Water and Environmental Sustainability (WES)
ISSN: 2710-3404
DOI: 10.52293/WES.3.1.3651
H o m e p a g e: https://www.journalwes.com/

ORIGINAL RESEARCH PAPER

An assessment of changes in the Rainfall Distribution of Abia State (Nigeria) between 1972 and 2050

Uwadiegwu Ibeabuchi*
Department of Geography, Faculty of Social Science, University of Lagos, Lagos, Nigeria

A R T I C l E I N F O

Keywords:
Rainfall
Water requirement
Climate change
Statistics
GIS
Abia state

Corresponding Author:
ibeabuchi09@gmail.com

Article History:
Received: 27 Sep, 2022
Revised: 1 Nov, 2022
Accepted: 6 Nov, 2022

A B S T R A C T

Change in rainfall is one of the most critical factors in determining the impact of climate change on Abia state. Annual rainfall data was acquired from HadCM3 baseline and future scenarios between 1972 and 2050 for Abia state. Analysis was performed using Geographical Information System (GIS) and statistical techniques. Descriptive statistics were extracted using statistical methods while for spatial rainfall distribution, standard deviation and coefficient of variation were mapped using GIS interpolation methods. For baseline scenario between 1972 and 2015, annual rainfall minimum, maximum, mean, variability, standard deviation and coefficient of variation in the southern part of Abia state is relatively higher than the northern part of the state which is lower compared to future scenario between 2015 and 2050. Significant changes in rainfall between 2015 to 2050 in-relation to its distribution pattern (using Log Pearson Type III probability distribution) in-terms of its frequency, climate extremes and extreme events is higher than 1972 to 2015. This change in rainfall implies that in Abia state an increase in heavy rainfall with a 0.2% chance exceedance annual rainfall event is likely to become 0.5% chance exceedance event in many regions with a higher emissions scenarios leading to a greater projected decrease in return period. Finally, water requirement for various crops were studied in-relation to effective rainfall and the results reveals that crops receive a high probability of critical rainfall amount in a given year needed for growth between 1972 and 2050. This study provides information on rainfall trend on a long-term basis and impact of climate change on Abia state which will be very useful for water resource management, agriculture and economic development of the region.

Introduction

Analysis of rainfall data strongly depends on its distribution pattern. It has long been a topic of interest in the field of meteorology in establishing a probability distribution that provides a good fit to daily rainfall. Several studies have been conducted in India and abroad on rainfall analysis and best fit probability distribution function such as normal, log-normal, gumbel, weibull and pearson type distribution (Sharma & Singh, 2010). The design and construction of certain projects, such as dams and urban drainage systems, management of water resources, and prevention of flood damage require an adequate knowledge of extreme events of high return periods (Tao et al., 2002; Dan'azumi et al., 2010).In most cases, the return periods of interest exceed usually the periods of available records and could not be extracted directly from the recorded data. Therefore, in current engineering practice, the estimation of extreme rainfalls or flood peak discharges is accomplished based on statistical frequency analysis of maximum precipitation or maximum stream flow records were available sample data could be used to calculate the parameters of a selected frequency distribution. The fitted distribution is then used to estimate event magnitudes corresponding to return periods greater than or less than those of the recorded events. Accurate estimation of extreme rainfall could help alleviate the damage caused by storms and floods, and it can help achieve more efficient design of hydraulic structures (Tao et al., 2002).

The study of rainfall pattern is very important for the agricultural planning of any region (Sikka, 1977). Thompson (1975) studied the effect of rainfall on crop yield taking into account the amount of monthly rainfall data and concluded that the amount of rainfall plays a crucial role in different stages of crop growth. The weather along with technology is the cause of 80 to 92 percentage variability in the yield. Raudkivi (1979) calculated rainfall probabilities using Markov chain model and explained how these are used to describe the hydrological phenomena. In his article, firstly, the distribution of rainfall data was order month wise and secondly, the probabilities of the number of rainy days were calculated. Fisher (1924) studied the influence of rainfall on the yield of wheat in Rothamasted. He showed that it is the distribution of rainfall during a season rather than its total amount which influence the crop yield. Analysis of rainfall would enhance the management of water resource application as well as the effective utilization of water resources. Such information can also be used to prevent floods and droughts, and applied to the planning and designing of water resource related engineering, such as reservoir design, flood control work, drainage design, and soil and water conservation planning, etc. All these works require rainfall data as a design basis. According to von Braun (1991), for instance, a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in the country's food production. Rainfall in most country is, on the other hand, often erratic and unreliable; and rainfall variability and associated droughts have historically been the major causes of food shortages and famines (Pankhurst & Johnson, 1988). Probability and frequency analysis of rainfall data enables us to determine the expected rainfall at various chances. Rainfall at 80 per cent probability can be safely taken as assured rainfall; while 50 per cent chance can be considered as the maximum limit for taking any risk (Gupta et al., 1975).

Previous studies have examined inter-annual rainfall variability in Nigeria and other part of West Africa (FAO,2001; Adejuwon, 2004; Akinseye et al., 2013). Jackson (1989) notes that even in wet locations rainfall variability at the daily time scale is critical to plant growth, particularly in the early part of the rainy season before soil moisture reserves have been built-up. Generally, the effect of rainfall variability on crop production varies with types of crops cultivated, types and properties of soils and climatic conditions of a given area. One of the major impacts of climate change is variation in rainfall pattern which directly or indirectly affects the regional water sources which are rain fed/recharged (Udayashankara et al., 2016)**.** A common consensus among environmental and agricultural economists is that climate change is a serious threat toward ensuring sustainable agriculture (Iheoma, 2014). Climate change has created challenges for the agricultural sector – and will continue to do so. Climate change is expected to negatively affect both crop and livestock production systems in most regions, although some countries may actually benefit from the changing conditions (Ignaciuk & Mason-D'Croz, 2014). Climate change has significantly affected global agriculture in the 21st century and future impacts are projected to worsen as the temperature continues to rise and precipitation becomes more unreliable (Ochieng et al., 2016). The intensity and frequency of heavy precipitation events have increased in the last 50 years and the spatial pattern of rainfall is likely to change, with rise in number and intensity of extreme rainfall events which adversely impact the natural resources on which majority of the population is dependent (Thakural et al., 2018). Nevertheless, while climate change is seen as a fact, the reality about the current predictions for the region is highly uncertain (TarekMerabtene & Abdallah, 2016). However, there is need to investigate into the rainfall distribution of Abia state, primarily: (1) to study the rainfall distribution; (2) to study the rainfall variations and storms; (3) relating rainfall trend to global climate change, and (4) to study the rainfall distribution as an environmental prerequisite for agro sustainable development in a changing climate between 1972 and 2050. Therefore, the aim of this research is to assess the rainfall distribution based on its descriptive and predictive abilities for describing accurately the distribution pattern of rainfall and understand what the future climate holds for Abia state based on simulated future trends between 1972 and 2050.

Data and Methods

Data acquired for this study includes: (1) Administrative base map of Abia state. This was obtained from Ministry of Lands, Survey and Urban Planning, Town Planning Department, Umuahia, Abia state, Nigeria; (2) Meteorological variable such as rainfall. This was acquired from: (a) rainfall records of HadCM3 - Atmosphere-Ocean General Circulation Models (AOGCMs) for baseline and future scenarios (between 1972 and 2050) in Microsoft Excel spread sheet CSV (Comma-Separated Value) format; and (b) rainfall records between 1972 to 2015 from National Root Crop Research Institute (NRCRI), Umudike, weather station; (3) GPS reading and ground trotting (field survey) of study location. This was conducted to help understand and get first-hand information on vegetation and agricultural land use throughout the study area which is useful to assess the dynamics of change in the rainfall disribution pattern; and in addition,(4) the review of current and relevant literatures on the research subject. Rainfall distribution and its implications on climate change over Abia state region was studied using HadCM3 (Hadley Centre Coupled Model, Version 3) - Atmosphere-Ocean General Circulation Models (AOGCMs). AOGCMs used in this study are from the contribution of Coupled Model Inter-Comparison Project (CMIP), IPCC 4^{th} assessment report with a resolution of 3.75˚x 2.5˚. HadCM3 was divided into: (a.) Baseline scenario between 1972 and 2000; and (b.) Future scenario between 2000 and 2050. HadCM3 was used because of its large coverage and accessibility of the study area. The model start their integration from the '20th Century Climate in Coupled Model' (20C3M) run, in which the level of anthropogenic forcing is based on historical data of the late 19^{th} century through to the 20^{th} century. From the end of the 20C3M run, Special Report on Emission Scenarios (SRES)-A1B scenario, conditions were imposed and integrated till the year 2100. The initial area extent is between 0.00˚–15˚ East and 2.5˚-12.5˚ North from which Abia state was extracted between longitude 07° 09' - 8° 05' East, and latitude 04° 48' - 06° 03' North (Figure 1). Abia state is located east of Imo state and shares common boundaries with Anambra, Enugu and Ebonyi states to the North West, North and North East respectively. To the East and South East, it is bounded by Cross River and Akwa Ibom states, and Rivers state to the South (Figure 1). Abia state occupies a landmass of 5,833.77 square kilometers.

