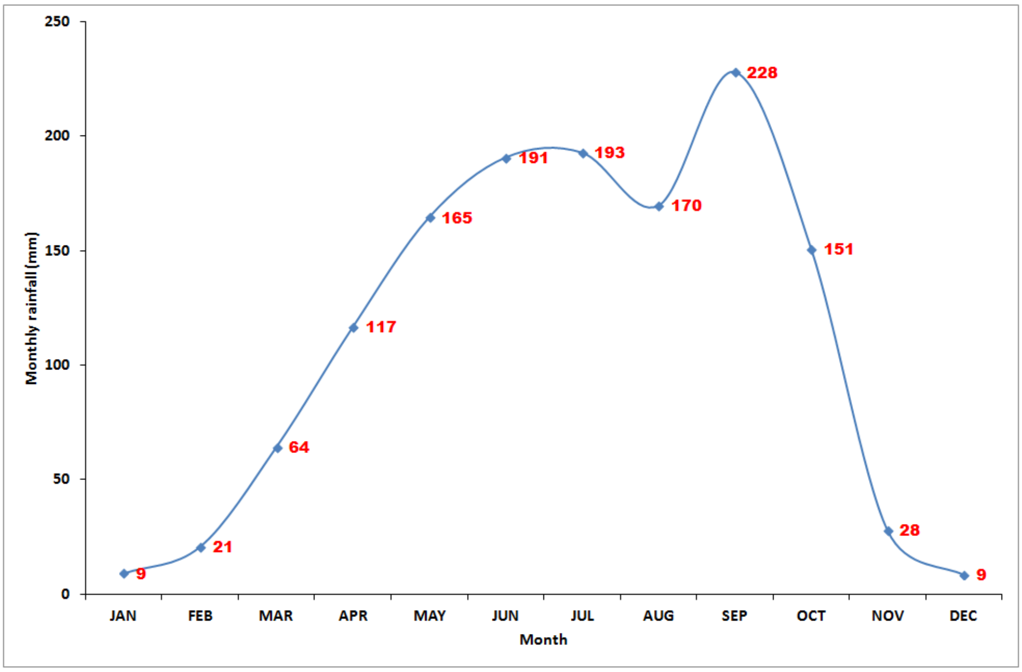


**Figure 5:** The seasonal distribution of annual rainfall (1941 – 2010)

### *4.2 Spatial pattern of rainfall variability*

The spatial patterns of annual rainfall and the corresponding coefficient of variation for the Derived savannah are presented in figures 6 and 7. The study revealed that the spatial distribution exhibits an increasing trend in the annual rainfall towards the southern (i.e. north to south direction) part of the study area. The annual rainfall ranges between 1,191mm and 1,628mm and these extremes were recorded in Ondo and Pategi areas respectively, as shown in figure 6. The result is similar to the findings of Oguntunde *et al.* and Odjugo that confirmed the latitudinal effect of rainfall, which decreases with an increase in latitude (30, 31).

The distribution of annual rainfall coefficient of variation (CV) varied from 14.82% to 19.25% for the study area as illustrated in figure 7. However, the coefficient of variation for the study area does not show a reversed latitudinal trend when compared with annual rainfall distribution as recorded by other researchers like (30). Pategi and Ilorin recorded the least and highest coefficient of variation of 15% and 19% respectively during the period as shown in figure 7. Also, the rainfall distribution pattern was more stable in areas like Pategi and Oshogbo which recorded 16% and 15% of rainfall coefficient of variation respectively than 18% and 19% recorded in Ondo and Ilorin respectively.

