Science World Journal Vol. 20(No 1) 2025 https://dx.doi.org/10.4314/swj.v20i1.11
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

ASSESSMENT OF CLIMATE VARIABILITY AND METEOROLOGICAL DROUGHT IN LERE, KADUNA STATE, NIGERIA

[1]Mawana Haruna, [1]Rabi Zakari Muhammad, [*1,2]Muhammad Lawal Abubakar

[1]Department of Geography and Sustainability Studies, Kaduna State University, Kaduna
[2]Climate Research Group, Kaduna State University, Kaduna

*Corresponding Author Email Address: muhdlawal@kasu.edu.ng

ABSTRACT

This study assessed climate variability in Lere by examining the seasonal and annual variability and trends of rainfall and temperature, as well as the trends of meteorological drought. Temperature and rainfall data were obtained from NASA Power Data Access. The variability was examined using the Coefficient of Variation (CV), the trend was analyzed using the Mann-Kendall trend test, and the drought was examined using the Standardized Precipitation and Evapotranspiration Index (SPEI). The coefficient of variation revealed moderate variability in rainfall (18%) and low variability in temperature (minimum: 13%; maximum: 2%). The Mann-Kendall trend detected significant increases in minimum ($Z = 3.014$, $p < 0.05$) and maximum temperatures ($Z = 0.23$, $p < 0.05$), while rainfall exhibited a non-significant decreasing trend ($Z = -1.431$, $p > 0.05$). Seasonal trends showed significant increases in minimum and maximum temperatures ($tau = 0.18$, $p < 0.0001$) and a significant decline in rainfall ($tau = -0.11$, $p = 0.004$). Monthly trends mirrored seasonal results, with significant increases in minimum and maximum temperatures but non-significant decreases in rainfall. Drought analysis revealed durations of 25 and 30 months for SPEI-3 and SPEI-12, respectively, with maximum intensities of -2.762 and -1.975. All droughts exhibited significantly decreasing trends, underscoring the increasing climate variability in the study area. The study concluded that meteorological droughts are decreasing, even though seasonal and annual rainfall are decreasing. The study recommends that stakeholders should improve climate-smart agriculture practices while boosting afforestation activities to reduce the impacts of rising temperatures

Keywords: Climate variability, SPEI, meteorological drought, Lere, Nigeria

INTRODUCTION

Climate variability is one of the main drivers of socioeconomic and environmental issues confronting humanity in the 21st century (Malhi et al., 2021). According to the Intergovernmental Panel on Climate Change (IPCC, 2022), this variability is brought about by the complex interaction of the climate system Atmosphere-Ocean, cryosphere, surface lithosphere, and biosphere. Climate variability refers to the variation from the long-term mean of climatic parameters in a given region (Abubakar et al., 2024a), which may lead to the occurrence of extreme weather or climate events (van der Wiel & Bintanja, 2021). These events are more severe than normal or average weather and they include heavy precipitation, droughts, heat waves, and cold waves (Herring et al., 2018, 2020). Climatic models have shown that the global climate has been changing over the past century and these changes may likely be more rapid in the future (Adeleke et al., 2018).

Nowadays climate variability and change are amongst the most important threats to sustainable development, with potentially severe consequences on agriculture in developing countries (Abbass et al., 2022). In Sub-Saharan Africa, climate variability poses a major challenge to the sustainability of millions of people whose livelihoods depend on agriculture (Ayanlade et al., 2022), possibly as a result of the region's low capacity to adapt and lack of strong institutional frameworks (Ahmed et al., 2024). Countries in sub-Saharan Africa (SSA) are particularly vulnerable to the adverse effects of climate change because of their dependence on agricultural production and their limited capacities to effectively adapt (Omotoso et al., 2023). Most farmers are already facing considerable threats, and climate variability and change only worsen these threats through losses in farm profits (Amare & Balana, 2023; Tajudeen et al., 2022). Challenges such as persistent poverty and socioeconomic inequality, low levels of development, limited economic capacity, and countless governance and institutional failures have led to low adaptive capacities and a significant adaptation deficit in SSA (David et al., 2025).

Reports of the IPCC (2007c) have highlighted the vulnerability of Africa to climate variability and change. Even though they are least responsible for these changes, they are prone to greater impacts because their economies are highly dependent on natural resources that are sensitive to climate in addition to the fewer resources and options, they have to combat the impacts of climate variability and change. Millions of its people may likely face catastrophes, and extreme weather events are likely to become more intense and more frequent with higher global temperatures affecting crops, and water supplies and increasing the spread of diseases among other impacts. The projected impacts of climate variability and change for Africa by 2020 are between 75 and 250 million people (IPCC, 2022). This will adversely affect the livelihoods of the people.

Extreme weather and climate events such as drought, flood, ocean surges, etc. have become more regular (Amaechina et al., 2022). These extreme weather events are associated with the increased frequency of anthropogenically motivated rise in greenhouse gas (GHG) concentration and land use changes (Bolan et al., 2024), and their consequences are the intensifications of global warming and hydrological cycle (Huntington, 2006). The impacts of these extreme events may be gradual but their destruction of lives and property hurts the economy (Furtak & Wolińska, 2023). Floods have become an almost annual occurrence, especially in the northern parts of the country with increasing intensity each year, leaving colossal losses and trauma (Abaje & Giwa, 2010).

Long-term climate is a fundamental issue in the scientific discipline. Previous studies have addressed that climate change has impacted a wide range of fields such as agriculture, environment, health, economy, and water resources (IPCC, 2004; Nelson et al., 2009; Patz et al., 2005; Vorosmarty et al., 2000). The IPCC 6th AR, (2021) projected that in the coming decades, changes in the climate system will increase in all regions, and for every 1.5°C of global warming, heatwaves, hot days and tropical nights will increase. The report also stated that at 2°C, the threshold for critical tolerance of agriculture and health sectors to heat extremes would be diminished.

Apart from the oil sector, Nigeria's economy for the past decades largely depends on agriculture, and policymakers have made agriculture a key driver for economic growth and development (Adamgbe et al., 2020). Despite this, Nigeria is constantly facing challenges due to climate conditions that negatively impact the livelihoods of millions of people, especially regarding flooding and drought, as well as late-onset and early cessation of rainfall. Ray et al. (2019) suggested that climate variability has already affected global food production. This research intends to assess spatial-temporal climate variability and drought occurrence in Lere using reanalysis data from 1981 to 2024. Thus, the objectives of the study are to (1) analyse the variability and trends of rainfall, and (2) examine the occurrence, magnitude and trend of meteorological drought in Lere Kicak Government Area of Kaduna State.

MATERIALS AND METHODS

Study Area

Lere is located in the eastern part of Kaduna State. It is located between Latitudes 9°58'59'' and 10°44'9'' North of the Equator and between Longitudes 8°19'19'' and 8°49'4'' East of the Greenwich Meridian, covering 2,158 km^2 (Vihi et al., 2018). Its headquarter is Saminaka (Uchenna et al., 2012). The climate is tropical Savannah, with daily temperatures as high as 30°C in July and September of 40°C in April and May (Musa & Abubakar, 2024). The mean daily temperature ranges from 15°C in December and February and about 27°C in April and June. Rainfall ranges from 2.8mm in July and September to about 16.2mm in March, with the highest temperature/evaporation around March/April (Abubakar et al., 2024a). The area witnesses a humid tropical condition that ranges from about 15 % in March to about 70% in September.