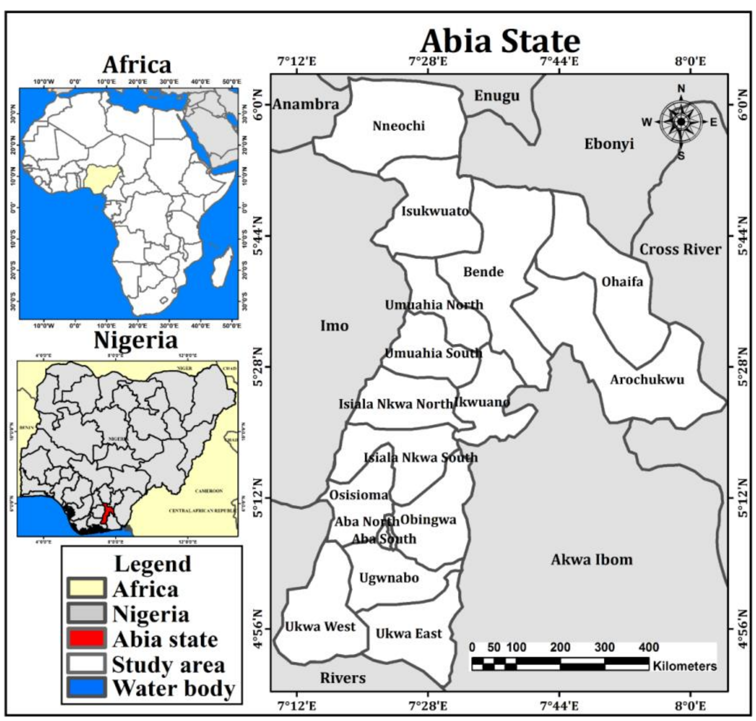

Fig. 1. Location of Abia state.

National Root Crop Research Institute (NRCRI) Umudike weather station is located at 5° 29' North and 7° 33' East on an elevation of 122metres in Abia state.

Acquired analogue administrative map of Abia state was converted to GIS shapefile (*shp*) format by: (1) scanning; (2) The scanned map was geo-referenced using UTM 32N co-ordinate system; and (3) The scanned map was digitized, database created and used as input to study the rainfall distribution of Abia state. While HadCM3 and GPS reading from weather station, vegetation and agricultural land use locations was captured in Microsoft Excel 2010 software and converted to shapefile format by adding the X, Y coordinates in ArcGIS 10 software. Rainfall distribution between 1972 and 2050 was modeled using HadCM3 as input into Kriging interpolation(Geostatistical wizard), implemented in ArcGIS 10 software. Kringing is a geostatistical procedure that generates an estimated surface from scattered sets of points with Z values. It involves an interactive investigation of the spatial behavior of the phenomenon before generating the output surface. It has been considered as a highly recommended spatial interpolation method in GIS. Kringing is a two-step process implemented using Ordinary Kringing, which includes semi variance and interpolation. Semi variance($\gamma(h)$) can be estimated from sampling data using the following formula:

$$\gamma(h) = \frac{1}{2} n \sum_{i=1}^{n} \{Z(X_i) - Z(X_i + h)\}^2 \quad (1)$$

Where, *X* and *h* = Two dimensional location and distance, *n*= Number of pairs of the data points separated by distance h or distance range *(h-d/2, h+d/2)*, if a distance interval *d* is used. To interpolated value at an unsampled location the following formula was used:

$$\hat{Z}(X_o) = \sum_{i=1}^{n} \lambda_i Z(X_i) \quad (2)$$

Where, X_o = Prediction location, $Z(X_i)$ = Measured value at the *i*th location, λ_i = An unknown weight for the measured value at the *i*th location, and *n*= Number of measured value. Output of the rainfall interpolation was divided into two scenarios, namely: (1) baseline scenario between 1972 and 2015; and (2) future scenario between 2015-2050. Furthermore, the baseline scenario was divided into three time slices: (a) 1972-1986; (b) 1986-2003; and (c) 2003-2015. Rainfall values for all observatories were extracted, exported and plotted on graph in Microsoft excel 2010 software to study the distribution of rainfall in Abia state.

Base on the baseline and future scenarios (between 1972 and 2050),the general characteristics of rainfall in Abia state were analyzed using the following descriptive statistics: Minimum, maximum, and mean, this was implemented in Microsoft excel 2010 software. Using the baseline and future scenarios, the mean rainfall was computed as:

$$Mean(\bar{x}) = \frac{\sum_{i=1}^{n} x_i}{N} \quad (3)$$

Where, *N* = Total number of observations and x_i= *i*th values of x-variables. Standard deviation was computed using the following:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{N}} \quad (4)$$

Where, *N* = Number of observations, σ = Standard deviation, *x* = Observations or values, $\bar{X}$= Mean. Coefficient of variation (CV) was computed using the following:

$$CV(\%) = \sigma / \bar{x} \times 100 \quad (5)$$

While, variance was computed using the following:

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{N} \quad (6)$$

Where, σ^2 = Variance, *N* = Number of observations, and $\bar{x}$= Mean. Standard deviation and coefficient of variation was used to study rainfall spatial variability computed in Microsoft Excel 2010 from HadCM3, then interpolated in ArcGIS 10 software using Kriging interpolation. To study rainfall temporal variability in Abia state, rainfall variability was computed by subtracting the observed mean from sequences of observations; used to define the amount of variance about the mean. This was applied to time series to plot the trend in sequence of observations made at equal interval of time for baseline and future scenarios as well as for annual rainfall distribution. This was used to study rainfall trend for baseline and future scenarios, implemented in Microsoft Excel 2010 software.

Bulletin 17B probability distribution was selected to model rainfall frequency for baseline and future scenarios for 0.2, 0.5, 1.0, 2.0, 5.0, 10, 20 and 50**%** chance exceedance rainfall event. Components of Bulletin 17B (Davie,2008) include: (a) To fit logarithms of annual rainfall to Log Pearson Type III probability distribution using the method of moments to compute mean, standard deviation, and skew of the log-transformed data; (b) Improve skew estimate by averaging it with a regional skew estimate obtained from Bulletin 17B. The Weight station and generalized skew reflects the relative accuracy; (c)Test to identify high and low outlier limits and screen data against them; and (d)Adjust the low outliers, zero flows, and gage base peaks based on conditional probability techniques. Rainfall between 1972 and 2050 extracted from the rainfall model was used to estimate the rainfall distribution and return period for specified rainfall amount. To validate the rainfall model, annual rainfall for Abia state collected between 1972 and 2015 from NRCRI weather station (observed rainfall) was plotted against HadCM3 model (expected rainfall) for similar years in SPSS 20 software using Pearson Correlation Coefficient (***r***) statistics, this was expressed as:

$$r = \frac{N\sum XY - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{N\sum X^2 - \left(\sum X\right)^2 N\sum Y^2 \left(\sum Y\right)^2}} \quad (7)$$

Where, r = Correlation coefficient, N = Total number of sample, X = Independent variable, Y = Dependent variable, and Σ= Summation function.

Water requirement for agricultural land use and crops was found and related to effective rainfall using the rainfall distribution (HadCM3) model. Effective rainfall is the amount of rainfall effectively used by crops. Rainfall is a major prerequisite and benchmark for agro sustainable development in Abia state. Effective rainfall (Arvind et al.,2017) was computed as:

$$R_e = 0.8 \times P-25, \text{ if } P \geq 75mm \quad (8)$$

$$R_e = 0.6 \times P-10, \text{ if } P < 75mm \quad (9)$$

Where, R_e = Effective rainfall (mm), and P = Total monthly rainfall (mm). This was implemented in Microsoft Excel 2010 software.

Results

Historical changes in the Rainfall distribution of Abia state between 1972 and 2015

Annual rainfall distribution was interpolated over Abia state in three time slices between 1972-1986, 1986-2003 and 2003-2015 (from HadCM3 model) for baseline scenario using ordinary kriging technique in ArcGIS 10 (Geostatistical wizard) with a spherical semi-variogram model. The estimated parameters of the model are: nugget (0.00029, 0.00026 and 0.00032), partial sill (0.29, 0.26 and 0.15), Lag size (0.121, 0.123 and 0.122) and major range (1.46, 1.48 and 1.47km) between 1972-1986, 1986-2003 and 2003-2015. The rainfall observatories was averaged to estimate the annual rainfall.

Figure 2 shows the annual rainfall distribution between 1972-1986, 1986-2003 and 2003-2015 for Abia state. In-terms of spatiotemporal difference, the rainfall decreases northward, the northern part of Abia state has a relatively lower annual rainfall than the southern part of the state with an estimated annual rainfall difference of 1.30, 1.40 and 1.14 mm/day between 1972-1986, 1986-2003 and 2003-2015. The low rainfall difference between the north and south was due to the presence of imo river and coastal city of Port Harcourt bordering southern part of the state, and the influence of the north-ward movement of Inter Tropical Convergence Zone (ITCZ) with maximum rainfall southward which decreases inland. Also, the location and terrain of the state influences the rainfall distribution. The rainfall mean is relatively higher for Aba north, Osisioma, Ugwnabo, Ukwa east and west than the rest of the Local Government Areas(LGAs) as presented in Figure 2 and 3 between 1972 and 1986. While between 1986 and 2003, Isiala Nkwa north, Aba north and Obingwa were included as having a relatively high rainfall, and between 2003 and 2015, all LGAs were observed as having a relatively low rainfall. The rainfall distribution encourages agricultural activities inland and soil erosion.