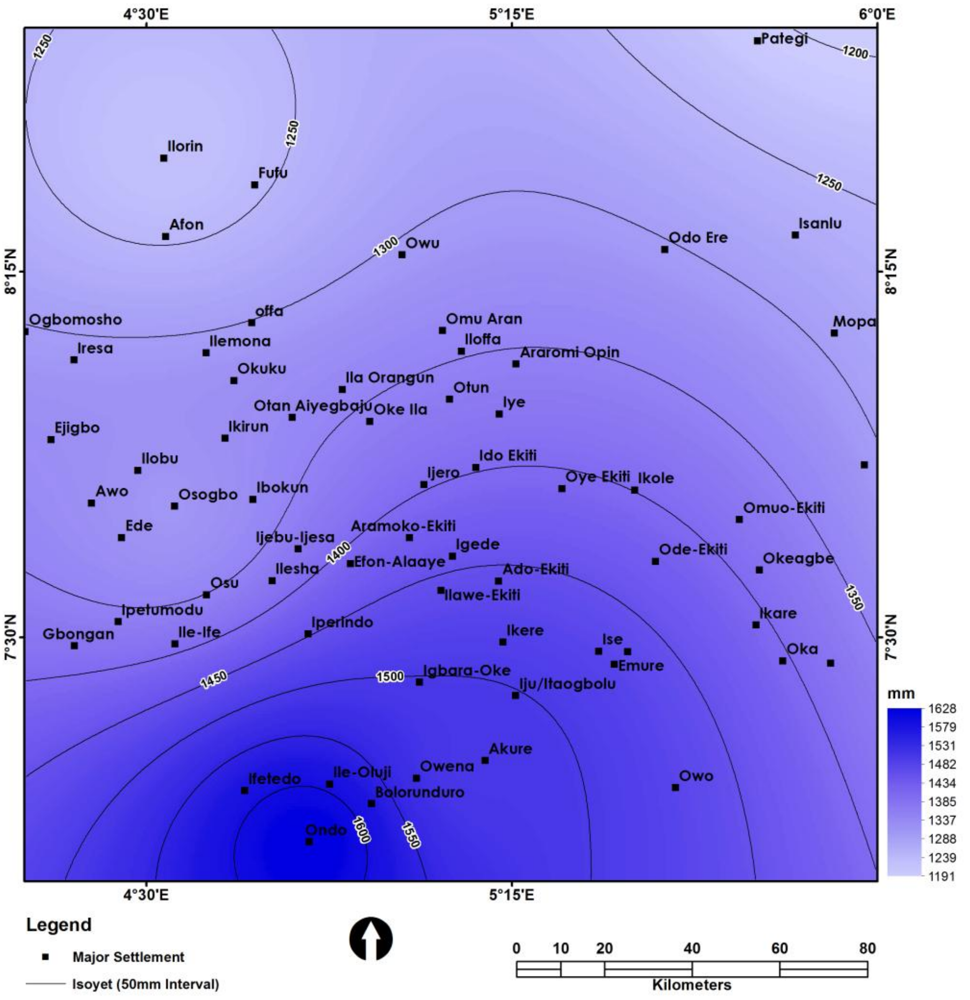


Figure 6: Spatial distribution of annual rainfall for Derived Savannah (1941 – 2010)