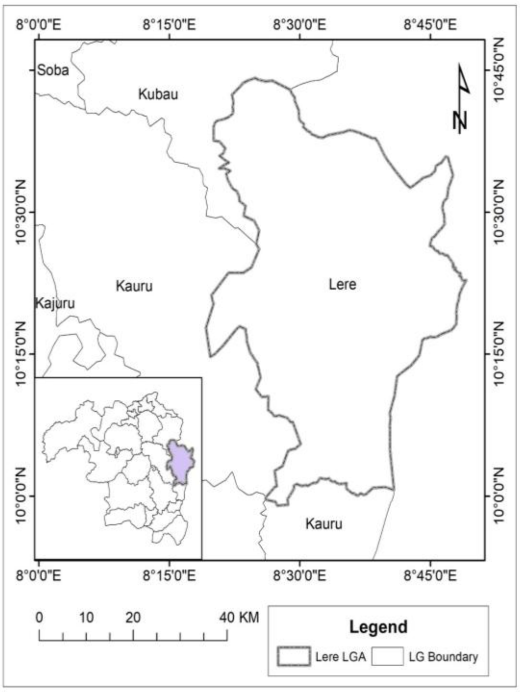


Figure 1: Lere Area of Kaduna State
Source: Modified from GRID^3 – Nigeria, 2021

Lere lies at an altitude of about 700m above sea level (Vihi et al., 2018). It is next door to the Jos plateau in central Nigeria, it lies to the southern highlands on a crystalline basement rock, that is dissected by many patches of Inselbergs a common soil formation that sprouts during the rainy season. This area is within the Guinea savanna zone, the soils in Saminaka and indeed Lere are of tropical leached humus, fine-grained, and that is sometimes quartz, suitable for the cultivation of grains (Vihi et al., 2018). The vegetation is characterized by deciduous trees that shed their leaves in the dry season. The major crops cultivated are: maize, millet, sorghum, groundnut, beans, sweet potatoes, watermelon, and rice, with Poultry, livestock, forestry, fishing, and beekeeping (Vihi et al., 2018).

Methodology

Data Sources

Monthly rainfall and temperature records were obtained from NASA's GMAO MERRA-2 assimilation model and GEOS-IT. The MERRA-2 reanalysis data is a variant of NASA's Goddard Earth Observing System (GEOS) Data Assimilation System (Bosilovich et al., 2017). Several studies have found the MERRA-2 datasets to be reliable for conducting climate-related studies in Nigeria (Ahmed et al., 2024). Base map of the study area was extracted from the Geo-Referenced Infrastructure and Demographic Data for Development (GRID3, 2024).

Data Processing

Homogeneity Test

The study employed the Standard Normal Homogeneity Test (SNHT) (Alexandersson, 1986) and Pettitt's (1979) homogeneity tests to assess the homogeneity of annual and seasonal rainfall in Lere Local Government Area of Kaduna State. Previous studies have demonstrated that various tests for homogeneity may exhibit varying degrees of sensitivity towards specific breakpoints, a crucial factor in determining the presence or absence of homogeneity in time series data. In addition, the SNHT is effective in detecting sudden changes at the beginning or end of a time series. However, the PT test is capable of finding shifts that occur amid the time series, hence improving the overall comprehensiveness of the study (Akinsanola & Ogunjobi, 2015; Kabbilawsh et al., 2023; Nath et al., 2024).

The SNHT (Alexandersson, 1986; Patakamuri et al., 2020) is a statistical method used to identify irregularities in time series datasets. It uses a likelihood ratio test to assess if a sequence of rainfall measurements shows sudden changes, such as leaps or breaks, rather than gradual and constant changes. The foundation of this approach is that the data generally conform to a normal distribution and that any deviations occur abruptly at a certain point in time.

Pettitt's test (PT) is a nonparametric test applied to detect changepoints in time series data, without making any assumptions on the pattern of distribution of the data (Pettitt, 1979). Thus, the premise is based on the notion that observations are autonomous and evenly distributed over time (Kabbilawsh et al., 2023; Yozgatligil & Yazici, 2016; Zhou et al., 2019).

Normality Test

Climatic data collected from NASA Power Access include daily rainfall and temperature (minimum and maximum). The climate data were subjected to normality tests using the Anderson-Darling test (AD) (1954). The formula is given in equation (1):

https://dx.doi.org/10.4314/swj.v20i1.11

$$A_n^2 = \int_{-\infty}^{\infty} |F_n(x) - F(x)|^2 \varphi\,(x) f(x) d(x) \qquad (1)$$

Where:

$$\psi(x) = {}^{n}/_{F}\,(x)\{1 - F(x)\} \qquad (2)$$

n = total number of data points
F(x) = distribution function of the fitted distribution
f(x) = density function of the fitted distribution
$F_n = \frac{i}{n}$
i = the cumulative rank of the data point

The AD statistics are more suitable in measuring fitness compared to other statistics such as Kolmogorov–Smirnov (KS), especially where there is consideration of fitting a distribution at the tails as well as the main body. The hypothesis for the Anderson-Darling normality test is H_o, Data is from a normally distributed population.

The p-value from the Anderson-Darling test assesses the probability that the data are from a normally distributed population. If the distribution fits the data, the A-D statistics will be small, and the associated p-value will be greater than the chosen alpha level (0.05 and 0.10). In this study, the Anderson-Darling Normality test procedure was used, and the analysis was performed using XlStat on Microsoft Excel.

Data Analysis

Variability of Rainfall and Temperature

Coefficient of Variation

This research employed the coefficient of variation (CV) to calculate the variability of climatological variables in Lere. Equation (3) was used to calculate it:

$$CV = \frac{\sigma}{\bar{X}} * 100 \qquad (3)$$

Where x is the climatological variables and σ is the standard deviation. Often, CV values below 20% are considered low, values between 20% and 30% are considered moderate, values between 30% and 40% are considered high, and values above 40% are considered very high (Asfaw et al., 2018; Durdu, 2010). This analysis was carried out using the hydroTSM package in R Studio.

Seasonal variability

Seasonal variability of climatological variables will be examined. The year will be divided into quarterly values, using the 3-month standard. The periods are March-April-May (MAM), June-July-August (JJA), September-October-November (SON), and December-January-February (DJF).