Annual rainfall of the LGAs in Abia state is presented in Figure 4 for baseline scenario between 1972 and 2015. The rainfall pattern reveals a positive increasing rainfall trend for the LGAs in Abia state between 1972 and 2015. Figure 5 presents the rainfall trend and variability in Abia state between 1972 and 2015. The result reveals that the rainfall trend is positive and reliable with 27.30% (R^2= 0.273) increase between 1972 and 2015 for Abia state. Validation was performed using the mean rainfall obtained from the weather station (NRCRI) between 1972 and 2015 compared with the derived mean rainfall from HadCM3. The results reveals that a relationship exist between both means at 95% level of confidence and its R^2=0.998, a mean of 5.16mm/day for weather station and 5.24mm/day for HadCM3 was recorded. The results further reveals that HadCM3 has similar rainfall pattern, trend and variability as the weather station.

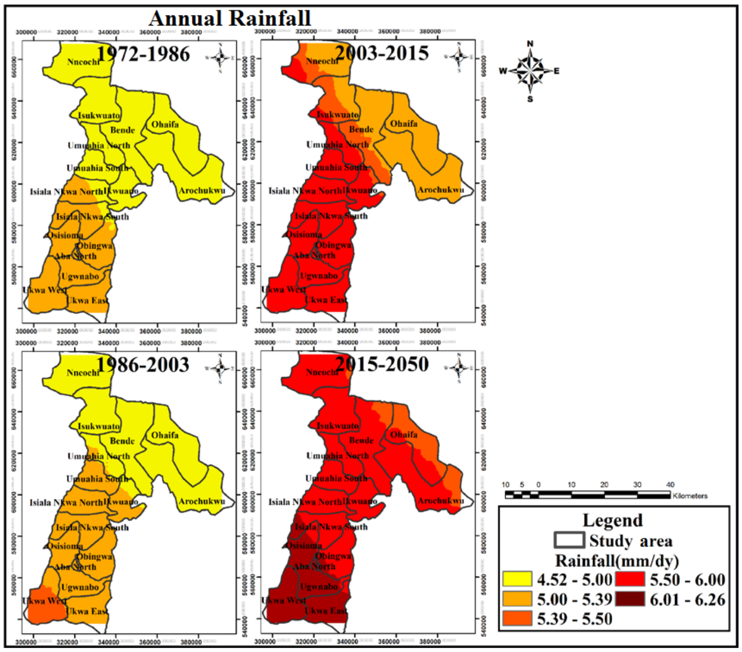

Fig. 2. Annual rainfall distribution between 1972-1986, 1986-2003, 2003-2015 and 2015-2050 for Abia state.

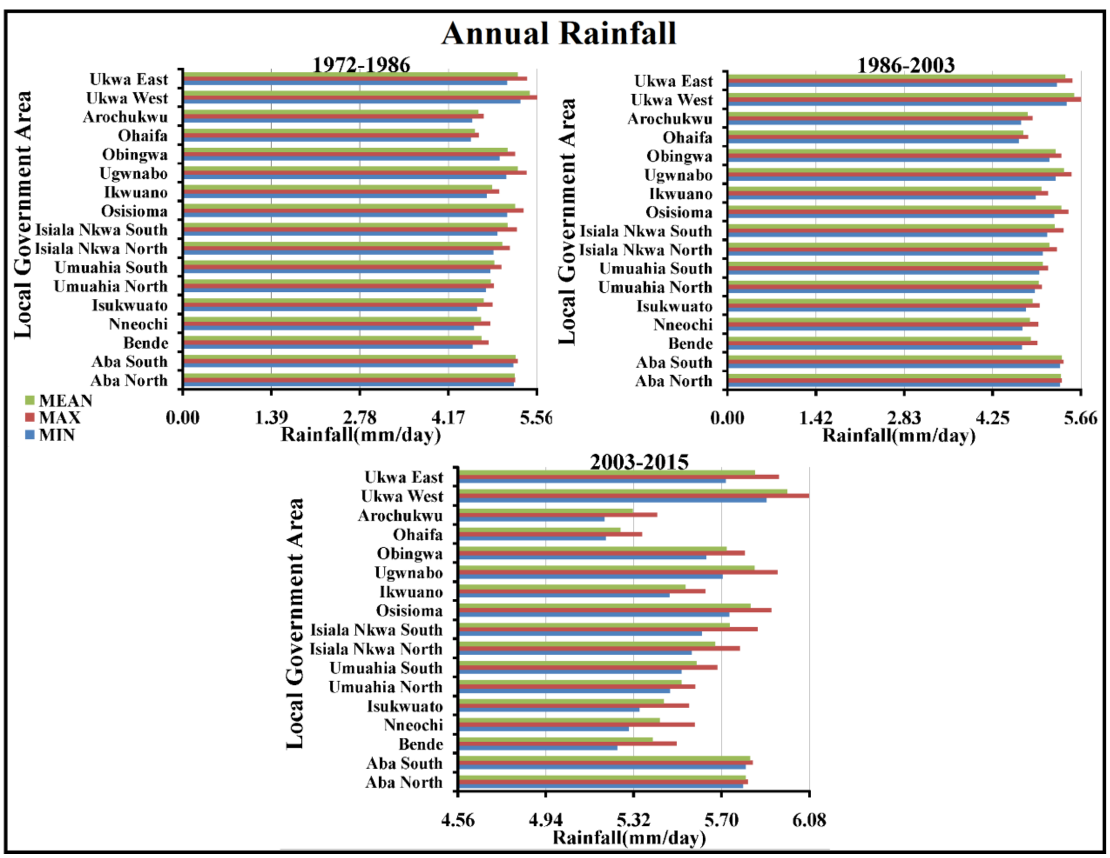

Fig. 3. Annual rainfall minimum, maximum, mean of the Local Government Areas (LGAs) between 1972-1986, 1986-2003, and 2003-2015 for Abia state.

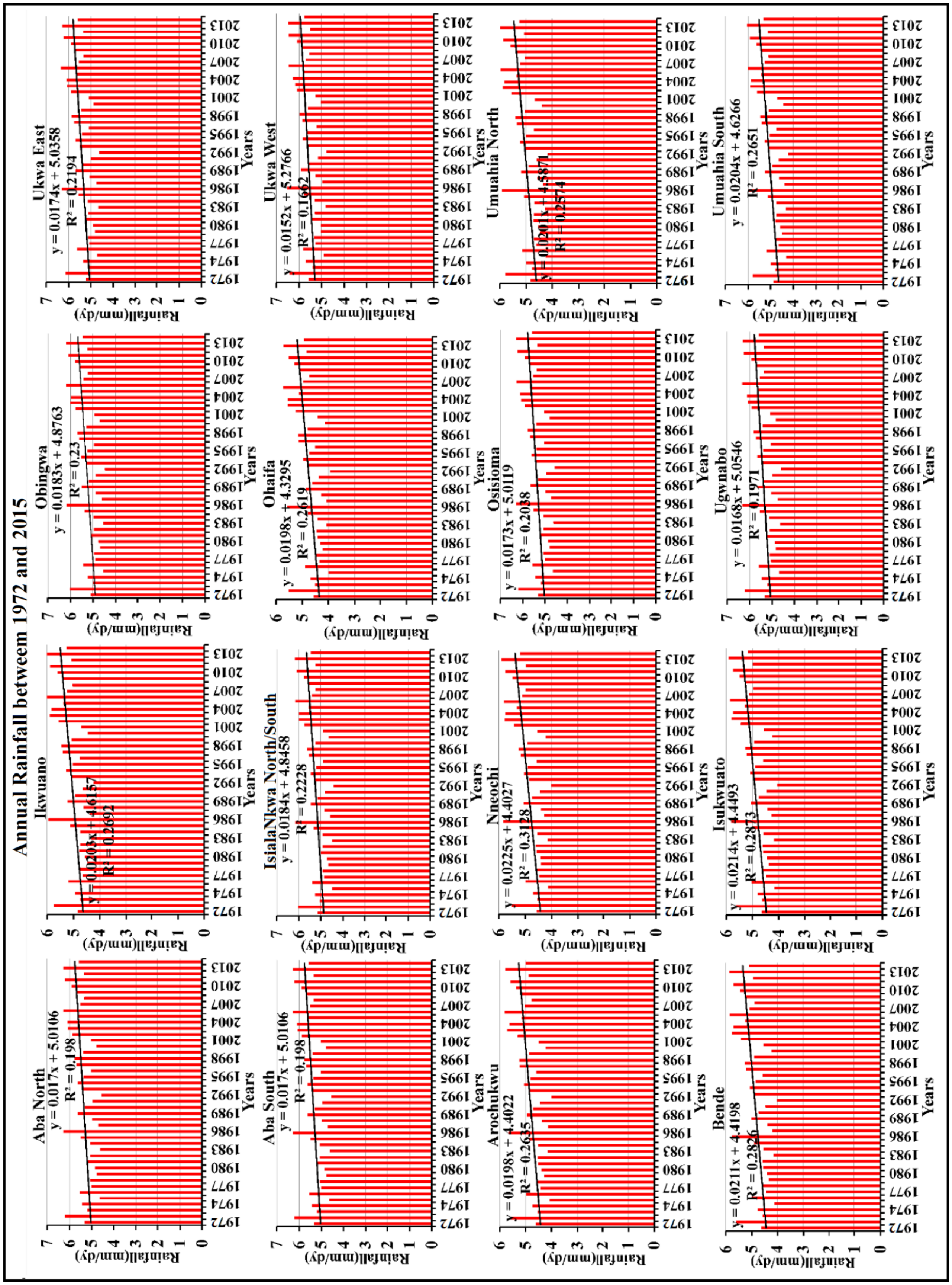

Fig. 4. Annual rainfall of the Local Government Areas (LGAs) in Abia state between 1972 and 2015.