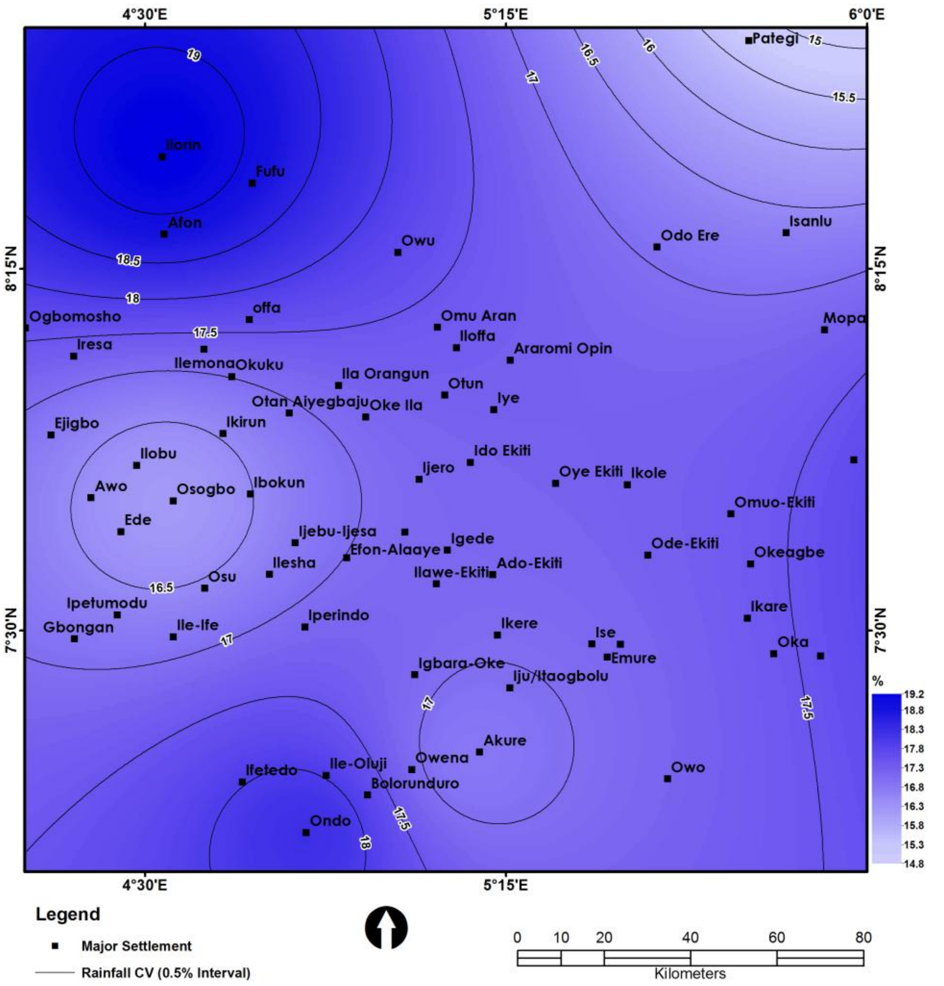


Figure 7: Spatial distribution of coefficient of variation of annual rainfall for Derived Savannah (1941 – 2010)

### *4.3 Temporal patterns of rainfall variability*

The patterns of annual and decadal rainfall variability indices of the derived savannah for the period of study (1941 – 2010) are shown in figures 8 and 9 respectively. Annual rainfall variability indices range from -2.00 to 2.38 (i.e. from severely dry to extremely wet, using World Meteorology Organisation (WMO) SPI values (32, 28) as shown in figure 8 and presented in table 1. During the period, 23 wet years, 33 dry years, and nine (9) normal climatic years were identified. This conformed to the findings of Oguntunde *et al.*, Nicholson *et al.*, L'Hóte *et al.*, Ayeni *et al.*, Ayeni, and Atedhor and Ayeni that identified 26 dry years, 34 wet years and 40 normal years for Nigeria between 1901 and 2000(6, 33, 34, 35, 36, 37). The decadal rainfall variability indices revealed that the study area recorded normal temporal pattern of rainfall except for the decade of 1941 -1950 that was dry. The study period was further divided into two climatic periods (i.e. 1941 – 1975 and 1976 – 2010) in order to understand the temporal variability pattern. The z-test for the two periods revealed that there was a change in rainfall pattern and variability since the **z** calculated of -0.3267 is less than the tabulated, 1.9599 at 5% significant. Also, figure 10 shows the change in the temporal distribution patterns of rainfall for the first period, and rainfall is slightly higher in the second period (1976 – 2010).

**Table 1: Standardized precipitation index**

| Indices | classification |
|---|---|
| 2.0+ | Extremely wet |
| 1.5 and 1.99 | Very wet |
| 1.0 and 1.49 | Moderately wet |
| -0.99 and 0.99 | Near normal |
| -1.0 and -1.49 | Moderately dry |
| -1.5 and -1.99 | Severely dry |
| -2.0 and less | Extremely dry |

*Sources: Akinsanola & Ogunjobi, 2014*

However, there are differences in the Spatio-temporal patterns, looking at the variability indices on the decadal basis as in figure 11 (a – g) and table 2. The study revealed that the area experienced varied temporal patterns of rainfall from very wet to moderately wet (1.31 – 1.69) periods in the southern part for all the decades, while the north recorded near normal conditions (-0.49 to -0.98) in all decades. Especially, Ondo recorded the highest rainfall variability index in decades between 1941 and 2010, which varied from 1.31 – 1.69 (which implies moderately wet to very wet condition) for all the decades with highest, 1.69 (very wet condition) in 1991 – 2000 decade as in figure 11(f). In addition, Ilorin and Pategi areas experienced near normal conditions for all the decade between 1941 and 2010 with indices varied between -0.49 and -0.98, which recorded in Ilorin except for the decades of 1951 – 1960 and 1991 – 2000 when Pategi recorded least rainfall variability index.

