Establishing Climate Variability and Change Using Rainfall, Temperature and Wind as proxies; Evidence from Northwestern Nigeria

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Abstract

This study attempts to establish climate change and variability through trend analysis using rainfall, temperature, and wind as proxies. This research intends to determine the geographical and earthly trends of the chosen atmospheric parameters. Data analysis was performed applying the Non-parametric Test, Mann-Kendall Trend Test, and Sen’s Slope Estimator. The statistics were prepared and examined using version 29 of the statistical package for social sciences (SPSS) software. Furthermore, Content Analysis (CA) was employed to compare the respondents' perceptions of atmosphere deviation and alteration with the climatic data. The results showed the occurrence of challenges linked to disproportionate rainfall connected to heightened climate variability. This was substantiated through the statistically significant spatial variations in rainfall, temperature, and wind speed, although at different scales. Generally, the results displayed a latitudinal and sequential inclination of rainfall, temperature, and wind speed. However, the time-based variability is more obvious than the longitudinal changes. Yet, this does not mean ignoring the spatial variations the fact that it will affect farmers' livelihoods at different proportion to the magnitude of the horizontal deviations within the study area. Though rainfall plays a significant position in global warming studies due to its influence on climate regulation and food production. Yet the significance of wind and temperature in the climate change mechanism cannot be overlooked considering their crucial roles via evaporation and transpiration.

Key Words; *Climate Variability, Northwestern, Nigeria, Rainfall, Temperature*

1. Introduction

Climatological studies reported a global raise in temperatures and variations in precipitation and wind systems in the coming decades (Dan’azumi & Ibrahim, 2023; Zhao et al., 2024). Thus, it is expected globally that various consequences of climate change, such as increasing incidence of heavy rains and erratic precipitations, uncertain onset and cessation of rainy periods, and rising air temperatures will be experienced in the different part of the world. These vagaries in some of the climatic elements terrorized the ecosystems, food production, livelihoods, and infrastructure (Tanko, 2013; Zhao et al., 2024). The changes are not consistent across the country; some regions are heavily affected and therefore more susceptible to climate change than others. It is one of the many difficulties encountered when attempting to differentiate between normal short-term fluctuations and indications of climate change (Roy et al., 2022) that local weather can differ considerably daily, seasonally, and anually.

Climate variability, particularly in terms of rainfall, is a significant feature of the Sahelian atmosphere. Over the past 40 years since 1969, there have been marked declines in average yearly precipitation across the area (Ledda et al., 2024; Pareek, Dhankher, & Foyer, 2020). The Intergovernmental Panel on Climate Change reports that the Sahel region experienced a rainfall reduction of 29–49% from 1968 to 1997 compared to the baseline period of 1931–1960 (O'Neill et al., 2017; Pachauri et al., 2014).

Numerous research have been performed on the forecasting of climatic variability; (Ghalehteimouri, Ros, Rambat, & Nasr, 2024; Njuguna, Onyango, Githaiga, Gituru, & Yan, 2020) examine geographical and earthly patterns of rainstorm variations in Kenya (Mwangi, Julich, Patil, McDonald, & Feger, 2016).Trend Analysis of Droughts during Crop Growing Seasons of Nigeria (Dan’azumi & Ibrahim, 2023). Spatial and Temporal Temperature Trends in Nigeria, 1901-2000 (Umar, Ramli, Aris, Jamil, & Tukur, 2019).

“Detection of Rainfall Trend in Northern Nigeria from 1970 to 2012,” (2025, Sasanya, Adesogan, & Ademola). Examination of changes in rainfall amounts across the northern region of Nigeria (Sawa & Adebayo, 2011). Fluctuation of temperature in Zaria, Northern Nigeria (Ndabula et al., 2013).

The significant climatic variables of rainfall and temperature, commonly analyzed as observed in various studies by numerous scholars, have undergone extensive review over time. Other factors, such as the interplay of wind, rain, and temperature, have yet to be investigated. This research aims to conduct a trend analysis of these variables to reveal the presence of climate variability and change in Northern Nigeria.