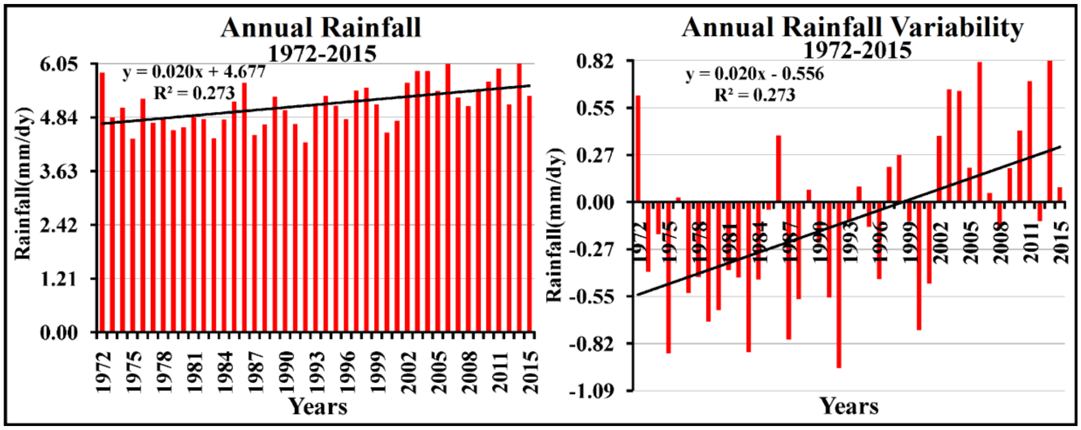

Fig. 5. Annual rainfall and variability for Abia state between 1972 and 2015.

Changes in the Annual Rainfall Variation of Abia state between 1972 and 2015

Annual rainfall variability for Abia state is shown in Figure 6 and this represents the yearly averaged value used to study rainfall temporal variability. The application of this method shows the existence of important changes in the moving mean rainfall for all the series under study. The weakest variability period occurs at the end of the 19^{th} century for all station between 1973 and 1984, and a short fall in mean rainfall was observed in major parts of this period, same was observed between 1987-1996 and 2000–2001. From then onwards there is a general increase in variability, with maximum values being reached at the present times for all observatories, and same for earlier part of the 21^{th} century (Figure 6). A relative increase in the mean rainfall was observed for major parts of Abia state for the period between 1986 and 2003 (Figure 6).While a decline in mean variability was observed between 2003 and 2015 (Figure 6). Increase in rainfall generally was recorded for 1972, 1986, and 2003, which decline in 2015 (5.85, 5.62, 5.88, and 5.32 mm/day) against a climatic mean (of 4.91, 5.06, 5.59 mm/day) and variability (of 0.94, 0.71, 0.82, and -0.27mm/day). Other rain years are shown in Figure 6 for Abia state which includes the following: 1976, 1985, 1989, 1994, 2003, 2004, 2011 and 2013.

Standard deviation was used to study rainfall spatial variability in Abia state as presented in Figure 7 between 1972-1986, 1986-2003 and 2003-2015. Figure 8 shows the rainfall minimum, maximum and mean standard deviation of the Local Government Areas between 1972-1986, 1986-2003, and 2003-2015 for Abia state. The results reveals a spatial difference in rainfall, high rainfall have low standard deviation but a temporal difference reveals a reduction in standard deviation over time, this imply that there is an increase in rainfall between 2003-2015 compared to 1986-2003 and 1972-1986 in Abia state as presented in Figure 7 and 8. Standard deviation is relatively high for Aba north, Osisioma, Ugwnabo, and Ukwa east and west than the rest of the Local Government Areas as presented in Figure 7 and 8 between 1972-1986. While between 1986 and 2003, Isiala Nkwa north, Aba north and Obingwa were included and marked as having a relatively high standard deviation, between 2003 and 2015, all locations were observed as having a relatively lower standard deviation.

Also, coefficient of variation (CV) was used to study rainfall spatial variability in Abia state as presented in Figure 9 between 1972-1986, 1986-2003 and 2003-2015. In 1972-1986, CV was observed to be between 0.01 and 3.51% with a mean of 1.26 %. While between 1986-2003, CV was observed to be between 0.01 and 2.89% with a mean of 1.06%. Also, between 2003-2015, CV was observed to be between 0.01 and 2.66% with a mean of 0.99%. The following speculation can be made considering the CV of Abia state: (1) It reduces over time (the years) between 1972-2015; (2) As the CV reduces rainfall received increases; (3) The fringe regions (in the north and south of Abia state) receive relatively lesser rainfall and rain days than the central region; (4) An increase and constant gap was observed in the central region between 1972-2015 with a constant CV value between 0.01 and 0.99%; and (5) CV does not affect the total rainfall received in Abia state but regional difference observed and experienced in locations and parts of the state. Figure 10 shows the minimum, maximum and mean CV of the Local Government Areas between 1972-1986, 1986-2003 and 2003-2015 for Abia state. CV follows the standard deviation pattern of Abia state, the northern and southern part of the state has a relatively low rainfall variability compared to the central part of the state which includes Ukwa west followed by Ukwa east, Ugwnabo and Osisioma. Based on spatial difference, the CV is relatively lower in the north-eastern and south-western part of Abia state.

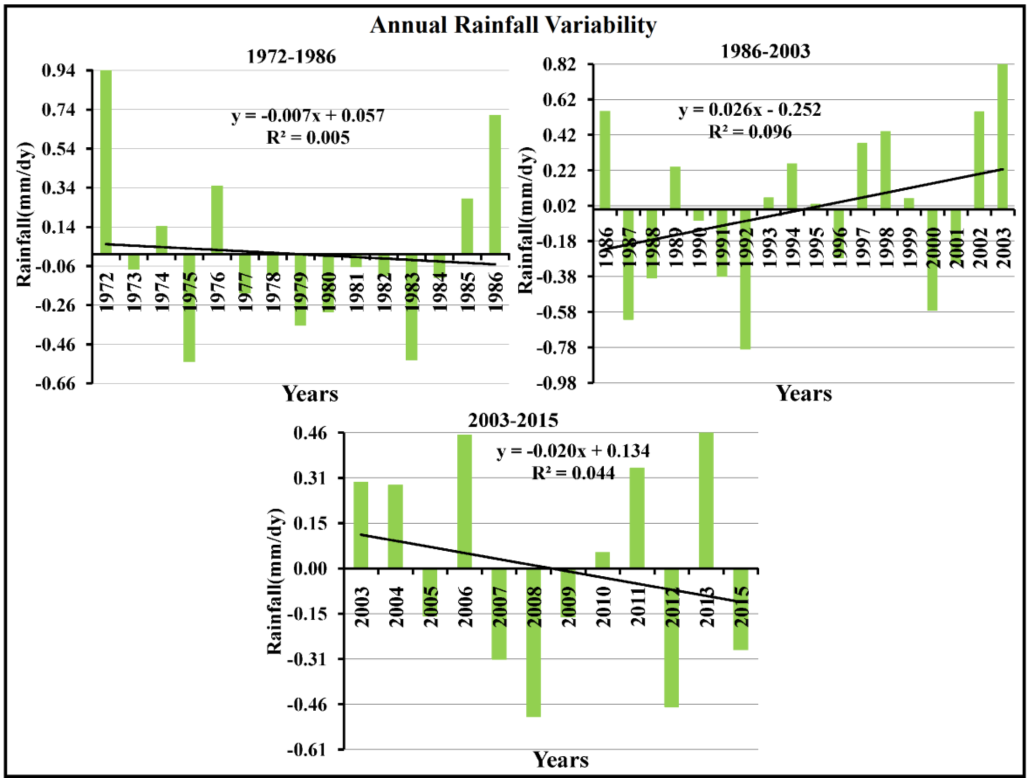

Fig. 6. Annual rainfall variability between 1972 - 1986, 1986 - 2003 and 2003 – 2015 for Abia state.