Trends of Rainfall and Temperature

To examine the trends of climatological variables in Lere, the Mann–Kendall (Kendall, 1948; Mann, 1945) trend test was used. The MK is frequently employed to identify pattern time series data, especially in hydroclimatic studies (Abubakar et al., 2025; Abubakar et al., 2024a). It is used to identify data that are not normally distributed and insensitive to outliers (Hamed, 2008). The null or alternate hypotheses are accepted or rejected. The null hypothesis suggests the absence of a trend, while the alternate hypothesis suggests that the time series is either increasing or decreasing. The S statistic is given in Equation (4):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \qquad (4)$$

Where *n* is the number of observations, x_i, and x_j are the *i*th and *j*th (*j > i*) observations in the time series, respectively, and $sgn(x_j - x_i)$ is the sign function computed Equation (5):

$$sgn(x_j - x_i) = \begin{cases} +1, if(x_j - x_i) > 0 \\ 0, if(x_j - x_i) > 0 \\ -1, if(x_i - x_j) > 0 \end{cases} \qquad (5)$$

For the series where sample size n > 10, the test statistic *S* is considered to be asymptotically normally distributed, with mean *E(S)* and variance *Var (S)* as equation (6):

E(S) = 0, and

$$Var(S) = \frac{n(n-1)(2n+5)}{18} \qquad (6)$$

The distribution of statistics S is inclined toward normalcy where n is greater than 10 and there is a likelihood of a tie in the value of x (Kendall, 1948); thus, the variance is calculated using equation (7):

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m} t_k(t_k - 1)(2t_k + 5)}{18} \qquad (7)$$

Where m indicates the number of tied groups and tk denotes the number of ties with length k. Equation (8) describes the conventional normal test statistic Z that is used to indicate a monotonic trend:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, if S > 0 \\ 0, if S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, if S < 0 \end{cases} \qquad (8)$$

In a two-tailed test, the null hypothesis of 'no trend' is accepted at the α significance level for − Z1−α/2 < Z ≤ Z1−α/2, where Z1−α/2 is the standard score (z score) of the standard normal distribution with a cumulative probability of 1 − α/2. Otherwise, the null hypothesis is rejected if a trend is identified at the α significance level. Hence, positive Z values imply an increasing tendency, whereas negative ones suggest a descending trend.

Assessment of Meteorological Drought in Lere using Standardized Precipitation and Evapotranspiration Index (SPEI)

SPEI is an index developed by Vicente-Serrano et al. (2010) that is used to calculate the status of drought in a given area. Unlike the Standardized Precipitation Index (SPI) which uses only precipitation data, SPEI calculates the difference between precipitation and evapotranspiration (Chen et al., 2018; Mohsenipour et al., 2018), aggregated across different time scales, and normalizes the potential evapotranspiration into a log-logistic probability distribution to calculate the SPEI index series (Vicente-Serrano et al., 2010). The Thornthwaite (1948) approach was used in the calculation of the potential evapotranspiration. SPEI is similar to SPI. In this study area, we performed SPEI3, SPEI6, SPEI9, and SPEI12 to monitor temporal occurrence and variations of droughts.

Table 1: Wet and Dry classification of SPEI based on the Index value

Category	SPEI
Extreme drought	≤ −2.0
Severe drought	−1.99 to −1.50
Moderate drought	−1.49 to −1.00
Near Normal	-0.99 to 0.99
Moderate wet	1.00 to 1.49
Severely wet	1.50 to 1.99
Extremely wet	≥ 2.0

Source: Beguería and Vicente-Serrano (2011)

RESULTS AND DISCUSSION

Description of the Climate Data

Rainfall, minimum, and maximum temperature time series data were described using homogeneity and normality tests.

Homogeneity Test

The rainfall, minimum (Tmin), and maximum (Tmax) temperature time series were subjected to a homogeneity test to detect abrupt shifts in the data. The result is shown in Table 2.

Table 2: Homogeneity Test for Rainfall, Minimum and Maximum Temperature in Lere

Pettitt's test

	Tmin	Tmax	Rainfall
K	9452.00	14669.00	6313.00
t	Mar-02	Dec-98	Sep-98
p-value	0.051	0.000	0.562
alpha	0.05	0.05	0.05

SNHT Tests

	Tmin	Tmax	Rainfall
T0	7.04	20.61	4.31
T	Feb-02	Dec-98	Sep-01
p-value	0.205	0.000	0.610
Alpha	0.05	0.05	0.05

Table 2 reveals the results of Pettitt's and SNHT for finding change points in minimum temperature, maximum temperature, and Rainfall (precipitation) datasets. For Pettitt's test, Tmax shows a significant change point in December 1998 (p-value = 0.000) at a 0.05 significance level, whereas Tmin suggests a marginally significant shift in March 2002 (p-value = 0.051). No significant change was identified for Rainfall (p-value = 0.562). Similarly, the SNHT results confirm a significant change point for Tmax in December 1998 (p-value = 0.000), whereas Tmin and Rainfall show no significant change (p-values of 0.205 and 0.610, respectively). These results show a strong and statistically significant shift in Tmax, with weaker evidence for Tmin and no evidence for Rainfall changes across the research period. The significant shift in the time series of maximum temperature time series suggests there was an artificial shift or inconsistency in the data, which was not caused by natural variations in the climate system.

Normality Test

Normality test was used to test the time series of the rainfall, minimum and maximum temperature for their distribution. The Anderson-Darling method was used. The result is shown in Table 3.

Table 3: Normality Test for Rainfall, Minimum, and Maximum Temperature in Lere

	Tmin	Tmax	Rainfall
A^2	18.302	6.723	36.352
p-value (Two-tailed)	< 0.0001	< 0.0001	< 0.0001
Alpha	0.05	0.05	0.05

Table 3 revealed the Anderson-Darling test results. The test statistic (A^2) values are 18.302 for Tmin, 6.723 for Tmax, and 36.352 for Rainfall. For all variables, the p-values are less than 0.0001, suggesting that the null hypothesis (the data follows the tested distribution) is rejected at the 0.05 significance level (alpha). These results imply that minimum and maximum temperatures and Rainfall values do not fit the tested distribution and exhibit considerable deviations.

Variability of Rainfall and Temperature in Lere

The variability of annual rainfall, minimum and maximum temperature was examined using mean, minimum, and maximum values, standard deviation, coefficient of variation, skewness, and coefficient of kurtosis. The result is shown in Table 4.

Table 4: Annual and Seasonal Variability of Rainfall and Temperature in Lere

Season	Variable	Tmin	Tmax	Rainfall
Annual	Mean	9.08	39.46	1161.00
	SD	1.21	0.89	214.32
	Min	6.33	37.61	686.00
	Max	12.51	41.49	1573.00
	CV (%)	0.13	0.02	0.18
	Skewness	0.29	-0.06	0.14
	Kurtosis	0.91	-0.65	-0.88
DJF	Mean	10.83	35.14	1.45
	SD	1.19	1.05	3.66
	CV (%)	0.11	0.03	2.53
MAM	Mean	17.57	38.23	174.70
	SD	1.02	1.26	77.48
	CV (%)	0.06	0.03	0.44
JJA	Mean	18.29	31.31	716.10
	SD	0.43	2.10	162.10
	CV (%)	0.02	0.07	0.23
SON	Mean	15.26	31.24	268.90
	SD	0.98	1.84	86.14

CV (%)	0.06	0.06	0.32

Source: Author's Analysis, 2024

Table 4 presents yearly and seasonal statistical analyses of Tmin, Tmax, and rainfall. Annually, Tmin has an average of 9.08°C with a standard deviation (SD) of 1.21°C, whereas Tmax averaged 39.46°C with a substantially smaller SD of 0.89°C. This is similar to the findings of Abaje and Oladipo (2019) which reported an SD of 0.73 in the northern part of Kaduna. Rainfall averaged 1161 mm annually, with a higher variability (SD = 214.32 mm) when compared to temperatures. Tmin, Tmax, and rainfall had CV values of 13%, 2%, and 18% respectively. From the CV, rainfall is highly variable. Skewness and kurtosis results suggest Tmin is moderately positively skewed with significant kurtosis, Tmax is virtually symmetrical, and rainfall was positively skewed but slightly platykurtic (flatter) distributions. This result is similar to the findings of Abubakar et al. (2024a) which revealed a CV of 14% in that region.

