

Assessing the Rainfall Distribution and Its Precipitation Concentration Index (PCI) for Crop Production in Northern Guinea and Sudan Savannas of Nigeria

A. I. Isaiah

akanisaiah57@gmail.com

Department of Agriculture, Federal University of Agriculture, Mubi

K. Ajani-Adegboye

Nodoc Research and Advisory Limited

Article

Keywords: Precipitation, Concentration, Rainfall Distribution and Crop production

Posted Date: September 25th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10483027/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Assessing the Rainfall Distribution and Its Precipitation Concentration Index (PCI) for Crop Production in Northern Guinea and Sudan Savannas of Nigeria

*Isaiah, A. I¹. & Ajani-Adegboye², K.

¹Department of Soil Science, Faculty of Agriculture, Federal University of Agriculture, Mubi, Adamawa State, Nigeria

²Nodoc Research and Advisory Limited, United Kingdom

*Corresponding Author's E-mail: akanisaiah57@gmail.com, Tel.: +2348137985208, orcid Id: 0000-0002-3928-0818

Abstract

The fluctuation in rainfall as a result of climate change has a great impact in crop production. The aim of this paper is to assess the rainfall distribution and its precipitation concentration index (PCI) for crop production in northern guinea and sudan savannas of Nigeria. Rainfall data for the study were collected at Nigeria Meteorological Service Unit, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Kaduna State, for a period of 31 years (1994 – 2024). Annual PCI was calculated using PCI equation as stated by Oliver, 1980. Trend of annual, monthly and number of rainy days rainfall was obtained using time series graph. The result shows the annual PCI value ranges from irregular to strong irregular rainfall distribution with 64.52% and 90.32% indicating strong irregular distribution for Samaru and Minjibri respectively. While 35.48% and 9.67% showing irregular rainfall distribution for Samaru and Minjibri respectively. The number of rainy days for Samaru ranges from 73 – 81 days and it decline by 8 days at $y = -0.1359x + 349.38$ and $R^2 = 0.1203$. In Minjibri, the number of rainy days ranges from 67 – 76 days and it decline by 9 days at $y = -0.1274x + 327.86$ and $R^2 = 0.1786$. The trend of annual rainfall also shows a decline in the amount of annual rainfall at $y = -6.5625x + 9992$ $R^2 = 0.046$ for Samaru; and $y = -4.5625x + 9992$ and $R^2 = 0.1003$ for Minjibri. The average annual rainfall ranges between 763.4 mm – 1333.3 mm and 502.70 – 1011.90 mm for Samaru and Minjibri respectively. The result revealed that the both areas are experiencing reduction in annual rainfall. It is therefore, recommended for the cultivation of short duration crops that can mature within three to four months or the used of irrigation facilities.

Keywords: Precipitation, Concentration, Rainfall Distribution and Crop production

1.0 INTRODUCTION

Earth's ecosystems are constantly changing due to changes in rainfall pattern and other climatic variables (Eze, 2021). Compared to the previous century, the changes in rainfall pattern have accelerated recently (IPCC, 2023). The last two to three decades have seen a more noticeable decline in food output due to extreme rainfall pattern. Despite being a worldwide issue, it is more common in developing nations, particularly in sub-Saharan Africa, which is among the tropical regions most impacted (Adejuwon, 2018). Rainfall distribution pattern has a great impact on the

kind of crops grown in these areas. Extreme rainfall is expected to have and will continue to have major detrimental effects on Nigeria's crop production, adding to problems with food security that have unfavorable socioeconomic effects and alter ecological circumstances (Adejuwon, 2020). It is anticipated that precipitation will increase in southern Nigeria, increasing the risk of floods and perhaps submerging farmlands and coastal cities. Droughts have also become common in northern Nigeria (i.e. the savanna areas) due to rising temperature and decrease in precipitation, and are predicted to persist (IPCC, 2021). Rainfall is essential to maintaining life on Earth, particularly in agriculture. It remained the most important climatic factor influencing crop production in rainfed areas of the world. Crop quality, farming system viability and production potential are all directly impacted by its quantity, timing, frequency, duration, intensity and dispersion (FAO, 2016). Crop productivity is greatly impacted by rainfall since it supplies water, but too much and too little can be harmful. While too little rainfall can result in drought and too much can cause waterlogging and soil erosion (Ayodele *et al.*, 2025). The physical harm caused by excessive rainfall which result in flooding and waterlogging, lead to root rot, decreased nutrient uptake and delayed planting and harvesting. It has a detrimental effect on agricultural productivity (Adesina *et al.*, 2019). Additionally, it can remove vital fertilizers and soil nutrients and foster an environment that is conducive to pests and illnesses (Adeola *et al.*, 2021). More so, insufficient rainfall has leads to reduction in agricultural yields, inducing crop failure and reducing overall harvest size owing to insufficient rainfall (Komolafe *et al.*, 2025). This occurs as a result of drought stress's detrimental effects on plant development, which impair root and leaf growth and interfere with water exchanges, resulting in fewer and lower-quality harvests. It can ultimately result in food shortages and jeopardize farmers' lives (Matthew *et al.*, 2025).

In Nigeria, crop productivity, particularly rainfed crops, is being impacted by the increased frequency of extreme weather events, particularly extended dry spells which is common in the savanna areas of the country (Ezenwaji, 2017). Changing climatic situations, the frequency and length of such extreme occurrences are drastically increasing, resulting in production losses in the major crops growing in Nigeria (Okon *et al.*, 2021). Droughts or prolonged and sustained rainfall deficits, are one type of extreme weather event that is causing changes in crop's calendar and additional economic costs for producing the same amount of produce (Ajayi *et al.*, 2019). These crop productivity reductions and increased cultivation costs are a greater threat to national food security (Adejuwon, 2017). Drought and flood have limited a greater percentage of the Nigeria's food production capacity. Nigeria has the potential to feed themselves and other countries of Africa (Adejuwon, 2019). These factors have hinder crop output in this country due to variations in the amount, intensity and distribution of rainfall as a result of climate change. The rising likelihood of droughts and floods due to unpredictable rainfall patterns at both spatial and temporal scales has been highlighted in severally studies involving projected climatic scenarios and climate change assessments (Anyadike *et al.*, 2019). This exposes the population in rainfed areas to greater challenges of socioeconomic development. Rainfed agriculture accounts for over 90% of Nigeria's net sown area (Odjugo, 2010). Nigeria has the largest area under rainfed agriculture in West Africa among the key countries that contribute to the regional's agricultural output. Crops like paddy, maize, wheat, sorghum, groundnut, soybean, yam and cassava etc., are all produced in the country using only rainfed conditions, with minimal supplementary irrigation. Changes in moisture availability brought on by rainfall dispersion pose a danger to these crops' productivity (Okafor *et al.*, 2024). Therefore, the aim of this study is to assess the rainfall distribution and its precipitation concentration index (PCI) for crop production in northern guinea and sudan savannas of Nigeria

2.0 MATERIALS AND METHODS

2.1 Study area:

The study was carryout in northern guinea and sudan savannas of Nigeria (figure 1), with a location chosen in each of the agro-ecological zones, i.e. Sobo gari and Minjbri for northern guinea and sudan savannas respectively.