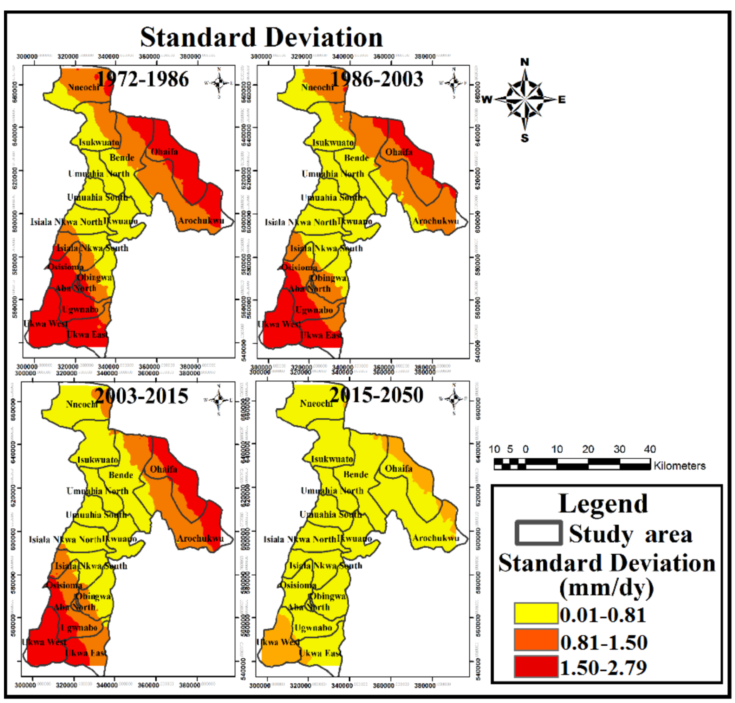

Fig. 7. Standard deviation of the annual rainfall between 1972-1986, 1986-2003, 2003-2015 and 2015-2050 for Abia state.

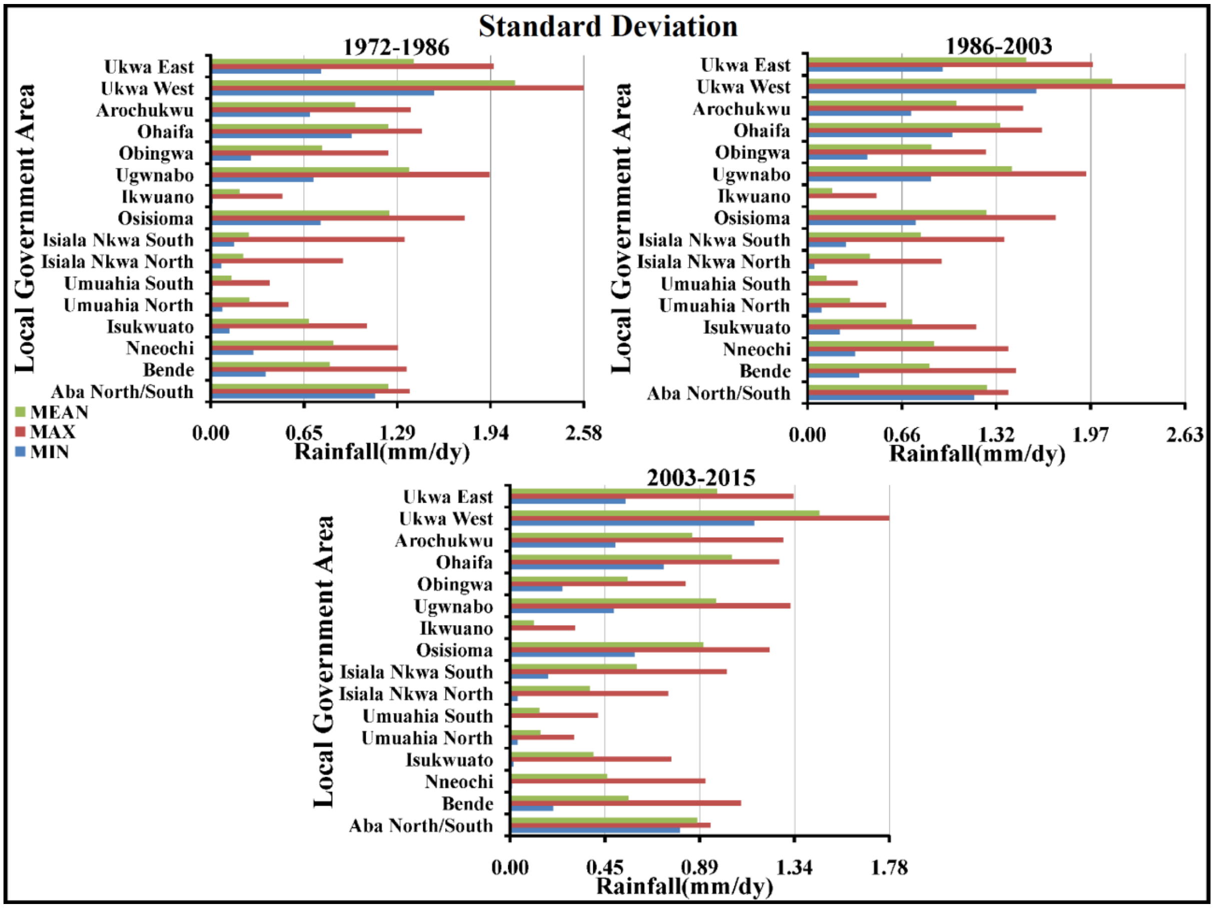

Fig. 8. Minimum, maximum and mean standard deviation of the rainfall for the Local Government Areas between 1972-1986, 1986-2003, and 2003-2015 for Abia state.

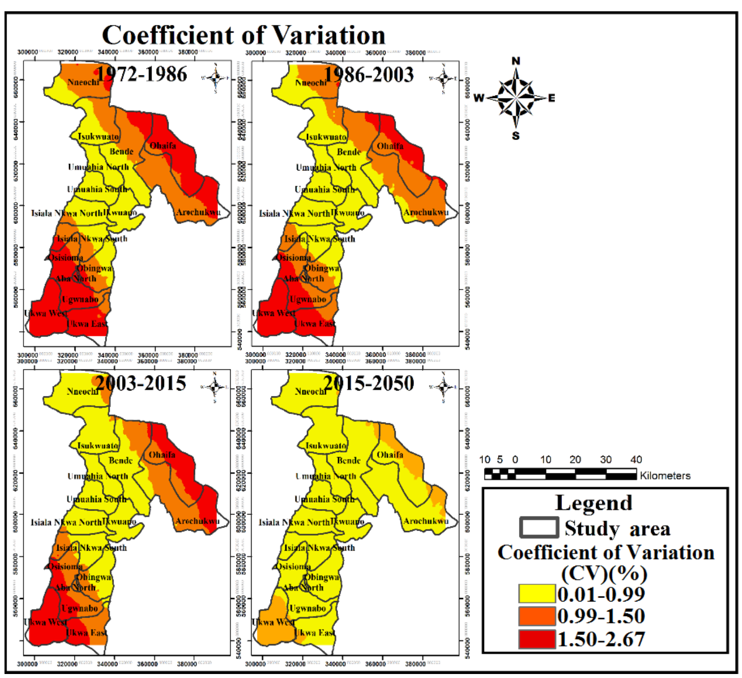

Fig. 9. Coefficient of variation (CV) of the annual rainfall between 1972-1986, 1986-2003, 2003-2015 and 2015-2050 for Abia state.

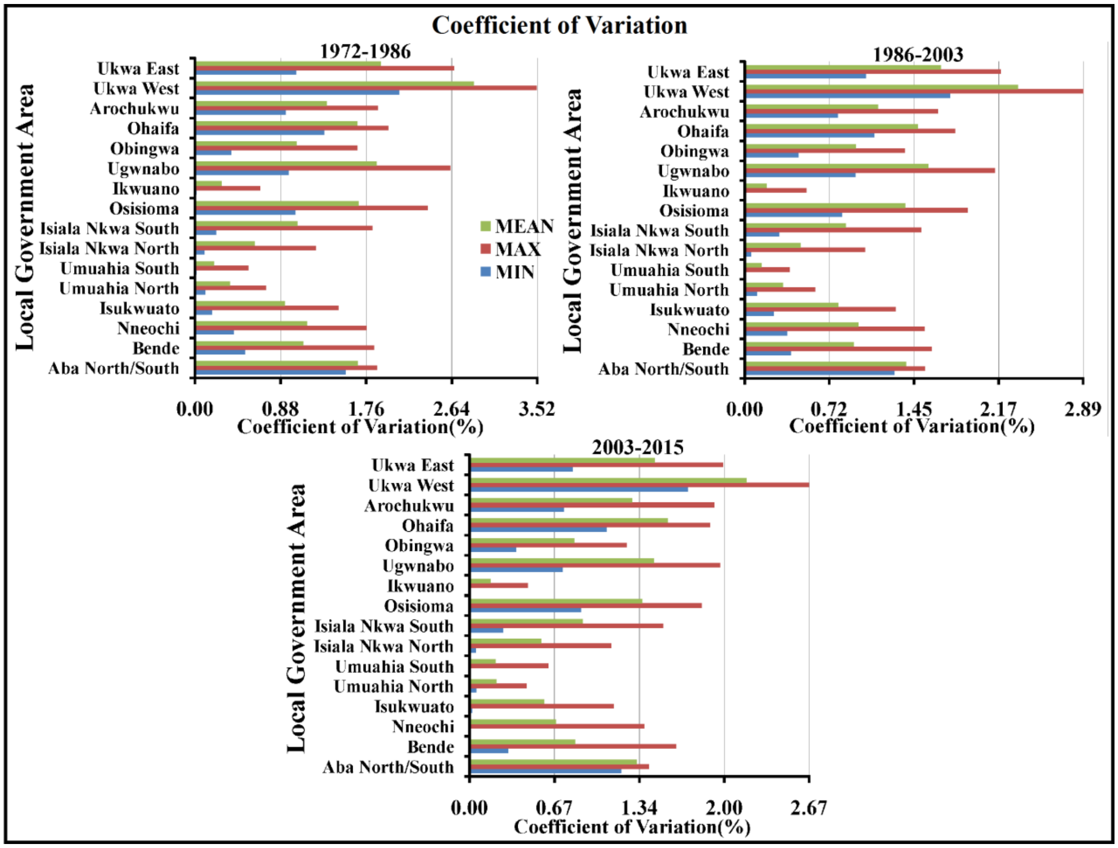

Fig. 10. Minimum, maximum and mean coefficient of variation (CV) of the annual rainfall for the Local Government Areas (LGAs) between 1972-1986, 1986-2003 and 2003-2015 in Abia state.