Seasonally, during the dry season (December–February), Tmin and Tmax average 10.83°C and 35.14°C, respectively, with low rainfall (1.45 mm). The CV for rainfall is particularly high at 253%, illustrating the erratic character of precipitation throughout this era. In contrast, during the March-May (MAM) season, rainfall increases to 174.7 mm, followed by warmer temperatures (Tmin = 17.57°C, Tmax = 38.23°C). Rainfall variability during this period is moderate (CV = 44%), while temperatures stay constant with CVs below 6%. The result shows that the dry season is marked by significant temperature contrasts and highly irregular rainfall, while the March-May season has increasing rainfall with moderate variability and rather stable temperatures.

The June–August (JJA) period, indicating the peak of the rainy season, recorded the most rainfall (716.1 mm) with a very moderate CV of 23%, implying more constant rainfall. Tmin and Tmax average 18.29°C and 31.31°C, respectively, with Tmax demonstrating more variability (SD = 2.10°C). During September–November (SON), rainfall reduces to 268.9 mm, but temperatures begin to decline (Tmin = 15.26°C, Tmax = 31.24°C). Rainfall variability is moderate (CV = 32%), although temperatures stay constant with CVs below 6%. These data emphasize the unique seasonal trends in temperature and rainfall, with rainfall being the most variable component across all seasons.

Trend of Rainfall and Temperature in Lere

Annual Trend of Rainfall and Temperature in Lere

The annual trends of temperature and rainfall in Lere were analyzed using the Mann-Kendall and Seasonal Mann-Kendall trend tests. The result is shown in Table 5 and Figure 2.

Table 5: Annual Trend of Rainfall and Temperature in Lere

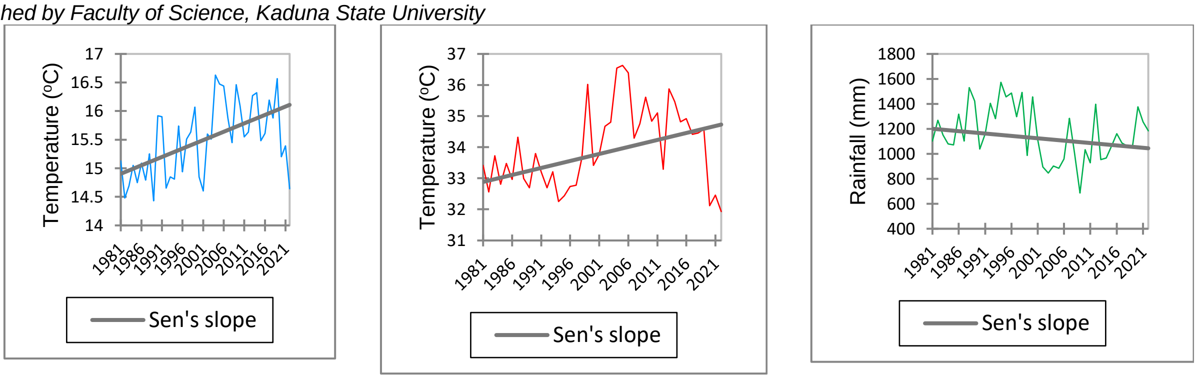
	Mann-Kendall			**Seasonal Mann-Kendall**		
	Tmin	**Tmax**	**Rainfall**	**Tmin**	**Tmax**	**Rainfall**
Kendall's tau	0.32	0.23	-0.15	0.18	0.18	-0.11
p-value (Two-tailed)	**0.002**	**0.033**	0.154	**< 0.0001**	**0.001**	**0.004**
Z	3.014	2.124	-1.431			
alpha	0.05	0.05	0.05	0.05	0.05	0.05
Sen's slope	0.029	0.045	-3.807	0.020	0.034	-0.158

Table 5 revealed the annual and seasonal trends of Tmin, Tmax, and rainfall time series. For annual trends, the Z value suggests positive trends in Minimum temperature (3.014, p = 0.002) and Tmax (0.23, p = 0.033), both statistically significant at the 0.05 alpha level. Conversely, rainfall indicates a negative trend (-1.431), but it is not statistically significant (p = 0.154). The Sen's slope revealed that Minimum temperature and Tmax were increasing by 0.029°C and 0.045°C annually. However, rainfall was decreasing annually by 3.807 mm. This agrees with the findings of Abubakar et al. (2024a) that rainfall is decreasing in the region, although the trend is not statistically significant.

Using the Seasonal Mann-Kendall, minimum and maximum temperatures had significantly increased trends (p < 0.0001 and p = 0.001, respectively). Rainfall had a decreasing trend (tau = -0.11), which was significant (p = 0.004). The Sen's slope revealed that the Minimum temperature was increasing by 0.020°C, and Tmax was also increasing by 0.034°C annually. However, rainfall was decreasing by 0.158 mm annually. These data reveal that temperature variables show continuous increasing trends on both annual and seasonal scales, while rainfall demonstrates a general diminishing tendency, notably at the seasonal level.

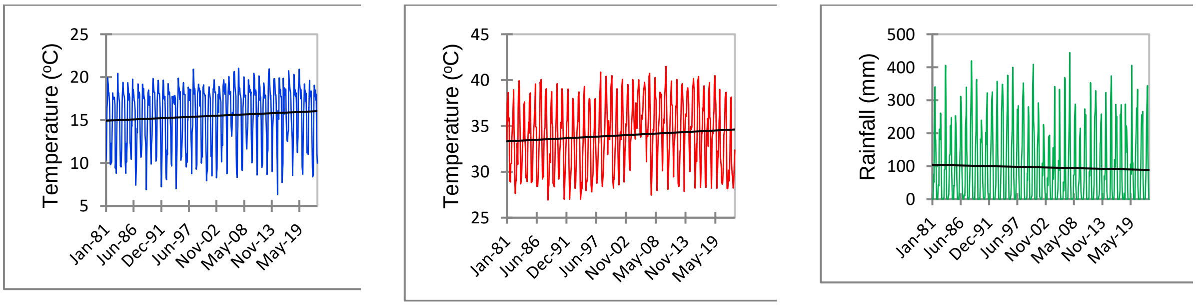
The results of this study revealed significantly increasing trends of minimum and maximum temperatures across the annual, seasonal, and monthly timescales. According to Singh et al. (2024), sustained warming could lead to increased crop thermal stress. Prolonged periods of high temperatures can damage crop growth, reduce yields, and potentially lead to crop failure, especially for heat-sensitive crops like maize and vegetables (Baffour-Ata et al., 2023; Kidane et al., 2025).