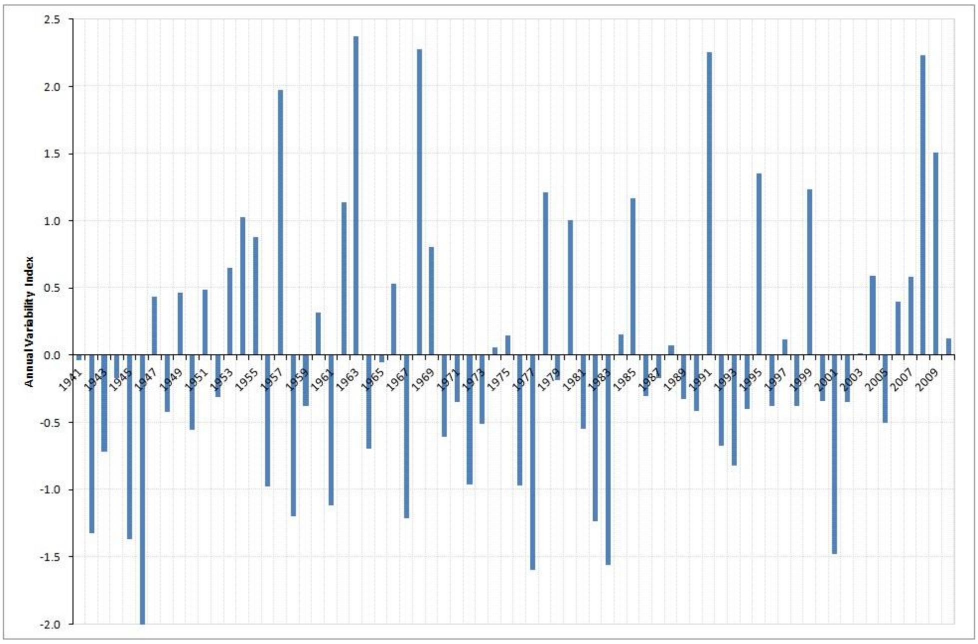


**Figure 8:** Annual Rainfall variability index for present climate (1941 – 2010)

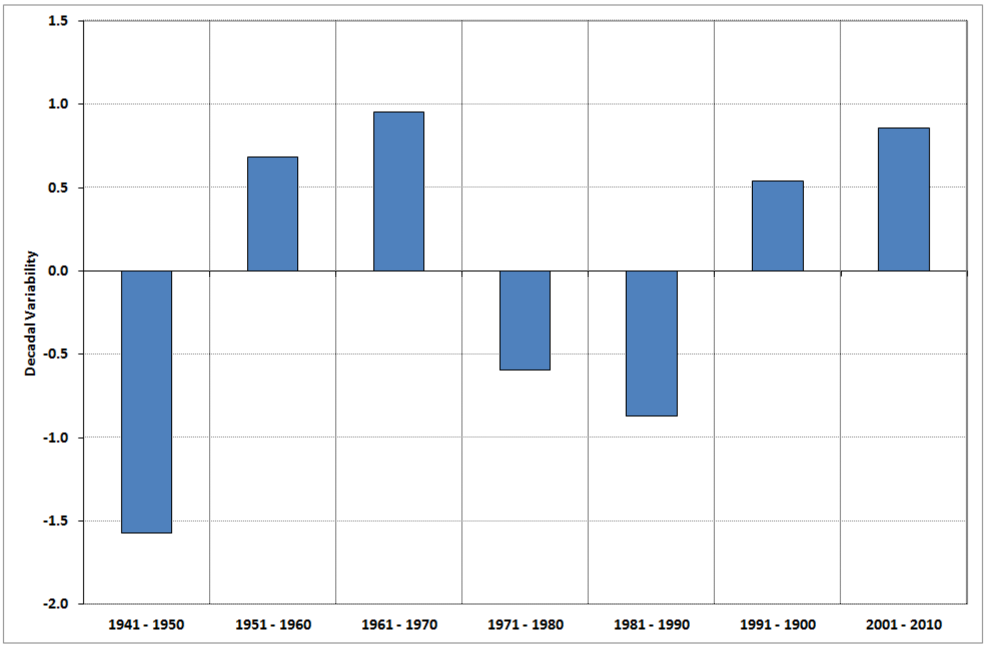


**Figure 9:** Decadal Rainfall variability index for present climate (1941 – 2010)

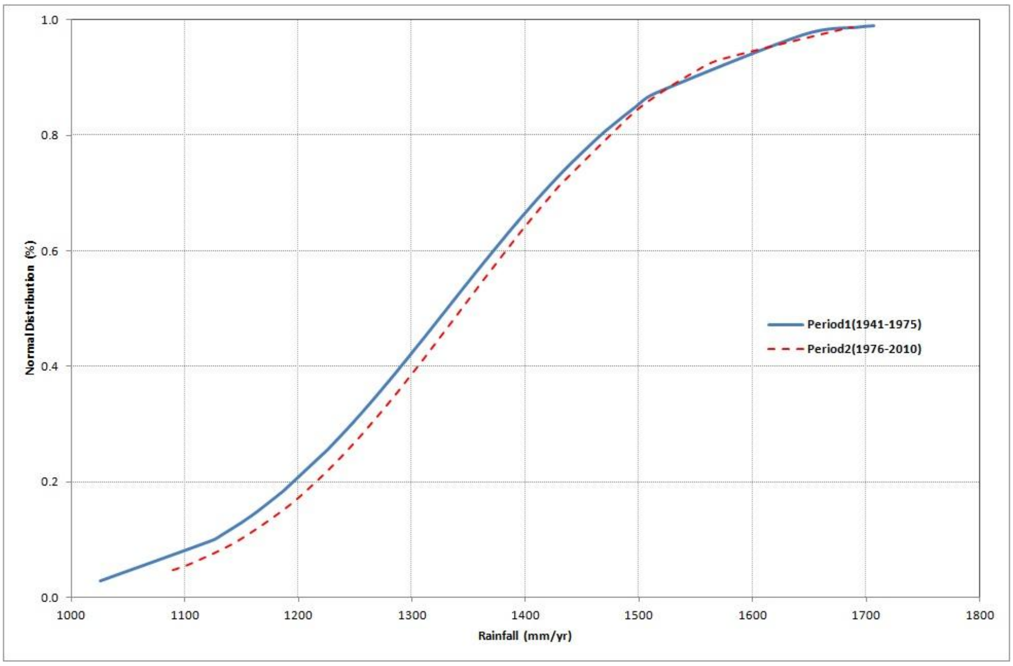


**Figure 10:** Temporal variability change in Rainfall for present climate (1941 – 2010) *(Author, 2015)*

Table 2: Decadal rainfall variability index of major settlements within Derived Savannah