CV in the south-western part of the state close to imo river and coastal city of Port Harcourt is higher than the north of Abia state. Also, the windward side, south-west of the state from Isiala Nkwa south to the mountain ridge along parts of Isukwato, Bende and Arochukwu axis has a constant CV which is lower than the leeward side (between 0.01 to 0.99%). Based on these, it can be observed that CV fluctuates in difference time slices. The highest CV was recorded between 1972 and 1986, and the lowest CV was found between 2003 and 2015. As CV decreases the mean annual rainfall increases.

Rainstorms in Abia state between 1972 and 2015

Frequency analysis was applied to the rainfall distribution of Abia state presented in Figure 3 using Log Pearson Type III probability distribution, recorded between 1972-2015 (spanning over 43 years) as presented in Table 1. Using the stations upper confidence limit (0.05%), Abia state records a high (frequency) rainfall between 5.2 to 7.2 mm/day over a short return period between 0.2 and 50% chance exceedance rainfall event. This reveals that the rainfall is reliable between 1972 and 2015 with no climate extremes. Generally, the rainfall amount is high in Abia state between 0.2 to 50% chance exceedance rainfall event. This looks good for agricultural activities and reliable to support water management in Abia state because it equals or exceeds 95% probability. However, this has intensified soil erosion and flood event across the state.

Rainfall distribution and Crop planning in Abia state

Effective rainfall minimum, maximum and mean for agricultural land use and crops between 1972-1986, 1986-2003 and 2003-2015 in Abia state was graphical presented in Figure 11. Records were presented annually to study how rainfall influences crop productivity in Abia state. Agricultural land use and crops were graphically plotted against effective rainfall as well as for the Local Government Areas to show how crops fare between 1972-1986, 1986-2003 and 2003-2015 as a prerequisite and benchmark for agro sustainable development in Abia state. Major crops picked for examination includes yam, cassava and oil palm. Based on recommended standard; yam requires a minimum of 1035 to over 1500 mm/year of rainfall (Knoth, 1993; Ayode, 1983), cassava 1000mm/year of rainfall (Hauser et al.,2014), and oil palm, 1500mm/year and above of rainfall (Ayode, 1983; Poku, 2002). Effective rainfall amount for the Local Government Areas in Abia state is shown in Figure 13. It is observed that the average effective rainfall for yam, cassava and oil palm between 1972 and 2015 is sufficient for its growth in this regions. Rainfall distribution between 1972 and 2015 reveals that food, root and commercial crops as well as commercial plantations, compound farms, open field cultivation, short and long cycle fallow areas have high probability (say > 80%) of the required critical rainfall amount needed in a year for growth of these relevant crops in the agricultural land use areas provided the soil is suitable.

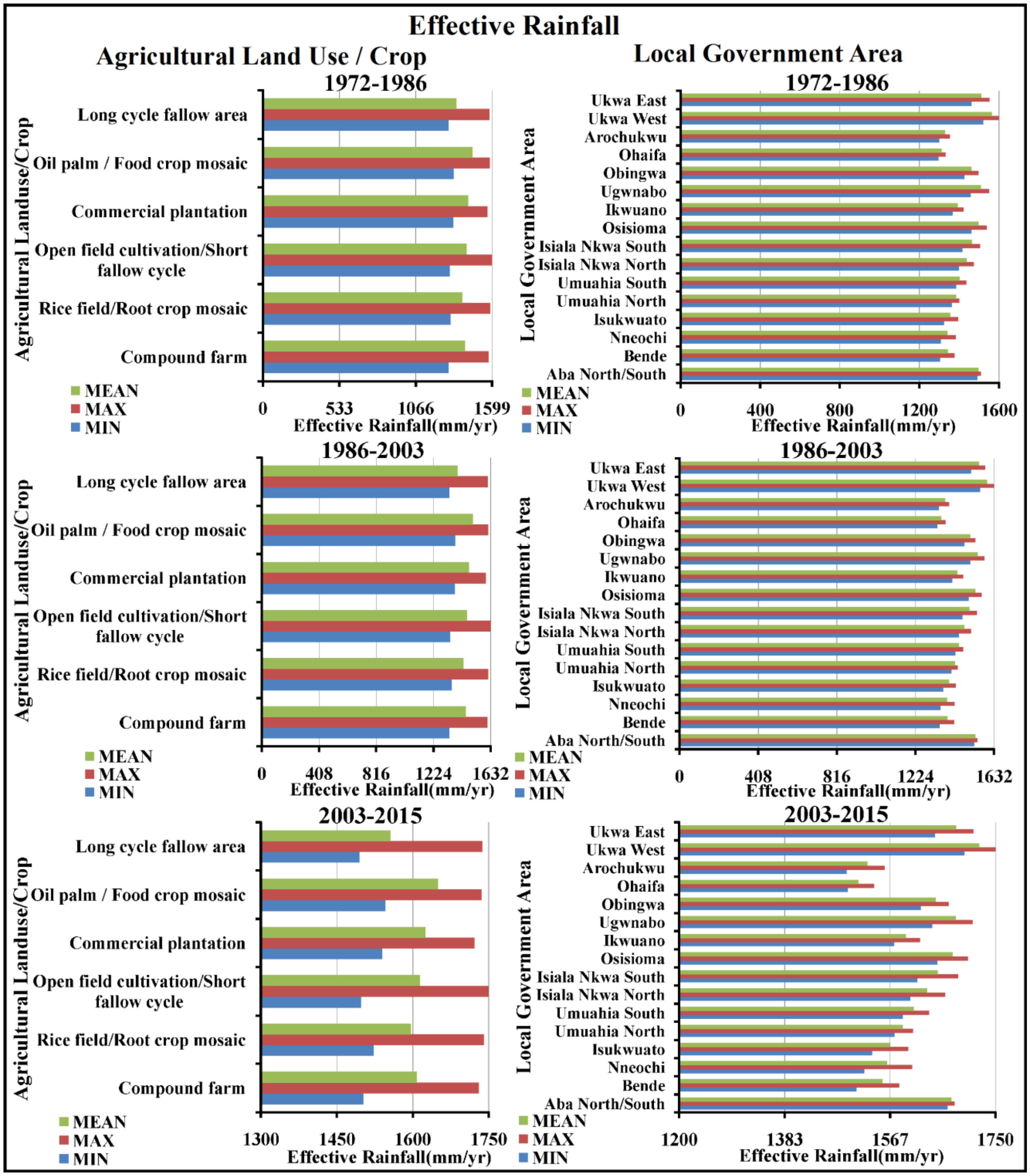

Fig. 11. Minimum, maximum and mean effective rainfall for agricultural land use / crops and Local Government Areas (LGAs) between 1972-1986, 1986-2003 and 2003-2015 in Abia state.

Future Rainfall distribution and Climate change in Abia state between 2015 and 2050

Annual rainfall distribution for future scenario between 2015 to 2050 was interpolated over Abia state using ordinary kriging technique in ArcGIS 10 (Geostatistical wizard) with spherical semi-variogram model and parameters such as: nugget(0.0002), partial sill(0.18), Lag size (0.121) and major range (1.41km) (using HadCM3 model). The rainfall observatories was averaged to estimate the annual rainfall distribution between 2015 to 2050. Annual rainfall distribution of Abia state is presented in Figure 3 between 2015 and 2050. Frequency analysis was applied to the rainfall distribution (in Figure 3) adopting Log Pearson Type III distribution between 2015 and 2050 (covering 35 years) as presented in Table 1. It is likely that the frequency of heavy rainfall or the proportion of total rainfall from heavy rainfall will increase between 2015 and 2050 over many areas of Abia state. Heavy rainfall associated with rainy season is likely to increase with continued warming induced by enhanced greenhouse gas concentrations. Increase in heavy rainfall will occur despite projected decrease in total rainfall in some years and areas. For HadCM3 SRES A1B scenario, using the stations upper confidence limit (0.05%) in Table 1, a 0.2% chance exceedance annual maximum 24-hour rainfall event is likely to become 0.5% chance exceedance event by the end of the 21st century in many regions, and in most regions a higher emissions scenarios lead to a greater projected decrease in return period. Nevertheless, increase or statistically significant changes in return periods are projected in some regions. Projected changes between 2015 and 2050 will include the following: (a) higher mean rainfall, (b) increase in variability, and (c) negatively skewed rainfall distribution indicating the presences of climate extremes and extreme events.

Figure 12 shows the annual rainfall in Abia state between 1972-2015 and 2015-2050. The study area recorded a high maximum rainfall of 6.70 mm/day between 2015-2050 against 6.05 mm/day between 1972-2015. Rainfall observed between 2015-2050 have a minimum of 5.39mm/day, maximum of 6.26mm/day and mean of 5.79mm/day.