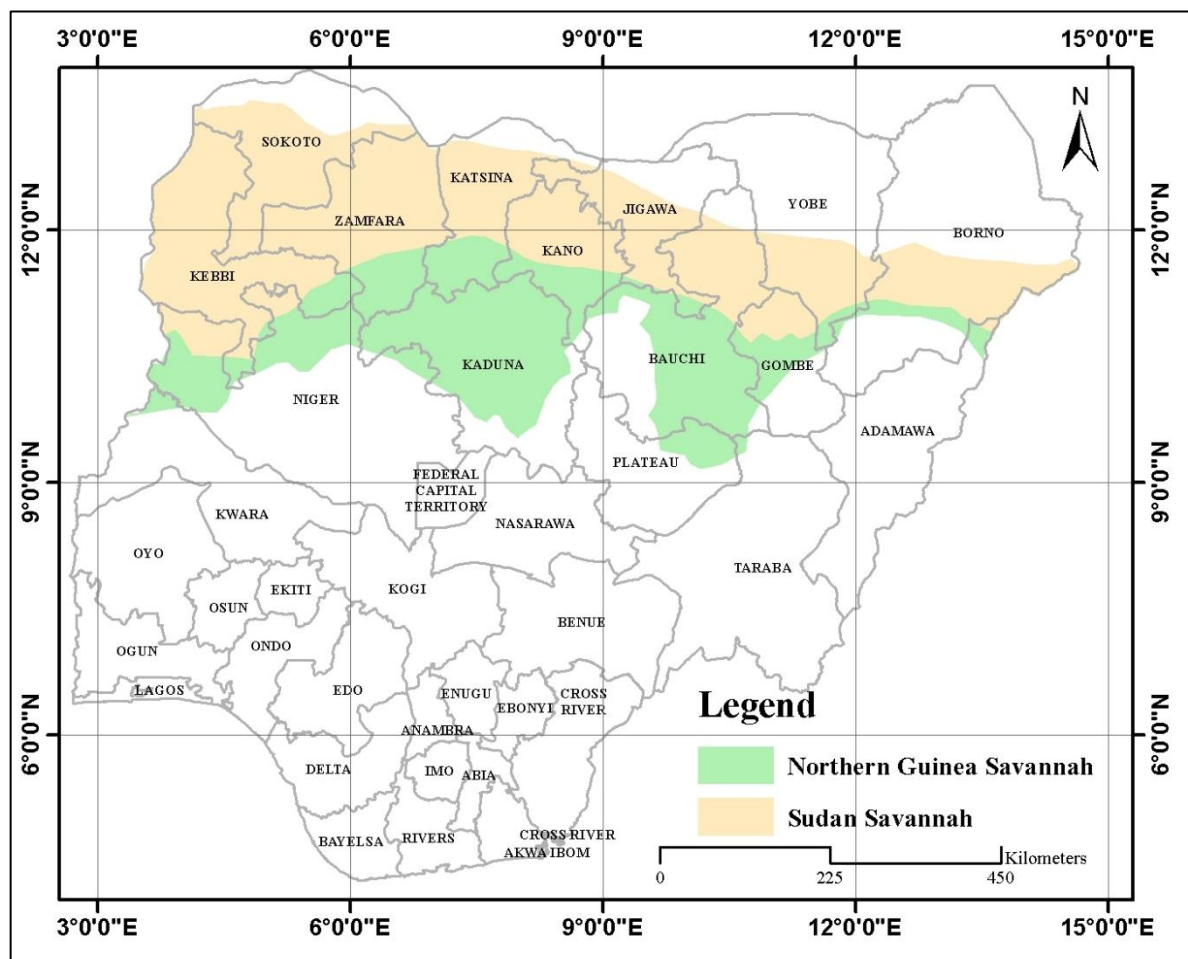


Figure 1: Nigeria Showing Northern Guinea and Sudan Savanna

2.1.1 Samaru: Samaru is a town in Sabon Gari local government area of Kaduna State, northern guinea Nigeria (figure 2). It is found in the northern guinea savanna of the country, and lies

year is hot and dry, with extreme temperatures during the dry season. The wet season provides some respite with lower temperatures and precipitation. The temperature ranges between 26.4°C to 33°C. During the Harmattan season (December-February), temperatures can drop as low as 10°C (NiMET, 2024). It is also a farming community.