| S/N | Towns | STATE | Long | Lat | decade 1941-50 | decade 1951-60 | decade 1961-70 | decade 1971-80 | decade 1981-90 | decade 1991-2000 | decade 2000-2010 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Ondo | Ondo | 4.834550 | 7.081210 | 1.41 | 1.31 | 1.59 | 1.54 | 1.50 | 1.69 | 1.33 |
| 2 | Bolorunduro | Ondo | 4.962290 | 7.159600 | 1.23 | 1.07 | 1.27 | 1.29 | 1.23 | 1.26 | 1.20 |
| 3 | Ifetedo | Osun | 4.702440 | 7.186240 | 1.22 | 1.13 | 1.35 | 1.30 | 1.29 | 1.40 | 1.15 |
| 4 | Owo | Ondo | 5.586030 | 7.192340 | 0.80 | 0.57 | 0.66 | 0.77 | 0.69 | 0.52 | 0.86 |
| 5 | Ile-Oluji | Ondo | 4.876410 | 7.199660 | 1.27 | 1.15 | 1.38 | 1.35 | 1.32 | 1.42 | 1.22 |
| 6 | Owena | Ondo | 5.054210 | 7.211910 | 1.08 | 0.78 | 0.89 | 1.04 | 0.91 | 0.70 | 1.14 |
| 7 | Akure | Ondo | 5.195050 | 7.247920 | 1.07 | 0.69 | 0.77 | 0.99 | 0.81 | 0.49 | 1.17 |
| 8 | Iju/Itaogbolu | Ondo | 5.258040 | 7.381280 | 1.00 | 0.68 | 0.76 | 0.94 | 0.80 | 0.53 | 1.08 |
| 9 | Igbara-Oke | Ondo | 5.060700 | 7.408600 | 0.96 | 0.71 | 0.80 | 0.91 | 0.83 | 0.63 | 1.00 |
| 10 | Oka | Ondo | 5.806030 | 7.452300 | 0.37 | 0.21 | 0.31 | 0.39 | 0.34 | 0.27 | 0.47 |
| 11 | Ise | Ekiti | 5.428680 | 7.472300 | 0.80 | 0.58 | 0.65 | 0.76 | 0.68 | 0.49 | 0.86 |
| 12 | Gbongan | Osun | 4.353090 | 7.483010 | 0.12 | 0.33 | 0.30 | 0.04 | 0.37 | 0.30 | 0.07 |
| 13 | Ile-Ife | Osun | 4.558790 | 7.487090 | 0.18 | 0.36 | 0.35 | 0.10 | 0.43 | 0.35 | 0.13 |
| 14 | Ikere | Ekiti | 5.232140 | 7.490950 | 0.88 | 0.64 | 0.71 | 0.83 | 0.74 | 0.54 | 0.93 |
| 15 | Iperindo | Osun | 4.832170 | 7.507630 | 0.55 | 0.57 | 0.61 | 0.50 | 0.65 | 0.57 | 0.52 |
| 16 | Ikare | Ondo | 5.751330 | 7.525790 | 0.38 | 0.23 | 0.32 | 0.40 | 0.35 | 0.27 | 0.47 |
| 17 | Ipetumodu | Osun | 4.442610 | 7.532660 | 0.00 | 0.25 | 0.21 | -0.09 | 0.31 | 0.22 | -0.04 |
| 18 | Osu | Osun | 4.623680 | 7.587840 | -0.04 | 0.22 | 0.18 | -0.15 | 0.29 | 0.18 | -0.08 |
| 19 | Ilawe-Ekiti | Ekiti | 5.104870 | 7.597060 | 0.68 | 0.57 | 0.61 | 0.63 | 0.64 | 0.50 | 0.69 |