Furthermore, the observed unpredictability in rainfall and temperature patterns can disrupt standard planting and harvesting seasons. Farmers may fail to forecast appropriate planting periods, leading to reduced yields and economic losses (Guido et al., 2020). Furthermore, rising minimum and maximum temperatures offer favorable conditions for the spread of pests and diseases, further affecting crop health and yield (Malhi et al., 2021). Higher temperatures can lower animal output, including milk production, weight gain, and fertility (Thornton et al., 2022). The availability of pasture and water for animals may also drop due to droughts and lower rainfall.



a) Minimum Temperature b) Maximum Temperature c) Rainfall

Figure 2: Annual trends of a) Minimum temperature b) Maximum temperature and c) Rainfall



a) Minimum Temperature b) Maximum Temperature c) Rainfall

Figure 3: Monthly trends of a) Minimum temperature b) Maximum temperature and c) Rainfall

Monthly and Seasonal Trend of Rainfall and Temperature in Lere
This subsection examined the monthly trends of rainfall and minimum and maximum temperatures in Lere. The result is shown in Table 6.

Table 6: Monthly Trends of Rainfall, Minimum and Maximum Temperature

	Tmin	**Tmax**	**Rainfall**
Kendall's tau	0.070	0.070	-0.033
S	8875.00	8880.00	-4155.00
Var(S)	14266861.67	14266992.00	14181804.33
p-value (Two-tailed)	**0.019**	**0.019**	0.270
Z	2.3494	2.3507	-1.1031
alpha	0.05	0.05	0.05
Sens Slope	0.0019	0.0026	0.0000

Table 6 presents the results of the Mann-Kendall trend tests for Minimum temperature, Tmax, and rainfall. The Z- Z-value for Minimum temperature was 2.35, while Tmax was 2.35, indicating increasing trends. Both trends are statistically significant at a 0.05 alpha level (p = 0.019). Rainfall (Z = -1.10, p = 0.270) was also decreasing, but the trend was not significant. The Sen's slopes revealed a slight annual increase of 0.0019 for Minimum temperature and 0.0026 for Tmax. Rainfall had a Sen's slope of 0.0000.

Seasonal Trend of Rainfall and Temperature in Lere
This subsection examined the seasonal trends of rainfall and minimum and maximum temperatures in Lere. The seasons were divided into four, namely December-February (DJF), March-May (MAM), June-August (JJA) and September-November (SON). The result is shown in Table 7.

Table 7: Seasonal Trend of Rainfall and Temperature in Lere

Season		**p-value**	**Z**	**Sens Slope**
DJF	Tmin	0.31	1.02	0.02
	Tmax	**0.02**	2.34	0.03
	Rainfall	0.23	-1.20	0.00
MAM	Tmin	**0.00**	2.85	0.04
	Tmax	**0.02**	2.38	0.04
	Rainfall	0.30	-1.04	-1.12

JJA	Tmin	**0.02**	2.35	0.01
	Tmax	0.21	1.25	0.04
	Rainfall	0.21	-1.26	-2.60
SON	Tmin	**0.00**	3.23	0.04
	Tmax	**0.05**	1.97	0.04
	Rainfall	0.68	-0.41	-0.34

Table 7 revealed the results of the Mann-Kendall trend test for Minimum temperature, Tmax, and Rainfall across December–February, March-May, June–August, and September–November. In DJF, the Minimum temperature shows no significant trend (p = 0.31, Z = 1.02), and Sen's slope suggests that it was increasing at 0.02°C per annum. Tmax indicates a statistically significant increasing trend (p = 0.02, Z = 2.34), increasing by 0.03°C per annum, indicating a warming trend. Rainfall was decreasing, but the was not significant (p = 0.23, Z = -1.20), with the Sen's slope of 0.00 mm annually.

In MAM, Minimum temperature and Tmax all revealed significantly increasing trends (p = 0.00, Z = 2.85 for Minimum temperature; p = 0.02, Z = 2.38 for Tmax). Both were annually increasing by 0.04°C. This indicates a significant warming trend during the spring season. Rainfall, however, does not display a significant trend (p = 0.30, Z = -1.04) and has a downward slope of -1.12 mm per year, indicating a minor but statistically insignificant reduction in rainfall throughout this period.

Throughout JJA, Minimum temperature reveals a significant increase (p = 0.02, Z = 2.35) with an insignificant Sen's slope of 0.01°C every year, implying moderate warming. Tmax demonstrates a non-significant trend (p = 0.21, Z = 1.25) although still has a positive slope of 0.04°C each year. Rainfall, on the other hand, indicates a non-significant decreasing trend (p = 0.21, Z = -1.26) with a somewhat high downward slope of -2.60 mm every year, indicating lower rainfall.

In SON, Minimum temperature and Tmax both indicate significantly increasing trends (p = 0.00, Z = 3.23 for Minimum temperature; p = 0.05, Z = 1.97 for Tmax), exhibiting Sen's slopes of 0.04°C annually. This underlines a steady increase throughout the autumn season. Rainfall in SON does not exhibit a significant trend (p = 0.68, Z = -0.41) and has a modest downward slope of -0.34 mm every year, indicating negligible changes in rainfall patterns. Overall, these findings demonstrate a persistent warming trend throughout seasons for Minimum temperature and Tmax, but precipitation trends are typically non-significant, with some signs of lower precipitation in MAM and JJA.

Although the decrease in rainfall was not significant, the observed trends suggest reduced and unpredictable rainfall, which may lead to inadequate soil moisture during important growing periods (Nielsen et al., 2024). This result is similar to the findings of Abubakar et al. (2024a) which revealed decreasing rainfall in the northern part of Kaduna State. This can damage rainfed agriculture, the region's major farming system.

Meteorological Drought in Lere

Assessment of Meteorological Drought in Lere

The occurrence and intensities of meteorological droughts Lere were examined on 3, 6, 9, and 12-month cycles using SPEI. For this study, only severe and extreme droughts were counted. The result is shown in Table 8.

Table 8: Meteorological Drought in Lere

Drought Index	**SPEI-3**	**SPEI-12**
Starting dates	3/98, 11/01, 08/04, 12/04, 12/05, 06/06, 03/07, 09/09, 01/10, 01.14, 05/15, 10/17	01/05, 04/05, 09/05, 09/09, 06/15,
Ending dates	4/98, 12/01, 10/04, 03/05, 01/06, 08/06, 04/07, 11/09, 05/10, 02/14, 07/15, 01/18	03/05, 08/05, 10/06, 07/10, 07/15,
Mean Intensity, M	-1.89788	-1.674
Maximum Intensity, Mmax	-2.762	-1.975
Duration, D (months)	25	30

Table 8 revealed the magnitude of droughts on 3-month and 12-month time scales with an emphasis on their beginning and ending dates, mean intensity, maximum intensity, and length. Shorter-term droughts are represented by the SPEI-3 index, which has beginning and ending dates between March 1998 and January 2018. Its maximum intensity (Mmax) was -2.762, indicating the most intense drought conditions throughout the recorded time, while its mean intensity (M) was -1.89788, suggesting rather severe droughts. The overall duration (D) for all SPEI-3 incidents indicates a comparatively shorter cumulative impact, which adds up to 25 months.