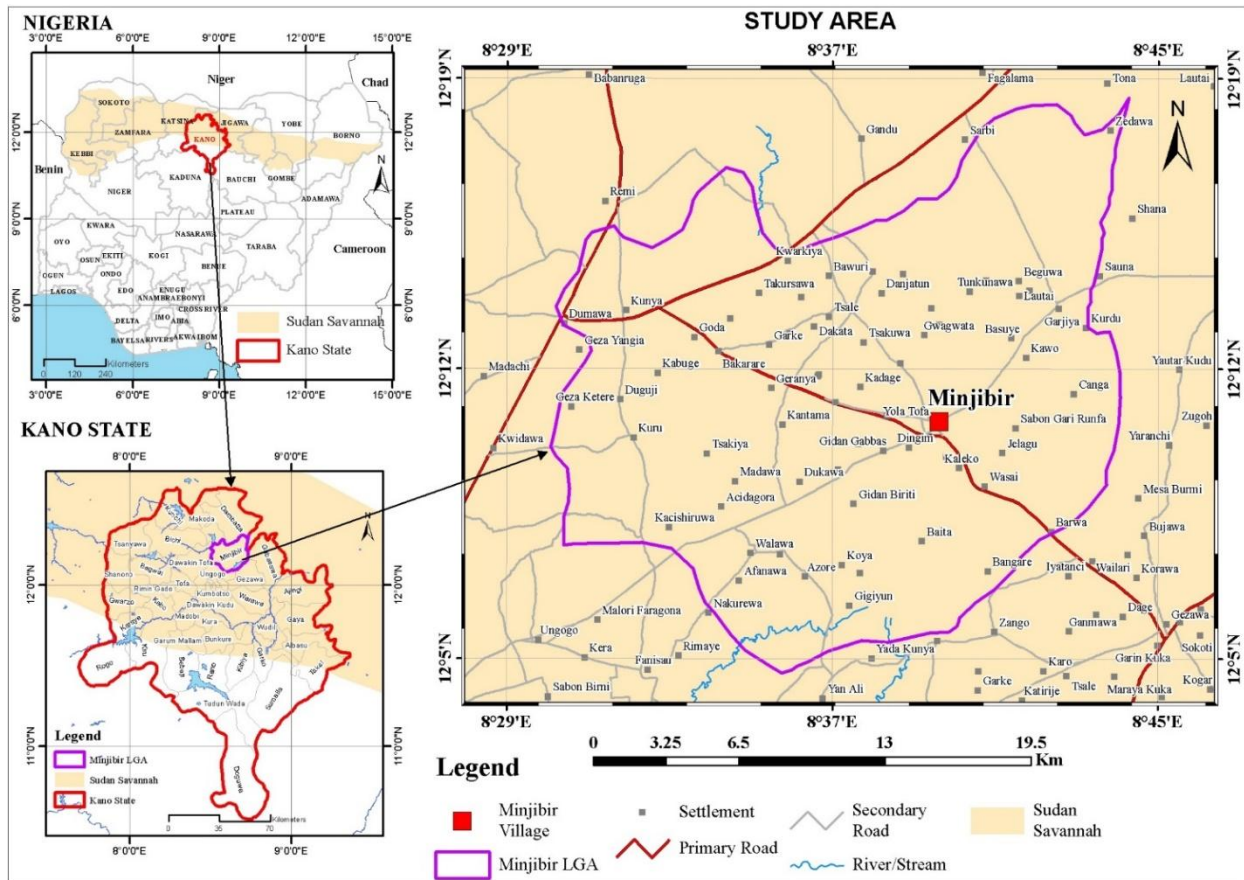


Figure 3: Sudan Savanna – Minjibir in Minjibir LGA of Kano State

2.2 Data collection: Daily rainfall data was obtained from the Nigerian Meteorological Agency (NIMET) for a period of 31 years (1994 - 2024).

2.3 Data Analysis: Precipitation concentration index (PCI) was determined using the equation developed by Oliver, 1980; and trend of rainfall was achieved using time series

$$PCI = 100 \left[\frac{\sum p_i^2}{(\sum p_i)^2} \right] \dots\dots\dots I$$

Where:

Pi = rainfall amount of the ith month

i = January ... December

$\sum$ = Summation over the 12 months

Table 1: Precipitation Concentration Index (PCI) Range and Classification

PCI Value (%)	Classification
≤ 10	Uniform Precipitation Distribution
10 – 15	Moderate Precipitation Distribution
16 – 20	Irregular Precipitation Distribution
>20	Strong Irregular Precipitation Distribution

Source: Oliver, 1980

3.0 RESULTS AND DISCUSSION

The result from the figures 1 & 2 below shows that the PCI of rainfall in Samaru and Minjibri respectively. In figure 1, it revealed that Samaru is characterized by strong irregular rainfall distribution i.e. > 20%; and irregular rainfall distribution i.e. <20%. The result further revealed that 64.52% of rainfall between 1994 – 2024 fall under strong irregular rainfall distribution while only 35.48% recorded irregular rainfall distribution. Figure 2 shows that Minjibri is characterized by strong irregular rainfall distribution i.e. > 20%; except in 2011, 2013 and 2023 recorded irregular rainfall distribution i.e. < 20%. The result further revealed that 90.32% of the rainfall

between 1994 – 2024 fall under strong irregular rainfall distribution while only 9.67% recorded irregular rainfall distribution. According to Oliver (1980), PCI estimations of not exactly or equivalent to 10% represents uniform precipitation distribution (i.e., low precipitation concentration); PCI values from 11 – 15% denotes moderate precipitation concentration; values from 16 – 20% denotes irregular distribution and values above 20% represents a strong irregularity (i.e., high precipitation concentration) of precipitation distribution. It shows that the rainfall concentrates in a few months in both locations, and the areas are prone to long drought and dry season, with Minjibri expected to experienced longer drought and dry sea than Samaru. This is due to its (Minjibri) proximity to the Sahara Desert and greater northern latitude. The impact and duration of the humid air masses that bring rain are directly impacted by this position. Seasonally, the Inter-tropical discontinuity (ITD), which separates the moist Tropical Maritime air mass from the Atlantic Ocean from the dry tropical continental air mass from the Sahara Desert, shifts north and south.

Therefore, the cultivation of short duration crops will be possible in both locations, with Samaru having the potential accommodate crops with live span longer than Minjibri due to its PCI values. Ajayi *et al.*, (2019) has stated that the cultivation of short duration crops with three to four months maturity period is of more economical importance with areas having PCI mostly dominated with strong irregular rainfall distribution, i.e. > 20% and above ways comes with short duration of rainy season.