| 20 | Ado-Ekiti | Ekiti | 5.222540 | 7.615840 | 0.70 | 0.55 | 0.60 | 0.65 | 0.63 | 0.48 | 0.72 |
| 21 | Ilesha | Osun | 4.758560 | 7.616780 | 0.11 | 0.30 | 0.28 | 0.02 | 0.36 | 0.26 | 0.07 |
| 22 | Okeagbe | Ondo | 5.758200 | 7.638470 | 0.28 | 0.14 | 0.23 | 0.30 | 0.26 | 0.20 | 0.37 |
| 23 | Efon-Alaaye | Ekiti | 4.918990 | 7.651320 | 0.36 | 0.43 | 0.42 | 0.29 | 0.47 | 0.38 | 0.33 |
| 24 | Ode-Ekiti | Ekiti | 5.544680 | 7.656490 | 0.50 | 0.37 | 0.42 | 0.48 | 0.44 | 0.34 | 0.54 |
| 25 | Igede | Ekiti | 5.128260 | 7.666880 | 0.57 | 0.51 | 0.53 | 0.52 | 0.56 | 0.44 | 0.57 |
| 26 | Ijebu-Ijesa | Osun | 4.812050 | 7.681980 | 0.11 | 0.30 | 0.26 | 0.02 | 0.34 | 0.24 | 0.06 |
| 27 | Aramoko-Ekiti | Ekiti | 5.040110 | 7.704600 | 0.43 | 0.45 | 0.44 | 0.38 | 0.48 | 0.38 | 0.41 |
| 28 | Ede | Osun | 4.449610 | 7.705110 | -0.24 | 0.09 | 0.04 | -0.37 | 0.17 | 0.04 | -0.28 |
| 29 | Omuo-Ekiti | Ekiti | 5.717100 | 7.741990 | 0.24 | 0.12 | 0.20 | 0.25 | 0.22 | 0.16 | 0.31 |
| 30 | Osogbo | Osun | 4.558450 | 7.769320 | -0.29 | 0.06 | 0.01 | -0.43 | 0.15 | 0.01 | -0.33 |
| 31 | Awo | Osun | 4.387710 | 7.775710 | -0.22 | 0.11 | 0.04 | -0.35 | 0.16 | 0.04 | -0.27 |
| 32 | Ibokun | Osun | 4.718990 | 7.783360 | -0.16 | 0.14 | 0.08 | -0.28 | 0.19 | 0.08 | -0.21 |
| 33 | Ikole | Ekiti | 5.502390 | 7.802670 | 0.35 | 0.28 | 0.30 | 0.33 | 0.32 | 0.24 | 0.38 |
| 34 | Oye Ekiti | Ekiti | 5.352880 | 7.805500 | 0.40 | 0.35 | 0.35 | 0.36 | 0.38 | 0.29 | 0.40 |
| 35 | Ijero | Ekiti | 5.069720 | 7.814010 | 0.30 | 0.37 | 0.32 | 0.24 | 0.36 | 0.28 | 0.26 |
| 36 | Ilobu | Osun | 4.482650 | 7.842860 | -0.27 | 0.08 | 0.02 | -0.40 | 0.15 | 0.02 | -0.31 |
| 37 | Ido Ekiti | Ekiti | 5.176260 | 7.848890 | 0.32 | 0.36 | 0.31 | 0.27 | 0.34 | 0.26 | 0.29 |
| 38 | Ejigbo | Osun | 4.304470 | 7.905870 | -0.17 | 0.16 | 0.02 | -0.29 | 0.11 | 0.04 | -0.26 |
| 39 | Ikirun | Osun | 4.661780 | 7.908790 | -0.20 | 0.12 | 0.03 | -0.32 | 0.14 | 0.04 | -0.26 |
| 40 | Oke Ila | Osun | 4.958520 | 7.943290 | 0.07 | 0.27 | 0.14 | -0.02 | 0.18 | 0.13 | -0.01 |