Table 1. Different percent chance exceedance rainfall (mm) for Abia state between 1972-2015 and 2015-2050.

Computed Curve		Expected Probability		Percent (%) Chance Exceedance	Confidence Limit 0.05		Confidence Limit 0.95	
1972-2015	2015-2050	1972-2015	2015-2050		1972-2015	2015-2050	1972-2015	2015-2050
6.7	6.7	6.9	7	0.2	7.2	7.4	6.4	6.3
6.5	6.6	6.6	6.8	0.5	6.9	7.2	6.2	6.2
6.4	6.5	6.4	6.6	1	6.7	7	6.1	6.2
6.2	6.3	6.3	6.5	2	6.5	6.8	6	6.1
5.9	6.2	6	6.3	5	6.2	6.6	5.8	6
5.7	6	5.8	6.1	10	6	6.4	5.6	5.8
5.5	5.9	5.5	5.9	20	5.7	6.2	5.4	5.7
5.1	5.5	5.1	5.5	50	5.2	5.7	5	5.4
Mean		Standard Deviation			Station Skew		Adopted Skew	
0.706	0.743	0.041	0.031		0.086	-0.184	0.086	-0.184

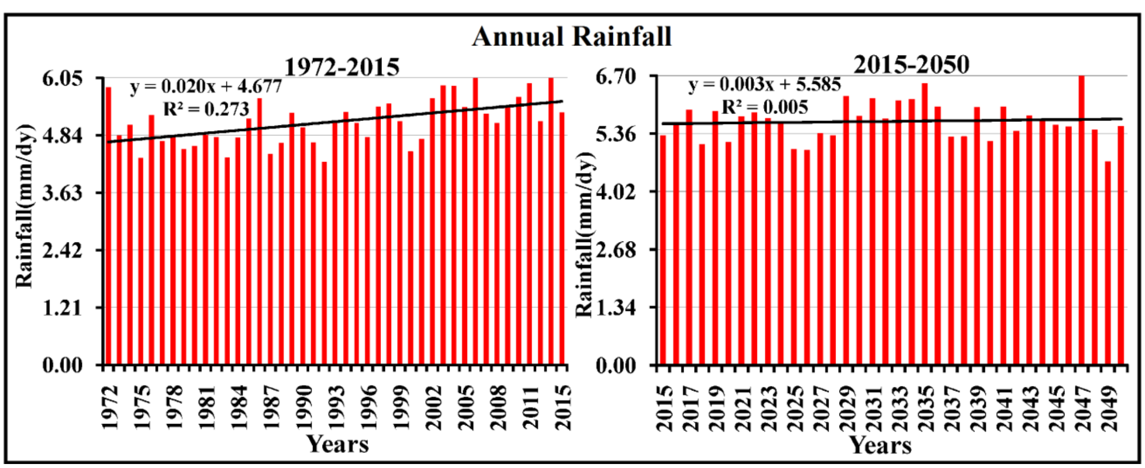

Fig. 12. Annual rainfall in Abia state between 1972-2015 and 2015- 2050.

The result reveals that the rainfall trend is positive with 0.05% (R^2= 0.005) increase between 2015 and 2050 in Abia state.

Figure 13 graphically presents minimum, maximum and mean annual rainfall of the LGAs in Abia state between 2015 and 2050. Annual rainfall was found to be relatively higher for Aba north, Osisioma, Ugwnabo, Ukwa east and west compared to the rest of the LGAs in the state between 5.01 to 6.26 mm/day while 5.80 to 6.00 mm/day cover a major part of Abia state down to Ohafia north (Figure 3). This shows the existence of important changes in the moving rainfall mean for all the series under study in Abia state.

Also, annual rainfall variability for Abia state is graphically presented in Figure 13 between 2015 and 2050. The weakest variability period occurs between 2024 and 2027 with an observed short fall in mean rainfall in major parts of Abia state. From then onwards a general increase in rainfall variability with maximum values being reached at the present times for all observatories was observed between 2029 to 2035. Also, short fall in rainfall was recorded for 2037, 2040, 2042, 2045, 2046 as well as for 2049 and 2050 for Abia state. Maximum rainfall variability will be observed in 2047 followed by 2035 and minimum variability will be observed in 2032 followed by 2023 for Abia state.

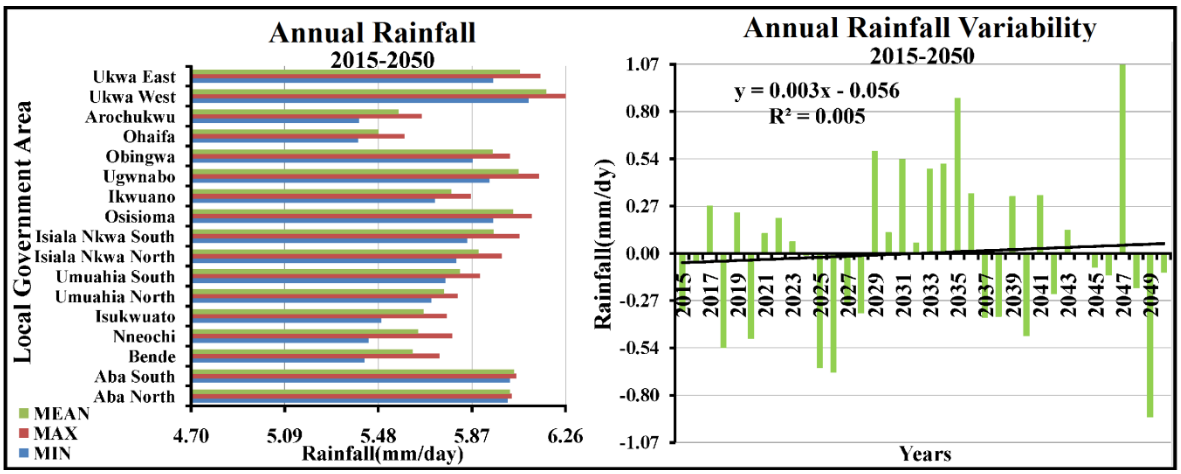

Fig. 13. Minimum, maximum and mean annual rainfall of the Local Government Area (LGA) and annual rainfall variability for Abia state between 2015 and 2050.

Standard deviation of the rainfall for Abia state between 2015 and 2050 map is shown in Figure 7 and graphically presented in Figure 14. Standard deviation of the rainfall between 2015 and 2050 was found to be low with a minimum of 0.00 mm/day, maximum of 2.79 mm/day and mean of 2.10 mm/day compared with 0.01 mm/day minimum, 2.58 mm/day maximum and a mean of 1.74 mm/day between 1972 and 2015. This reveals that there will be an increase in rain days and extreme rainfall observed for Abia state, higher between Ukwa east and Ohafia than the rest of Abia state with a rainfall standard deviation which ranges from 0.01 to 1.50 mm/day (Figure 9).

Figure 9 presents the map and Figure 14 graphically shows rainfall coefficient of variation (CV) for Abia state between 2015 and 2050. Rainfall coefficient of variation between 2015 and 2050 was found to be low with a minimum of 0.00%, maximum of 1.38% and mean of 0.55% compared with 0.01% minimum, 3.35% maximum and a mean of 1.26% between 1972 and 2015. This reveals that there will be an increase in rain days and climate extremes for Abia state, higher between Ukwa east to Ohafia with a rainfall coefficient of variation which ranges from 0.99 to 1.50%.

Conclusively, the following speculation was made considering the rainfall distribution of Abia state:

(1) Projected increase in heavy rainfall associated with rainy season is likely to continue due to warming induced by enhanced greenhouse gas concentrations between 2015 and 2050. Increase in heavy rainfall will occur despite projected decrease in total rainfall in some years and parts of Abia state.

(2) An increase in future rainfall will be observed between 2015 and 2050 and this will lead to increase in agricultural productivity. It is projected that Abia state may actually benefit from the changing conditions in climate.

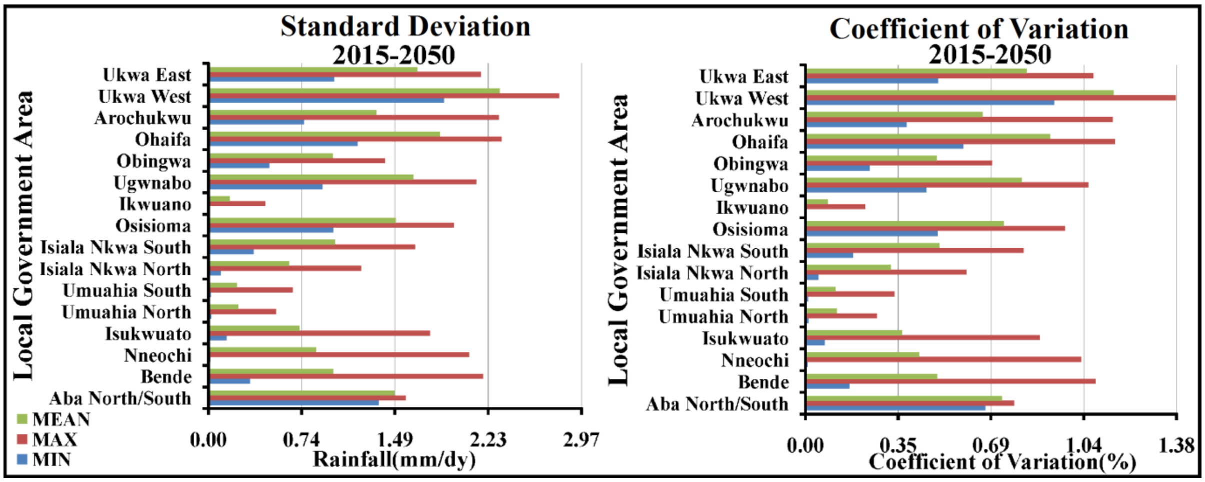

Fig. 14. Minimum, maximum and mean standard deviation and coefficient of variation (CV) of the annual rainfall for the Local Government Areas (LGAs) in Abia state between 2015 and 2050.