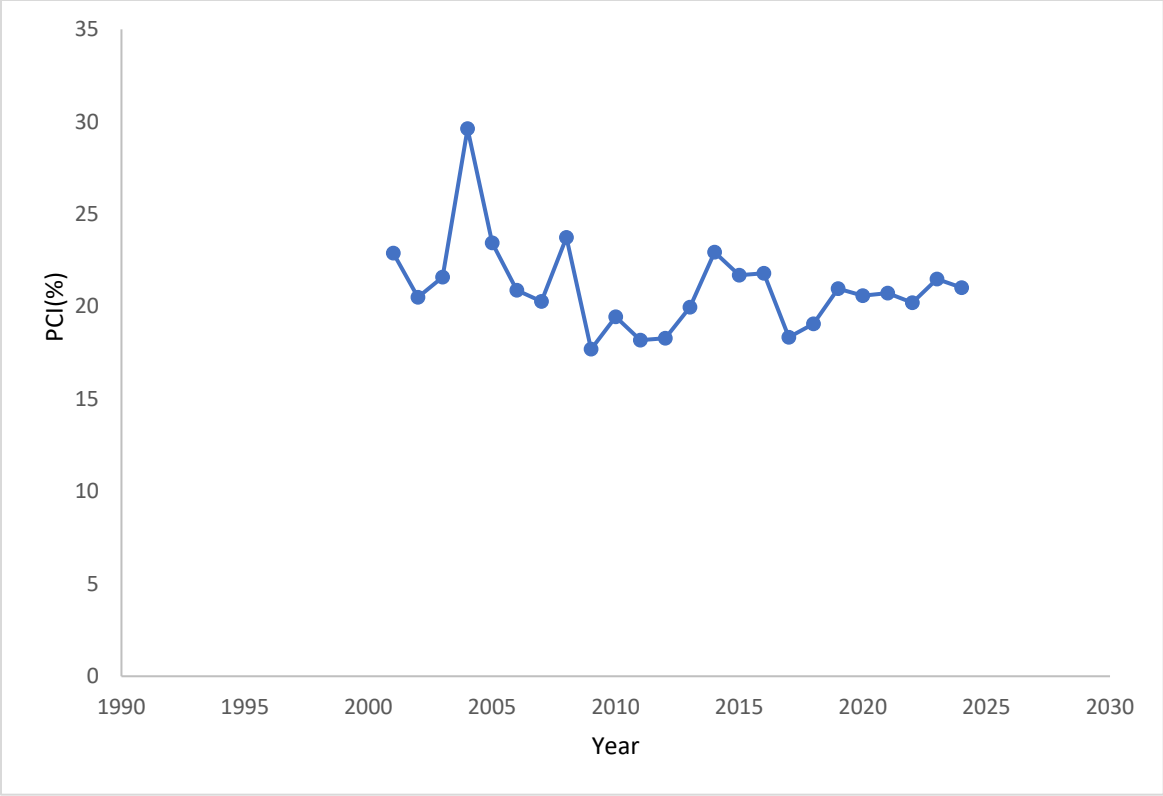


Figure 1: Precipitation Concentration Index for Samaru (1994 -2024)

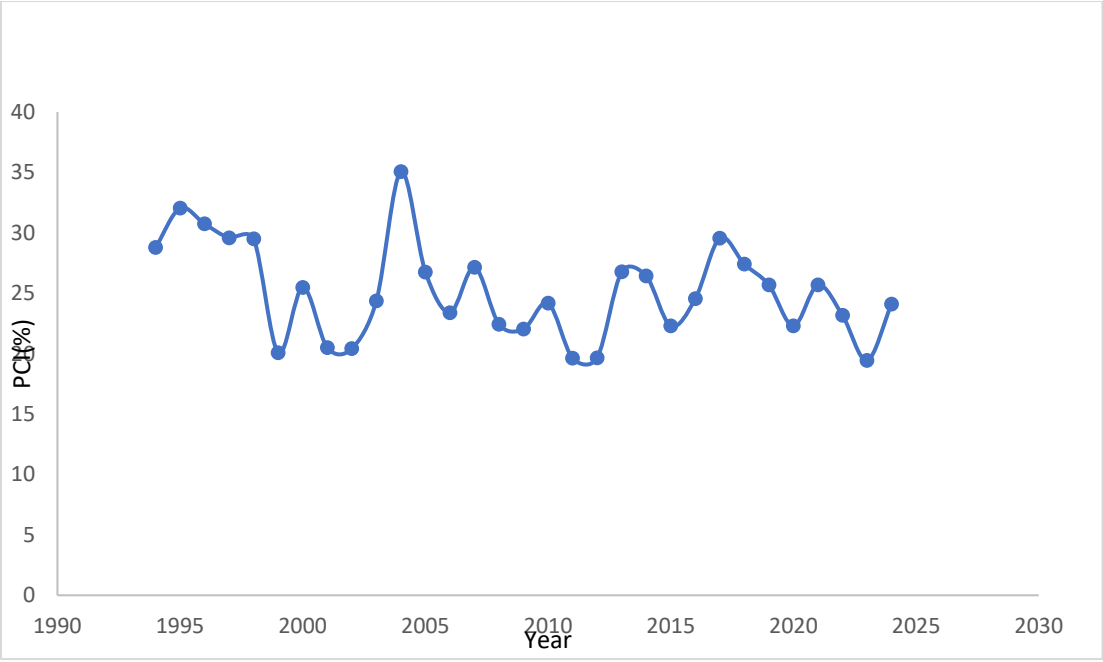


Figure 2: Precipitation Concentration Index for Minjibri (1994 -2024)

The result from figures 3 and 4 below shows that the number of rainy days in Samaru and Minjibri respectively. The number of rainy in Samaru (figures 3) ranges from 73 – 81 days with the highest number of rainy days recorded in 1995, whilst the least was recorded in 2010, 2016, 2018 and 2022. This shows that the number of days reduced by 8 days at $y = -0.1359x + 349.38$ and $R^2 = 0.1203$. It also shows that Samaru experienced an average of 76.27 days of rainfall between 1994 – 2024. On the other hand, the number of rain days in Minjibri ranges from 67 – 76 days with the highest number of rainy days recorded in 1994, whilst the least was recorded in 2007 and 2012. This reveals that the number of days reduced by 9 days at $y = -0.1274x + 327.86$ $R^2 = 0.1786$, and experiencing an average of 71.87 days of rainfall between 1994 – 2024.

It shows that Minjibri witnessed more decrease in number of rain days than Samaru, due to its location further north, which causes the Intertropical Convergence Zone (ITCZ) to migrate seasonally, shortening the rainy days. The decrease in number of rainy days may also be attributed to change in climate as a result of the emission of gases into the atmosphere. According to Intergovernmental Panel on Climate Change (IPCC) (2021), an average decrease in global rainfall will be observe in semi-arid and arid areas leading to change in rainfall pattern and amount of rainfall whilst the tropical wet areas of the world will continue to experience increase in rainfall. Thus, early maturing crops can be cultivated in both locations, also the used of irrigation will help in achieving sustainable crop production.