| 41 | Otan Aiyegbaju | Osun | 4.799860 | 7.951290 | -0.08 | 0.20 | 0.06 | -0.19 | 0.13 | 0.07 | -0.17 |
| 42 | Iye | Ekiti | 5.224400 | 7.958600 | 0.21 | 0.28 | 0.20 | 0.16 | 0.22 | 0.17 | 0.16 |
| 43 | Otun | Ekiti | 5.122550 | 7.988530 | 0.14 | 0.27 | 0.15 | 0.07 | 0.17 | 0.13 | 0.06 |
| 44 | Ila Orangun | Osun | 4.902480 | 8.008760 | -0.02 | 0.23 | 0.05 | -0.12 | 0.09 | 0.06 | -0.13 |
| 45 | Okuku | Osun | 4.680220 | 8.026860 | -0.17 | 0.17 | -0.03 | -0.29 | 0.04 | -0.01 | -0.29 |
| 46 | Araromi Opin | Kwara | 5.258720 | 8.060920 | 0.11 | 0.20 | 0.10 | 0.05 | 0.11 | 0.07 | 0.04 |
| 47 | Iresa | Oyo | 4.351940 | 8.069410 | -0.20 | 0.19 | -0.11 | -0.32 | -0.06 | -0.06 | -0.36 |
| 48 | Ilemona | Kwara | 4.622670 | 8.083770 | -0.20 | 0.18 | -0.11 | -0.32 | -0.06 | -0.07 | -0.36 |
| 49 | Iloffa | Kwara | 5.146890 | 8.087090 | 0.06 | 0.22 | 0.05 | -0.02 | 0.07 | 0.05 | -0.04 |
| 50 | Mopa | Kogi | 5.911540 | 8.124220 | -0.24 | -0.35 | -0.24 | -0.19 | -0.24 | -0.24 | -0.13 |
| 51 | Ogbomosho | Oyo | 4.251460 | 8.127430 | -0.21 | 0.21 | -0.18 | -0.33 | -0.15 | -0.12 | -0.42 |
| 52 | Omu Aran | Kwara | 5.107520 | 8.129250 | 0.00 | 0.21 | 0.00 | -0.08 | 0.01 | 0.00 | -0.12 |
| 53 | offa | Kwara | 4.716440 | 8.145460 | -0.21 | 0.21 | -0.18 | -0.33 | -0.17 | -0.13 | -0.42 |
| 54 | Owu | Kwara | 5.025080 | 8.284540 | -0.15 | 0.18 | -0.19 | -0.25 | -0.19 | -0.15 | -0.35 |
| 55 | Odo Ere | Kogi | 5.563910 | 8.295710 | -0.13 | -0.14 | -0.17 | -0.17 | -0.19 | -0.23 | -0.18 |
| 56 | Afon | Kwara | 4.539660 | 8.322230 | -0.41 | 0.24 | -0.56 | -0.56 | -0.62 | -0.42 | -0.82 |
| 57 | Isanlu | Kogi | 5.831790 | 8.325250 | -0.28 | -0.40 | -0.32 | -0.29 | -0.34 | -0.39 | -0.27 |
| 58 | Fufu | Kwara | 4.722480 | 8.428130 | -0.42 | 0.24 | -0.58 | -0.57 | -0.65 | -0.44 | -0.83 |
| 59 | Ilorin | Kwara | 4.536210 | 8.483010 | -0.49 | 0.26 | -0.70 | -0.66 | -0.79 | -0.53 | -0.98 |
| 60 | Pategi | Kwara | 5.754200 | 8.723700 | -0.49 | -0.72 | -0.58 | -0.59 | -0.68 | -0.83 | -0.59 |