The SPEI-12 index, on the other hand, which gauges longer-term drought patterns, has beginning and ending dates that cover January 2005 through July 2015. It displays somewhat less severe conditions with a maximum intensity (Mmax) of -1.975 and a mean intensity (M) of -1.674. Because SPEI-12 focuses on longer durations of water scarcity, its cumulative duration (D) for drought occurrences is 30 months. The comparison highlights how these indices provide information on both short-term and long-term hydrological stress by capturing various drought intensities and temporal scales. The persistent and harsh droughts detected by the SPEI indices suggest significant water deficits that can impede irrigation operations, limit the availability of drinking water for livestock, and increase desertification (Rahman et al., 2025). These variables collectively reduce agricultural productivity by affecting soil moisture (Abubakar et al., 2024b).

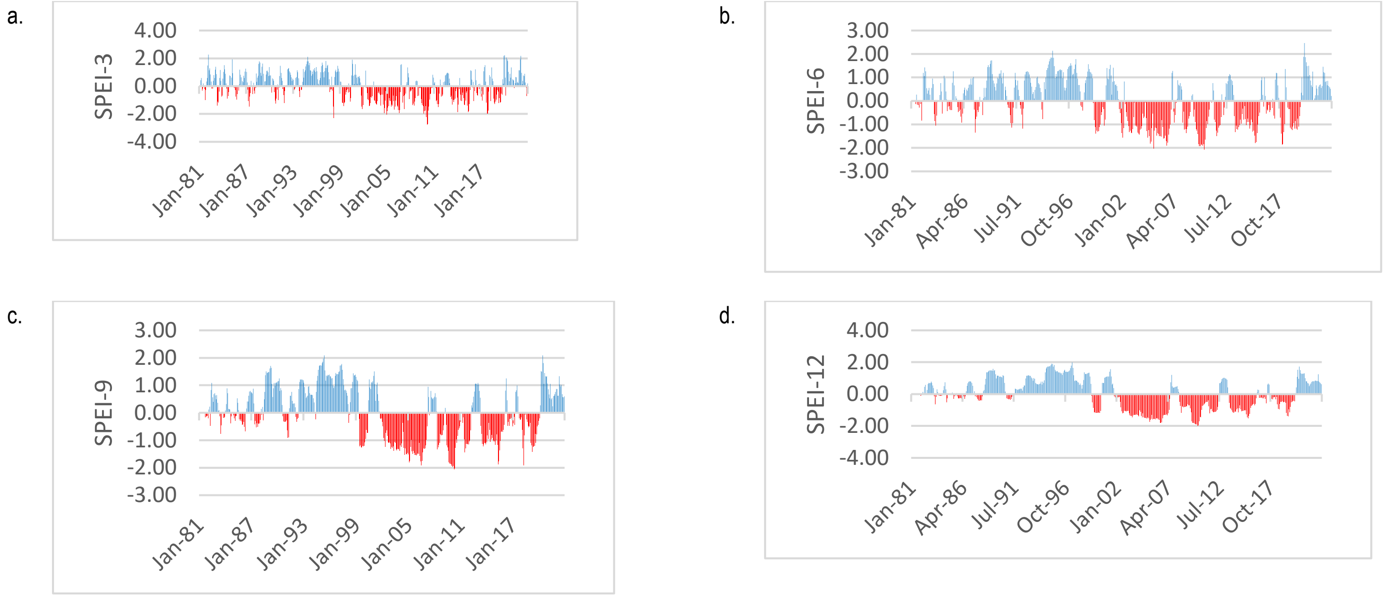


Figure 4: Seasonal Mann-Kendall Trend Test

Trend of Meteorological Drought in Lere

Trends of meteorological droughts Lere were examined for the 3, 6, 9, and 12-month cycles using the Mann-Kendall trend test. The result is shown in Table 9.

Table 9: Trends of Meteorological Drought in Lere

	SPEI-3	**SPEI-6**	**SPEI-9**	**SPEI-12**
Kendall's tau	-0.152	-0.142	-0.148	-0.162
Z	-5.095	-4.784	-4.960	-5.426
p-value (Two-tailed)	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**
alpha	0.05	0.05	0.05	0.05
Sen's Slope	-0.017	-0.002	-0.002	-0.002

Table 9 presents the results of trend analysis for four variations of the Standardized Precipitation-Evapotranspiration Index (SPEI) over different time scales (3, 6, 9, and 12 months). Kendall's tau values for all indices are negative, ranging from -0.142 to -0.162, indicating a consistent declining trend in drought conditions across all time scales. The Z-values are highly negative, with values between -4.784 and -5.426, further supporting the presence of statistically significant downward trends. The p-values, all less than 0.0001, confirm that these trends are highly significant, well below the alpha threshold of 0.05.

The Sen's slope, which measures the rate of change, is negative for all indices, with values ranging from -0.017 for SPEI-3 to -0.002 for SPEI-6, SPEI-9, and SPEI-12. This suggests that shorter time scales (SPEI-3) exhibit a more pronounced decline in drought-related parameters compared to longer time scales. Overall, the analysis indicates a statistically significant, persistent decreasing trend in drought conditions over time, particularly for shorter-term indices. Crop production and quality would probably increase if the trends of droughts decreased. More water availability for crops will lessen stress and promote greater growth and development (Orimoloye, 2022).

Conclusion

This study's findings underscore the escalating climate variability in Lere, marked by increasing minimum and maximum temperatures and a decreasing trend in precipitation. The notable increases in temperature, recorded annually and seasonally, signify a warming environment that may have substantial consequences for agriculture, water resources, and local livelihoods. Despite modest variability in rainfall and a non-significant decline, the diminishing trends in meteorological drought indicate an increased probability of extended dry spells, potentially intensifying water stress in the region. These patterns correspond with extensive climate change forecasts, highlighting the necessity for adaptive methods to alleviate the detrimental impacts of rising temperatures and variable precipitation patterns.

In light of the documented climatic trends, proactive steps are essential to bolster resilience in Lere. The increased frequency and intensity of meteorological droughts require better water management strategies, including rainwater harvesting and efficient irrigation systems, to preserve agricultural productivity. The study recommends that stakeholders should improve climate-smart agriculture practices while boosting afforestation activities to reduce the impacts of rising temperatures. Moreover, ongoing surveillance of climatic variables through sophisticated geospatial and statistical methodologies will be crucial for formulating evidence-based adaptation programs. Future studies should investigate the socio-economic effects of climatic variability in Lere, ensuring that local people possess viable ways to adapt to the changing environment.

Acknowledgement

We would like to thank the National Space Administration (NASA) for providing the MERRA-2 reanalysis data. We wish to also thank the Climate Research Group (CRG) of Kaduna State University for supporting this study.

REFERENCES

Abaje, I. B., & Giwa, P. N. (2010). Flood Risk Assessment and Vulnerability in Kafanchan Town, Jema'a Local Government Area of Kaduna State, Nigeria. *International Journal of Sustainable Development*, *3*(3), 94–100.

Abaje, I. B., & Oladipo, E. O. (2019). Recent Changes in the Temperature and Rainfall Conditions. *Ghana Journal of Geography*, *11*(2), 127–157.