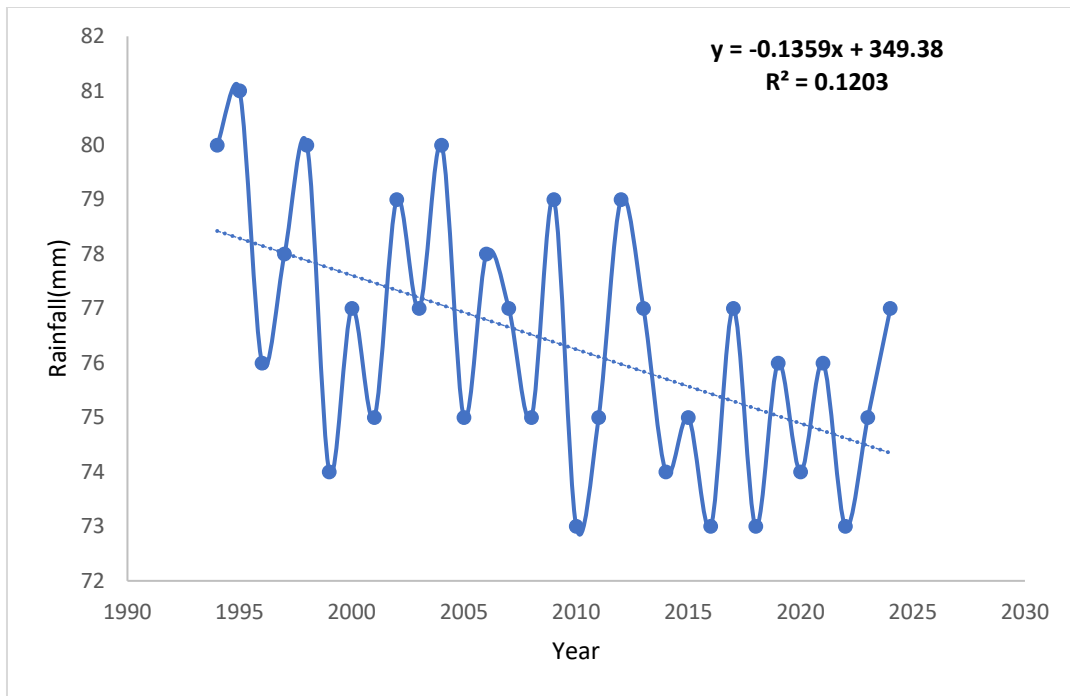


Figure 3: Number of Rainy Days for Samaru (1994 -2024)

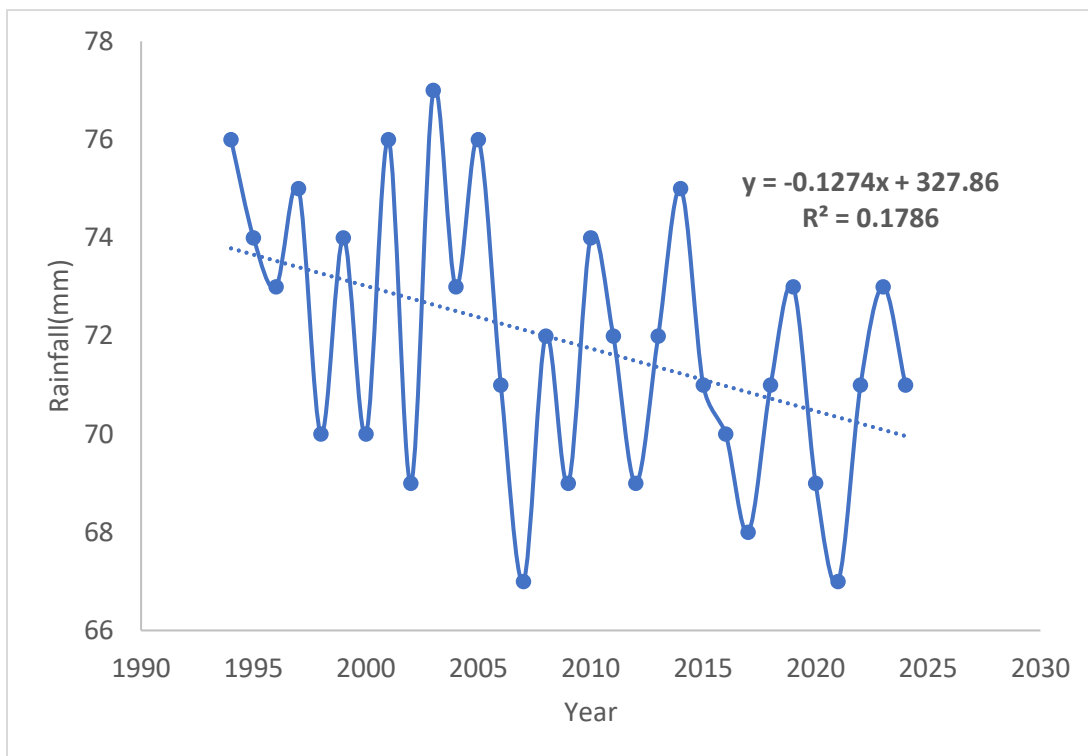


Figure 4: Number of Rainy Days for Minjibri (1994 -2024)

The result in figure 5 & 6 shows that monthly rainfall distribution. The bar chart revealed that the onset of rain for Samaru (i.e. figure 5) occur in May with an average rainfall of 107.22 mm and the establishment of rainfall on June with an average rainfall of 130.71 mm. The month of August received the highest amount of rainfall with 288.61 mm (i.e. the peak of rainfall), and it is characterized by unimodal rainfall distribution pattern. Also, for Minjibri (i.e. figure 6) it revealed the onset of rain occur in May with an average rainfall of 64.31 mm and the establishment of rainfall on June with an average rainfall of 132.27 mm. The month of August received the highest amount of rainfall with 265.80 mm (i.e. the peak of rainfall). It also witnessed unimodal rainfall distribution pattern.

Both areas experienced four months of concentrated rainfall for crop production, with Minjibri recorded the least amount of rainfall monthly due to its proximity to dry, continental air mass from the Sahara Desert. This revealed that planting of crops with the lifecycle within duration of rainfall will be possible, with Samaru having the potential to sustain crop more than Minjibri. According to Anyadike *et al.*, (2019), farmers must comprehend rainfall patterns and how they affect the various stages of the crop lifecycle, because while sufficient and evenly distributed rainfall during the growing season can increase crop yields, drought and excessive rainfall are detrimental to the crop growth and development.