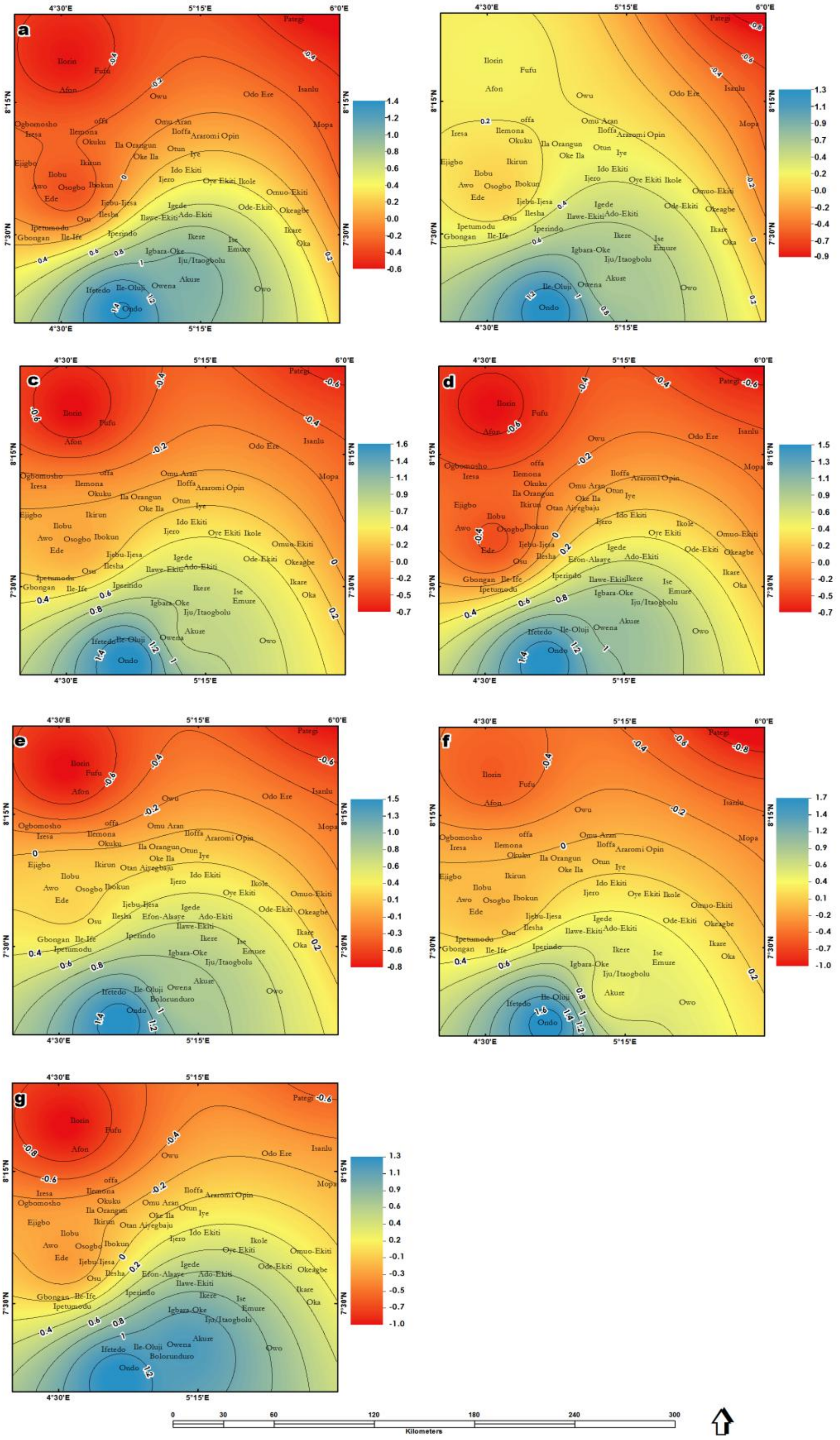


Figure 11: Decadal rainfall variability patterns between 1941 and 2010 - (a) decade 1941 -50; (b) decade 1951 – 60; (c) decade 1961 – 70; (d) decade 1971 – 80; (e) decade 1981 – 90; (f) 1991 – 2000 and (g) decade 2001 - 2010

## 5. Conclusion

The study evaluates the spatial and temporal variability patterns of rainfall in the Derived Savannah region of Nigeria for the period between 1941 and 2010. The study confirmed the spatial pattern and trend for the zone in which rainfall will continue to increase in a north-southward direction and affirmed the characteristics of rainfall to remain as double maxima with the highest recorded in September, which makes it to have a single peak period. Due to the shift in Spatio-temporal distribution and variability patterns within the area, there is a need for more climatic research in order to adopt appropriate adaptation and mitigation strategies.

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