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research 2022 29:28*, *29*(28), 42539–42559. https://doi.org/10.1007/S11356-022-19718-6

Abubakar, M. L., Abdussalam, A. F., & Ahmed, M. S. (2024). Assessment of Agricultural Drought Using VCI and VHI in Niger River Basin, Nigeria. *Geosfera Indonesia*, *9*(2), https://jurnal.unej.ac.id/index.php/GEOSI/Accepted. https://jurnal.unej.ac.id/index.php/GEOSI/Accepted

Abubakar, M. L., Abdussalam, A. F., Ahmed, M. S., & Wada, A. I. (2024). Spatiotemporal variability of rainfall and drought characterization in Kaduna, Nigeria. *Discover Environment*, *2*, 72. https://doi.org/10.1007/s44274-024-00112-7

Abubakar, M. L., Ahmed, M. S., Abdussalam, A. F., & Mohammed, S. (2025). Meteorological drought and long - term trends and spatial variability of rainfall in the Niger River Basin , Nigeria. *Environmental Science and Pollution Research*, *0123456789*. https://doi.org/10.1007/s11356-025-36048-5

Adamgbe, E. T., Belonwu, M. C., Ochu, E. R., & Okafor, I. I. (2020). Analysis of the Impact of Central Bank of Nigeria's Agricultural Intervention Funds on the Economy. *CBN Economic and Financial Review*, *58*(1), 57–80.

Adeleke, M. L., Al-Kenawy, D., Nasr-Allah, A. M., Murphy, S., El-Naggar, G. O., & Dickson, M. (2018). Fish Farmers' Perceptions, Impacts and Adaptation on/of/to Climate Change in Africa (The Case of Egypt and Nigeria). *Climate Change Management*, 269–295. https://doi.org/10.1007/978-3-319-72874-2_16

Ahmed, M. S., Abubakar, M. L., Lawal, I. A., & Richifa, K. I. (2024). Influence of Extreme Temperature on Adverse Pregnancy Outcomes in Kaduna State, Nigeria. *Science World Journal*, *19*(2), 409–417. https://doi.org/10.4314/swj.v19i2.17

Akinsanola, A. A., & Ogunjobi, K. O. (2015). Recent homogeneity analysis and long-term spatio-temporal rainfall trends in Nigeria. *Theoretical and Applied Climatology*, *128*(1–2), 275–289. https://doi.org/10.1007/s00704-015-1701-x

Alexandersson, H. (1986). A homogeneity test applied to precipitation data. *Journal of Climatology*, *6*(6), 661–675. https://doi.org/10.1002/JOC.3370060607

Amaechina, E. C., Anugwa, I. Q., Agwu, A. E., Ifelunini, A. I., Umeonuora, T. G., & Okwor, C. A. (2022). Assessing climate change-related losses and damages and adaptation constraints to address them: Evidence from flood-prone riverine communities in Southern Nigeria. *Environmental Development*, *44*, 100780. https://doi.org/10.1016/j.envdev.2022.100780

Amare, M., & Balana, B. (2023). Climate change, income sources, crop mix, and input use decisions: Evidence from Nigeria. *Ecological Economics*, *211*, 107892. https://doi.org/10.1016/j.ecolecon.2023.107892

Anderson, T. W., & Darling, D. A. (1954). A Test of Goodness of Fit. *Journal of the American Statistical Association*, *49*(268), 765–769. https://doi.org/10.1080/01621459.1954.10501232

Asfaw, A., Simane, B., Hassen, A., & Bantider, A. (2018). Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. *Weather and Climate Extremes*, *19*, 29–41. https://doi.org/10.1016/J.WACE.2017.12.002

Ayanlade, A., Oluwaranti, A., Ayanlade, O. S., Borderon, M., Sterly, H., Sakdapolrak, P., Jegede, M. O., Weldemariam, L. F., & Ayinde, A. F. O. (2022). Extreme climate events in sub-Saharan Africa: A call for improving agricultural technology transfer to enhance adaptive capacity. *Climate Services*, *27*, 100311. https://doi.org/10.1016/J.CLISER.2022.100311

Baffour-Ata, F., Tabi, J. S., Sangber-Dery, A., Etu-Mantey, E. E., & Asamoah, D. K. (2023). Effect of rainfall and temperature variability on maize yield in the Asante Akim North District, Ghana. *Current Research in Environmental Sustainability*, *5*, 100222. https://doi.org/10.1016/J.CRSUST.2023.100222

Beguería, S., & Vicente-Serrano, S. M. (2011). SPEI: Calculation of the Standardized Precipitation-Evapotranspiration Index. In *CRAN: Contributed Packages*. https://doi.org/10.32614/CRAN.package.SPEI

Bolan, S., Padhye, L. P., Jasemizad, T., Govarthanan, M., Karmegam, N., Wijesekara, H., Amarasiri, D., Hou, D., Zhou, P., Biswal, B. K., Balasubramanian, R., Wang, H., Siddique, K. H. M., Rinklebe, J., Kirkham, M. B., & Bolan, N. (2024). Impacts of climate change on the fate of contaminants through extreme weather events. *Science of The Total Environment*, *909*, 168388. https://doi.org/10.1016/j.scitotenv.2023.168388

Bosilovich, M. G., Robertson, F. R., Takacs, L., Molod, A., & Mocko, D. (2017). Atmospheric water balance and variability in the MERRA-2 reanalysis. *Journal of Climate*, *30*(4), 1177–1196. https://doi.org/10.1175/JCLI-D-16-0338.1

Chen, S., Zhang, L., Liu, X., Guo, M., & She, D. (2018). The Use of SPEI and TVDI to Assess Temporal-Spatial Variations in Drought Conditions in the Middle and Lower Reaches of the Yangtze River Basin, China. *Advances in Meteorology*, *2018*. https://doi.org/10.1155/2018/9362041

David, A., Leibbrandt, M., Ranchhod, V., & Yasser, R. (Eds.). (2025). *Inequalities in Sub-Saharan Africa: Multidimensional Perspectives and Future Challenges*. World Bank, Washington, DC. https://doi.org/10.1596/978-1-4648-2150-9

Durdu, Ö. F. (2010). Effects of climate change on water resources of the Büyük Menderes river basin, Western Turkey. *Turkish Journal of Agriculture and Forestry*, *34*(4), 319–332. https://doi.org/10.3906/tar-0909-402

Furtak, K., & Wolińska, A. (2023). The impact of extreme weather events as a consequence of climate change on the soil moisture and on the quality of the soil environment and agriculture – A review. *CATENA*, *231*, 107378. https://doi.org/10.1016/J.CATENA.2023.107378

GRID3 - Nigeria. (2024). *Geo-Referenced Infrastructure and Demographic Data for Development*. National Space Research and Development Agency. https://grid3.gov.ng/dataset/kaduna-operational-ward-boundaries/resources

Guido, Z., Zimmer, A., Lopus, S., Hannah, C., Gower, D., Waldman, K., Krell, N., Sheffield, J., Caylor, K., & Evans, T. (2020). Farmer forecasts: Impacts of seasonal rainfall expectations on agricultural decision-making in Sub-Saharan Africa. *Climate Risk Management*, *30*, 100247. https://doi.org/10.1016/j.crm.2020.100247

Hamed, K. H. (2008). Trend detection in hydrologic data: The Mann–Kendall trend test under the scaling hypothesis. *Journal of Hydrology*, *349*(3–4), 350–363. https://doi.org/10.1016/J.JHYDROL.2007.11.009

Huntington, T. G. (2006). Evidence for intensification of the global water cycle: Review and synthesis. *Journal of Hydrology*, *319*(1–4), 83–95. https://doi.org/10.1016/j.jhydrol.2005.07.003

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

IPCC. (2022). *IPCC Sixth Assessment Report: Summary for Policymakers*.