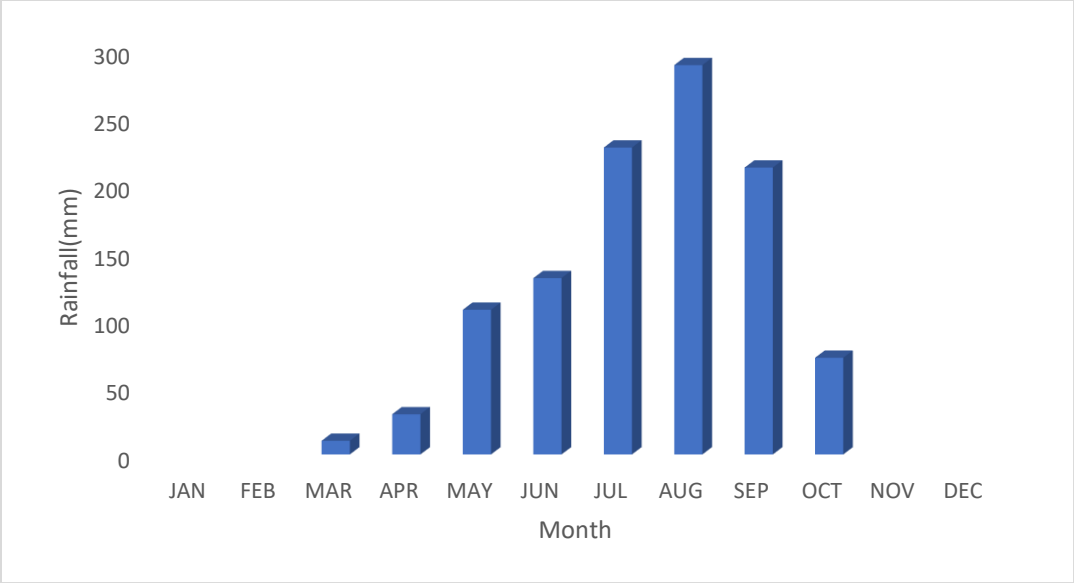


Figure 5: Monthly Rainfall Distribution Samaru

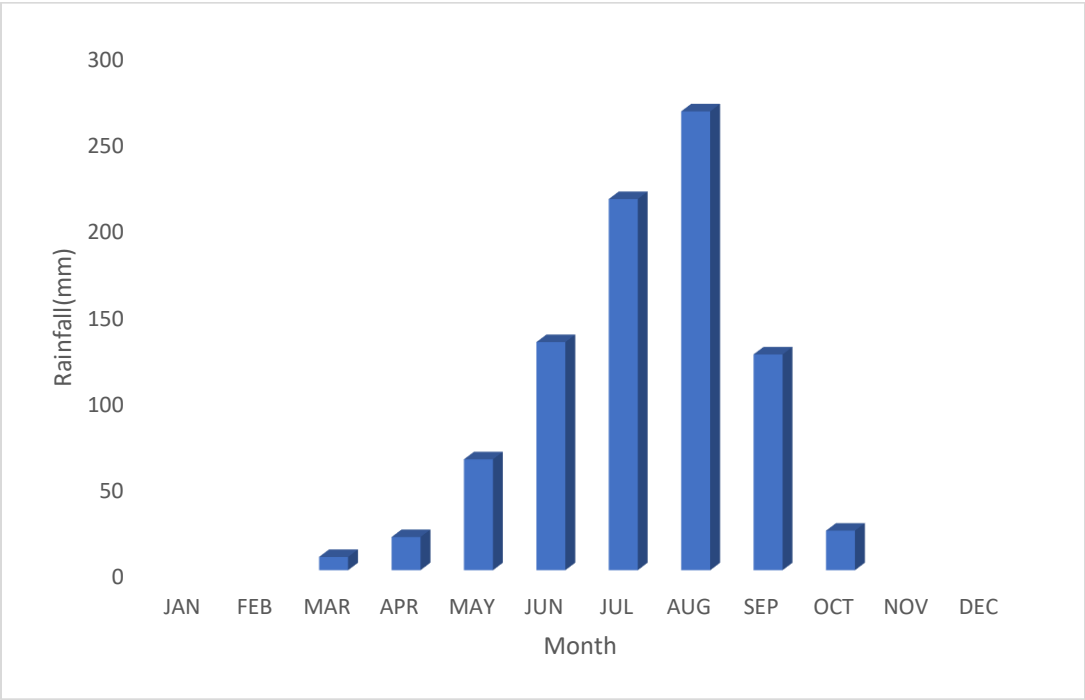


Figure 6: Monthly Rainfall Distribution Minjibri

Figure 7 & 8 shows the trend of annual rainfall for Samaru and Minjibri. For Samaru (i.e. figure 7), it shows a decrease in the amount of rainfall at $y = -6.5625x + 9992$ and $R^2 = 0.046$. The average annual rainfall ranges between 763.4 mm in 2007 to 1333.3 mm in 2012. It also shows a decrease in the amount of rainfall in Minjibri (figure 8) at $y = -4.5625x + 9992$ and $R^2 = 0.1003$. The average annual rainfall ranges between 502.70 mm in 2007 to 1011.90 mm in 2002. This also revealed that Minjibri witnessed more decrease in the annual rainfall than Samaru due to its proximity to dry, continental air mass from the Sahara Desert. Thus, both areas require short duration crops. Okafor *et al.*, (2024) stated that rainfall has a direct impact on crop growth and yield since it supplies the water required for plant growth and development. Additionally, it contributes to soil health, nutrient transfer and drought mitigation.