Based on the rainfall distribution in Abia state, there is a high probability (say > 80%) that the critical future rainfall amount received will be enough for water resource management, growth of relevant agricultural crops and economic development of Abia state between 2015 and 2050. However, increase in climate related event such as soil erosion and flooding may accompany such increase in rainfall, other adverse effects of climate change cannot be neglected such as shifts in arable land, water stress, increased water and food scarcity imposed by urbanization, natural resources deterioration, population, and declining economic performance. These, in-turn, can manifest themselves in increased social and political instability. Projected increase in rainfall is expected to lead to the growth, propagation and spread of disease organism or their carriers (vectors) such as malaria, yellow fever, Covid-19 (which is extremely transmissible), etc. Also, projected increase in rainfall lowers the temperature and body resistance to disease.

(3) Rainfall coefficient of variation (CV) for Abia state is relatively less between 2015 and 2050 compared with 1972 to 2015, which implies that there will be an increase in rainfall, rain days, climate extremes and extremes events.

(4) Rainfall standard deviation reveals a significant and projected increase in rainfall received, rain days, climate extremes and extremes events in some regions and parts of the state between 2015 and 2050 compared with 1972 to 2015.

(5) Rainfall characteristics predicts a short return period in weather, climate, climate extremes, and extreme events between 2015 and 2050.

Conclusion

In this study, the rainfall distribution was assessed for Abia state from HadCM3 model for baseline and future scenarios (between 1972-2015 and 2015-2050) using GIS and statistical techniques. Statistical analysis was used to extract descriptive statistics such as minimum, maximum and mean while for spatial rainfall distribution, standard deviation and coefficient of variation (CV) was mapped using GIS interpolation methods. Bulletin 17B distribution was used to model rainfall frequency in Abia state based on Log Pearson Type III distribution between 1972-2015 and 2015-2050. The result shows that the rainfall frequency across Abia state is high with a short return period which is irregular and similar to what was obtained from NRCRI weather station between 1972-2015. Thus, rainfall received is reliable and sufficient for agricultural activities in Abia state using effective rainfall as well as for the increase of climate related events such soil erosion. However, LGAs located on the south of Abia state receive higher mean and maximum rainfall compared to those in the north. In Abia state for rainfall variability between 1972-2015, the result reveals the existence of important changes in the moving mean rainfall with the weakest variability occuring between 1973 to 2002 accompanied by short fall in rainfall in major parts of the period. For 2015-2050, an increase in variability was observed for major parts of the state and period. Generally, CV and standard deviation of the rainfall have similar pattern, however, as its decreases over time rainfall increases over Abia state. Furthermore, between 2015-2050, it is likely that the frequency of heavy rainfall or the proportion of total rainfall from heavy rainfall events will increase with projected increase in rainfall received, rain days and extremes in some regions and parts of the state. This paper highlights the need to also model other rainfall characteristics such as duration, intensity and length of rainfall to understand and predict what the future climate looks like and holds for Abia state.

Conflict of interest

The author declare there is no conflict of interest.

Acknowledgment

I acknowledge Late. Mrs. P.N. Ibeabuchi for her contribution towards this research, as well as suggestions, advice and guidance in the course of my academic endeavours and pursuit.

References

Adejuwon, J.O. (2004, March 24-27). *Assessing the impacts of climate variability on crop yield: The example of the Sudano-Sahelian ecological zone in Nigeria* [Paper presentation]. 2nd AIACC Regional Workshop for Africa & Indian Ocean Islands, Dakar, Senegal.

Arvind, G., Kumar, P.A., Karthi, S.G., & Suribabu, C.R. (2017). Statistical analysis of 30 years rainfall data: A case study. *IOP Conference Series: Earth and Environmental Science*, *80* (012067). doi:10.1088/1755-1315/80/1/012067

Akinseye, F.M., Ajayi, V.O., & Oladitan, T.O.(2013). Assessing the impacts of climate variability on crop yield over Sudano-Sahelian zone in Nigeria. *Access International Journal of Agricultural Science*, *1*(7), 91-98.

Ayode, J.O. (1983). *Introduction to Climatology for the Tropics.* Spectrum Books; John Wiley & Sons.

Dan'azumi, S., Shamsudin, S., & Rahman, A.A. (2010). Probability distribution of rainfall depth at hourly time-scale. *International Journal of Environmental and Ecological Engineering*, *4*(12), 670-674. doi.org/10.5281/zenodo.1077659

Davie, T. (2008). *Fundamentals of Hydrology* (2nd ed.).Routledge.

Fisher, R.A. (1924). The influence of the rainfall on the yield of wheat at Rothamsted. *Philosophical transaction of the Royal Society B*, *213*(402-410),89-142. https://doi.org/10.1098/rstb.1925.0003

Food and Agriculture Organization (FAO). (2001). *Climate variability and change: A challenge for sustainable agricultural production*. FAO - Committee on Agriculture. https://www.fao.org/DOCREP/MEETING/003/X9177e.HTM

Gupta, S.K., Babu, R., & Tejwani, K.G. (1975). Weekly rainfall of India for planning cropping programme. *Soil Conservation Digest*, *3*(1), 31-36.

Hauser, S., Wairegi, L., Asadu, C.L.A., Asawalam, D.O., Jokthan, G., & Ugbe, U. (2014). *Cassava system cropping guide.* Africa Soil Health Consortium.

Ignaciuk, A., & Mason-D'Croz, D. (2014). *Modelling adaptation to climate change in agriculture* (OECD Food, Agriculture and Fisheries paper No. 70). OECD Publishing. http://dx.doi.org/10.1787/5jxrclljnbxq-en

Iheoma, C.G. (2014). Impact of climate change on agricultural production and sustainability in Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*, *4*(1), 29-41. doi:10.9734/AJAEES/2015/11518

Jackson, I.J. (1989). *Climate, water and agriculture in the tropics* (2nd ed.). Longman Scientific & Technical; Wiley.

Knoth, J.(1993). Traditional storage of yams and cassava and its improvement. GTZ-Postharvest Project. https://www.nzdl.org/gsdlmod%3Fe%3Dd-00000-00

Sharma, M.A., & Singh, J.B. (2010). Use of probability distribution in rainfall analysis. *New York Science Journal*, *3*(9), 40-49. http://www.sciencepub.net/newyork

Obasi, G.O.P. (2003, March 31). World Meteorological Organization (WMO) Statement No. 238. *International Symposium on Climate Change (ISCC)*, Beijing, China.

Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production: The case of Small scale farmers in Kenya. *NJAS:Wageningen Journal of Life Sciences*, *77*, 71–78. doI: 10.1016/j.njas.2016.03.005

Pankhurst, R., & Johnson, D.H.(1988). The great drought and famine of 1888-92 in northeast Africa. In D.H. Johnson & D.M. Anderson (Eds.), *The ecology of survival: Case studies from Northeast African history* (pp. 47-72). Lester Crook Academic Publishing.

Poku, K. (2002). Small-scale palm oil processing in Africa. Food and Agriculture Organizations (FAO) of the United Nation. www.fao.org/DOCREP/005/Y4355E/y4355eoohtm-content

Raudkivi, A.J. (1979). *Hydrology: An introduction to hydrological processes and modeling*. Pergamom.

Sikka, D.R. (1977). *Some aspects of the life history*, structure and movement of monsoon depression. *PAGEOPH*, *115*, 1501–1529.

Tarekmerabtene, M.S., & Abdallah, S. (2016). Assessment of seasonal and annual rainfall trends and variability in Sharjah city, UAE. *Advances in Meteorology*, *2016*, Article 6206238. http://dx.doi.org/10.1155/2016/6206238

Tao, D.Q., Nguyen, V.T.V., & Bourque, A. (2002, June 5-8). On selection of probability distributions for representing extreme precipitations in southern Quebec [Paper presentation]. *Annual Conference of the Canadian Society for Civil Engineering*, Montréal, Québec, Canada.

Thompson, L.M. (1975). Weather variability, climatic change and grain production. *Science*, *188* (4188), 535-541. doi: 10.1126/science.188.4188.535

Thakural, L.N., Kumar, S., Jain, S.K., & Ahmad, T. (2018). The impact of climate change on rainfall variability: A study in central Himalayas. In V.P. Singh, S. Yadav, & R.N. Yadava (Eds.), *Climate Change Impacts* (pp. 181–192). Springer.

Udayashankara, T.H., Murthy, B.M.S., & Madhukar, M.(2016). Impact of climate change on rainfall pattern and reservoir level. *Journal of Water Resource Engineering and Management*, *3*(1), 10-14.

Von Braun, J. (1991). *A policy agenda for famine prevention in Africa* (Food Policy Statement No. 13). International Food Policy Research Institute.