Kabbilawsh, P., Kumar, D. S., & Chithra, N. R. (2023). Assessment of temporal homogeneity of long-term rainfall time-series datasets by applying classical homogeneity tests. *Environment, Development and Sustainability*, 1–45. https://doi.org/10.1007/S10668-023-03310-0/METRICS

Kendall, M. G. (1948). *Rank Correlation Methods.* (4th Editio). Charles Griffin.

Kidane, B., Urugo, M. M., Hirpha, H. H., Paulos, T., Hundea, W., & Tessema, F. (2025). Nutritional challenges of staple crops due to increasing atmospheric carbon dioxide levels: Case of Sub-Saharan Africa. *Journal of Agriculture and Food Research*, *19*, 101592. https://doi.org/10.1016/j.jafr.2024.101592

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. *Sustainability*, *13*(3), 1318. https://doi.org/10.3390/su13031318

Mann, H. B. (1945). Nonparametric Tests Against Trend. *Econometrica*, *13*(3), 245. https://doi.org/10.2307/1907187

Mohsenipour, M., Shahid, S., Chung, E. sung, & Wang, X. jun. (2018). Changing Pattern of Droughts during Cropping Seasons of Bangladesh. *Water Resources Management*, *32*(5), 1555–1568. https://doi.org/10.1007/s11269-017-1890-4

Musa, K., & Abubakar, M. L. (2024). Monitoring urban growth and landscape fragmentation in Kaduna, Nigeria, using remote sensing approach. *Journal of Degraded and Mining Lands Management*, *12*(1), 6757–6769. https://doi.org/10.15243/jdmlm.2024.121.6757

Nath, H., Adhikary, S. K., Nath, S., Kafy, A. Al, Islam, A. R. M. T., Alsulamy, S., Khedher, K. M., & Shohan, A. A. A. (2024). Long-term trends and spatial variability in rainfall in the southeast region of Bangladesh: implication for sustainable water resources management. *Theoretical and Applied Climatology*, *0123456789*. https://doi.org/10.1007/s00704-024-04843-8

Nielsen, M., Cook, B. I., Marvel, K., Ting, M., & Smerdon, J. E. (2024). The Changing Influence of Precipitation on Soil Moisture Drought With Warming in the Mediterranean and Western North America. *Earth's Future*, *12*(5). https://doi.org/10.1029/2023EF003987

Omotoso, A. B., Letsoalo, S., Olagunju, K. O., Tshwene, C. S., & Omotayo, A. O. (2023). Climate change and variability in sub-Saharan Africa: A systematic review of trends and impacts on agriculture. *Journal of Cleaner Production*, *414*, 137487. https://doi.org/10.1016/j.jclepro.2023.137487

Orimoloye, I. R. (2022). Agricultural Drought and Its Potential Impacts: Enabling Decision-Support for Food Security in Vulnerable Regions. *Frontiers in Sustainable Food Systems*, *6*. https://doi.org/10.3389/fsufs.2022.838824

Patakamuri, S. K., Muthiah, K., & Sridhar, V. (2020). Long-Term Homogeneity, Trend, and Change-Point Analysis of Rainfall in the Arid District of Ananthapuramu, Andhra Pradesh State, India. *Water*, *12*(1), 211. https://doi.org/10.3390/W12010211

Pettitt, A. N. (1979). A Non-Parametric Approach to the Change-Point Problem. *Applied Statistics*, *28*(2), 126. https://doi.org/10.2307/2346729

Rahman, G., Jung, M.-K., Kim, T.-W., & Kwon, H.-H. (2025). Drought impact, vulnerability, risk assessment, management and mitigation under climate change: A comprehensive review. *KSCE Journal of Civil Engineering*, *29*(1), 100120. https://doi.org/10.1016/j.kscej.2024.100120

Ray, D. K., West, P. C., Clark, M., Gerber, J. S., Prishchepov, A. V., & Chatterjee, S. (2019). Climate change has likely already affected global food production. *PLOS ONE*, *14*(5), e0217148. https://doi.org/10.1371/JOURNAL.PONE.0217148

Singh, R., Sah, S., Das, B., Jaiswal, R., Singh, A. K., Reddy, K. S., & Pathak, H. (2024). Innovative and polygonal trend analysis of temperature in agro climatic zones of India. *Scientific Reports*, *14*(1), 29914. https://doi.org/10.1038/s41598-024-78597-8

Tajudeen, T. T., Omotayo, A., Ogundele, F. O., & Rathbun, L. C. (2022). The Effect of Climate Change on Food Crop Production in Lagos State. *Foods*, *11*(24). https://doi.org/10.3390/FOODS11243987/S1

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geographical Review*, *38*(1), 55–94.

Thornton, P., Nelson, G., Mayberry, D., & Herrero, M. (2022). Impacts of heat stress on global cattle production during the 21st century: a modelling study. *The Lancet Planetary Health*, *6*(3), e192–e201. https://doi.org/10.1016/S2542-5196(22)00002-X

Uchenna, E. I., Olisaemeka, O., & Lekwot, V. E. (2012). an Appraisal of Urban Sprawl / Growth Pattern in Saminaka Town , Lere Local Government Area of Kaduna State , Nigeria From 1986 To 2006. *Global Advanced Research Journal of Geography and Regional Planning*, *1*(2), 45–49.

van der Wiel, K., & Bintanja, R. (2021). Contribution of climatic changes in mean and variability to monthly temperature and precipitation extremes. *Communications Earth & Environment 2021 2:1*, *2*(1), 1–11. https://doi.org/10.1038/s43247-020-00077-4

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. *Journal of Climate*, *23*(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Vihi, S. K., Jesse, B., Dalla, A. A., & Sadiku, Y. (2018). Analysis of Farm Risk and Coping Strategies among Maize Farmers in Lere Local Government Area of Kaduna State, Nigeria. *Asian Journal of Research in Agriculture and Forestry*, *1*(3), 1–10.

Yozgatligil, C., & Yazici, C. (2016). Comparison of homogeneity tests for temperature using a simulation study. *International Journal of Climatology*, *36*(1), 62–81. https://doi.org/10.1002/joc.4329

Zhou, C., van Nooijen, R., Kolechkina, A., & Hrachowitz, M. (2019). Comparative analysis of nonparametric change-point detectors commonly used in hydrology. *Hydrological Sciences Journal*, *64*(14), 1690–1710. https://doi.org/10.1080/02626667.2019.1669792