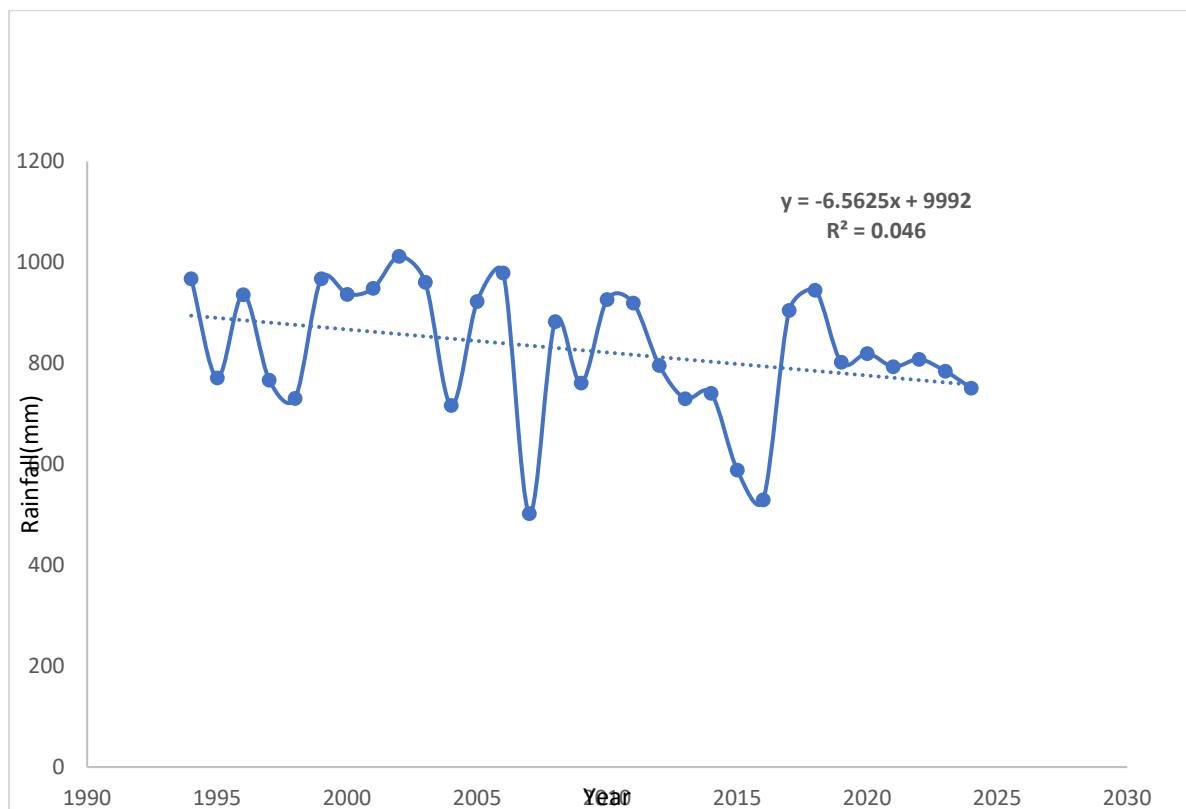


Figure 7: Annual Rainfall Distribution for Samaru

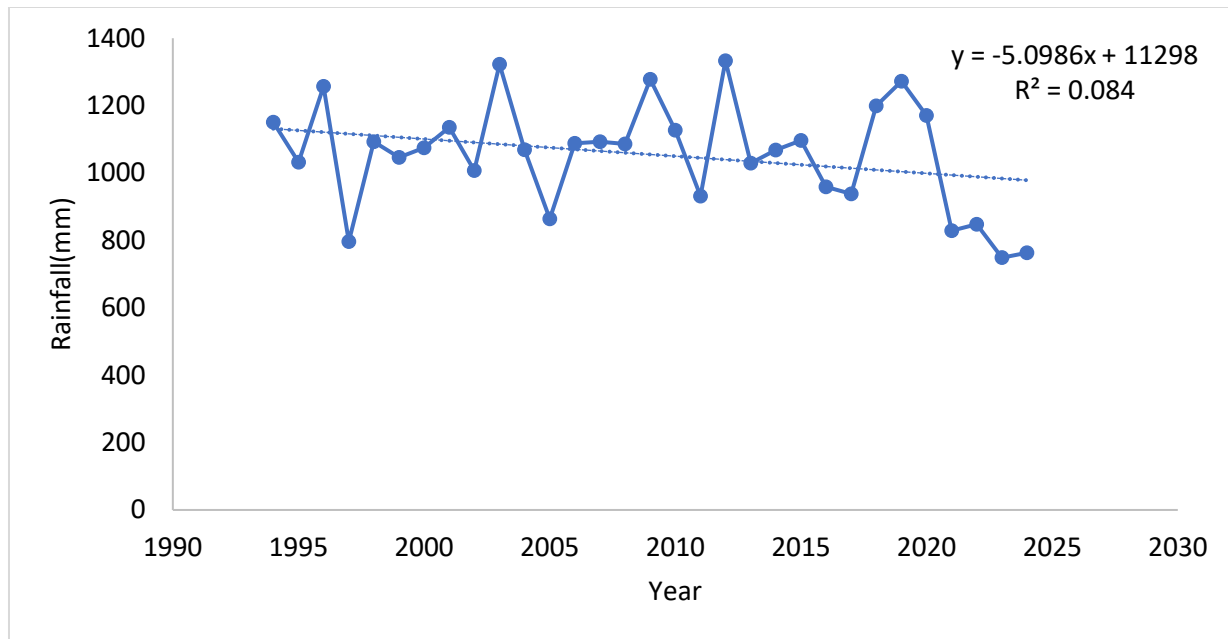


Figure 8: Annual Rainfall Distribution for Minjibri

From the bar chart below in figure 9. It shows the decadal rainfall distribution in Samaru and Minjibri. It indicated decrease in rainfall distribution across the three decades. From the bar chart, between the first and the second decade, Samaru and Minjibri recorded 2.03% and 7.92% decrease respectively. Also, between the second and third decade, Samaru and Minjibri recorded 7.21% and 9.38% decrease respectively. This shows that the two locations witnessed decrease in decadal rainfall with Minjibri experiencing more decrease than Samaru which may be attributed its location in the north and the consequent impact of atmospheric dynamics. According to intercontinental panel on climate change (IPCC) (2021) annual report, it stated annual precipitation would decline in these areas, and agricultural and ecological droughts will occur more frequently with greater severity. This revealed that both areas require irrigation for sustainable crops production.

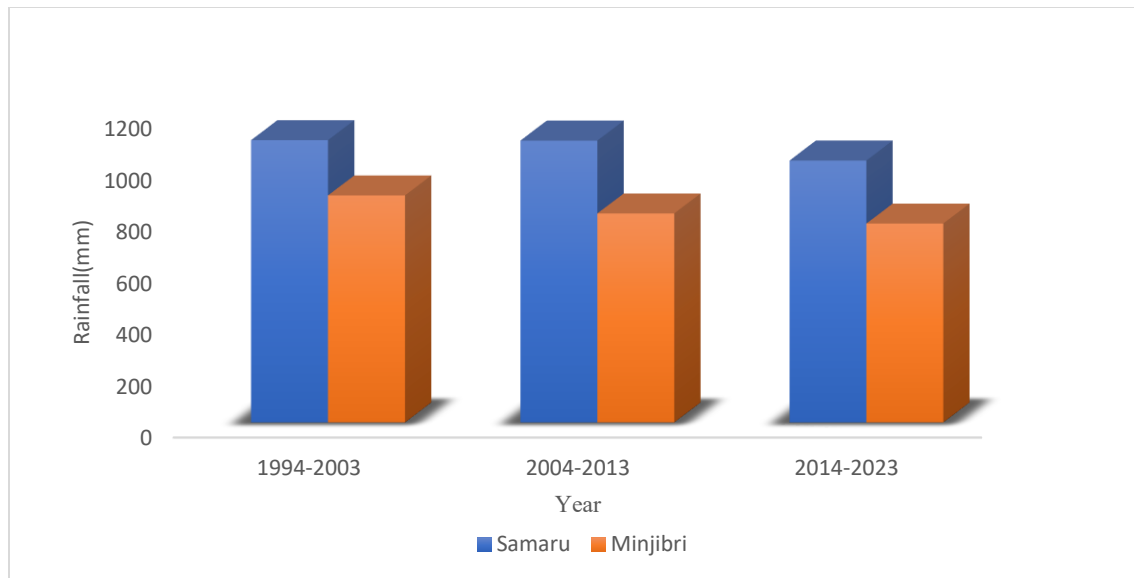


Figure 9: Average Annual Decadal Rainfall for Minjibri and Samaru (1994 -2023)

4.0 CONCLUSION

Despite the adaptation efforts through resilient crop varieties and improved agricultural practices, climate change in Nigeria and other countries of the world has led to declining crop yields like maize, rice, millet, cowpea, sorghum etc. because of altered rainfall patterns, rising temperatures and increase in the frequency of extreme weather events like droughts and floods. Therefore, understanding of rainfall distribution and changes in other weather parameters are crucial for sustainable crop production.

REFERENCES

- Adejuwon, A. D., (2020). Future projections of maize production in Nigeria under climate change scenarios, *Journal of Agricultural Science*, 10(3), 45-56.
- Adejuwon, J. O. (2017). Impact of climate change on yam production in Nigeria: implications for food security. *Environmental Development*, 24, 39-49.
- Adejuwon, J. O. (2019). Effects of climate change on crop production in Nigeria. *The Environmentalist*, 39(2), 153-166.
- Adejuwon, J.O. (2018). Climate change and agriculture in Nigeria: Impacts, adaptation and mitigation strategies, in climate change and agriculture, *Springer*.

- Adeola, A.O., Adeoye, N.O., and Atoma, C. N. (2021). Assessment of climate change impacts on maize yield in Nigeria using remote sensing and GIS techniques, *International Journal of Remote Sensing & Geoscience*, 1.3(1), 12- 24.
- Adesina, F. A., Bolarinwa, K. T., and Ajewole, O. I., (2019). Climate change and maize production in Nigeria: A review of current challenges and future prospects, *Journal of Agricultural Science and Technology*, 21, (5), 1023-1036.
- Ajayi, V. O., Ogunjobi, K. O., Salami, A. T., and Adejuwon, J. O. (2019). Impact of climate variability on rice productivity in nigeria. *International Journal of Biometeorology*, 63(8), 1101-1114.
- Anyadike, R. N. C., Ojehomon, V. E. T., Agbogidi, O. M., and Egesi, C. N. (2019). Effect of climate variability on Cowpea (*Vigna unguiculata* (L.) Walp) production in Nigeria. *Scientific African*, 6, e00176.
- Ayodele, M., Omotoso, A. B., Sulaimon, I. and Daud, S. (2025). Vulnerability assessment of food crop production and climate change: implication for agricultural productivity and development in Nigeria. *Rural and Regional Development*. 3(3):10008.
- Eze, J. E., Ogunmola, S. F., Okunade, D. A., & Ogunjobi, K. O. (2020). Climate change and cassava production in Nigeria: An empirical analysis. *Agricultural and Food Economics*, 8(1), 5.
- Eze, J. E., Ogunmola, S. F., Okunade, D. A., & Ogunjobi, K. O. (2021). Climate change and food security in Nigeria: An analysis of spatial and temporal patterns of rainfall variability. *Sustainable Development*, 29(1), 114-126.
- Ezenwaji, E. E. Nzoiwu, C. P. and Chima G. N. (2017). Analysis of precipitation concentration index (PCI) for Awka Urban Area, Nigeria. *Hydrology Current Resources* 8: 287.
- Food and Agriculture Organization, FAO (2016). "The state of food and agriculture: Climate change, agriculture and food security", Rome, FAO. [Online]. Available: <https://openknowledge.fao.org/server/api/core/bitstreams/07bc7c6e-72e5-488d-b2f7-3c1499d098fb/content>.
- Inter-governmental panel on climate change (IPCC) (2021). *Climate change: The Supplementary report to the IPCC scientific assessment*. Cambridge University Press, pp. 231 – 289.
- Intergovernmental Panel on Climate Change IPCC, Climate Change (2023): Synthesis Report, Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 35-115. <https://doi.org/10-59327/IPCC/AR6-9789291691647>.
- Komolafe, J. O., Ikotun, D. O. and Aghedo, H. O. (2025). Assessment climate change adaptation strategies on maize production in selected states, in South-West, Nigeria. *Agriculture, Food, Environment and Animal Sciences*, 6(1): 244-257.
- Matthew, M., Timothy, E., and Olorunshola, E. (2025). adaptation strategies to climate variability among maize farmers in Oyo State, Nigeria. *Journal of Agricultural Extension*, 29(3), 111– 117.

- Nigerian Meteorological Agency (NiMet) (2024). *Climate review bulletin*. Annual publication of Nigerian Meteorological Agency (NiMet) Abuja, pp 14 – 25.
- Odjugo P. A. (2010) General overview of climate change impacts in Nigeria. *Journal of Human Ecology*, 29: 47-55.
- Okafor, C. C., Ajaero, C. C., Madu, C. N., Nzekwe, C. A., Otunomo, F. A., and Nixon, N. N. (2024). Climate change mitigation and adaptation in Nigeria: A Review. *Sustainability*, 16(16), 7048.
- Okon, E. M., Falana, B. M., Solaja, S. O., Yakubu, S. O., Alabi, O. O., Okikiola, B. T., Awe, T. E., Adesina, B. T., Tokula, B. E., Kipchumba, A. K. and Edeme, A. B. (2021) Systematic review of climate change impact research in Nigeria: Implication for sustainable development. *Heliyon*, 7(9).
- Oliver J. E. (1980). Monthly Precipitation Distribution: A Comparative Index. *Professional Geographer* 32: 300-309.

FUNDING

This work is solely funded by the authors.

DATA AVAILABILITY

The meteorological data used in this study were obtained from the Meteorological Service Unit, Ahmadu Bello University, Zaria (an out station of Nigeria Meteorological Agency (NiMet), Abuja). Due to data-sharing restrictions imposed by NiMet, the dataset cannot be publicly deposited or shared without prior permission from the Agency. The data may be available from Meteorological Service Unit, Ahmadu Bello University, Zaria and NiMet head office, Abuja upon reasonable request and subject to Agency's approval.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Authorsdetails.docx](#)