2. Material and Method

The study is positioned in the north-western region of the land, wrapped in the middle of Latitudes 11°N to 13°N and Longitudes from 80°E to 10.150°E. This area covered 24,742 km^2 in Jigawa State of Nigeria. According to the 2012 data from the National Bureau of Statistics (Dan'azumi & Ibrahim, 2023), it consists of 27 local administrations and has a population of 4,361,002 people. The State shares its boundaries with Kano and Katsina to the west, Bauchi State to the east, and Yobe State to the northeast. According to the National Population Commission (NPC) of Nigeria, 2009 (White, Uljee, & Engelen, 2012), it splits an international boundary to the north with the Zinder region of the Republic of Niger, as showcase in Figure 1.

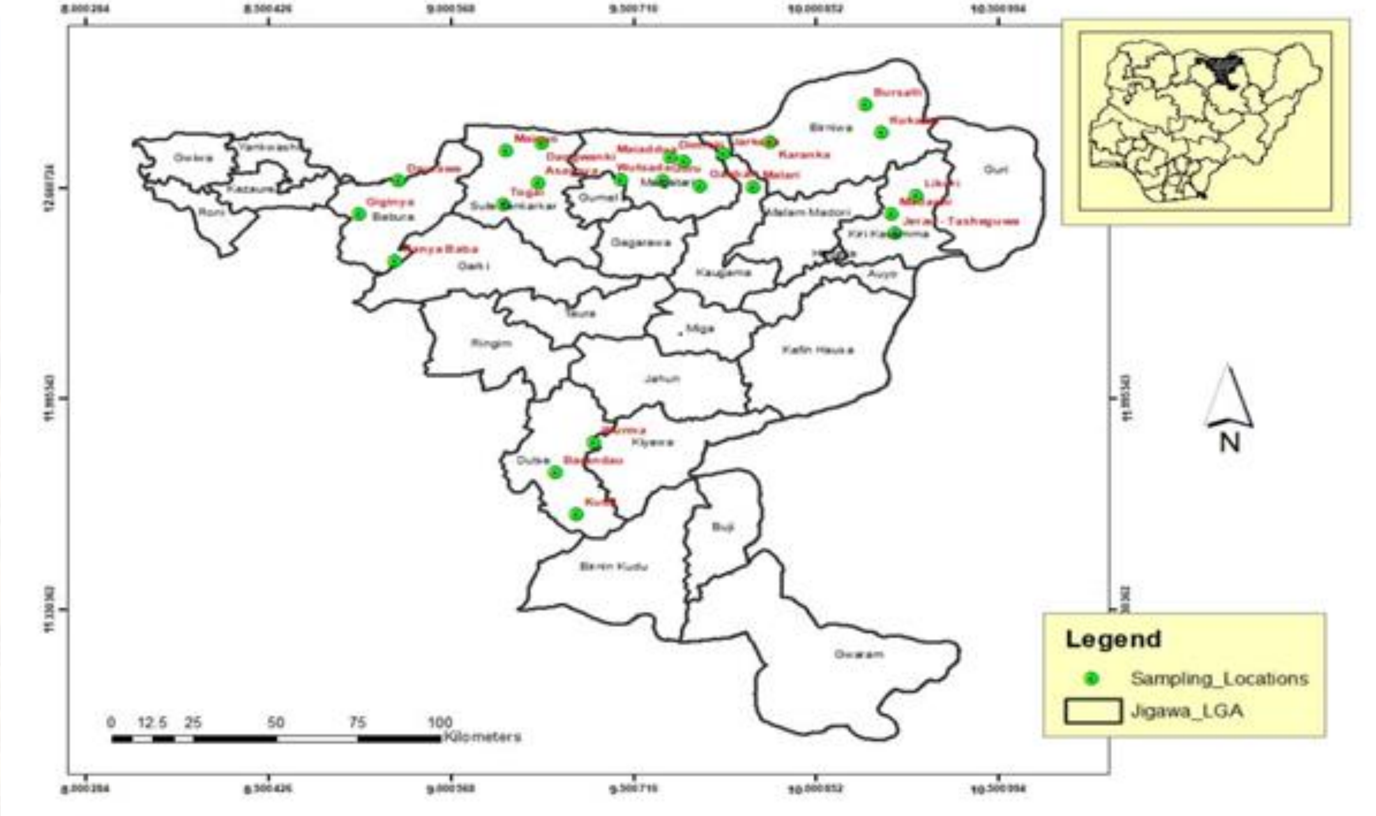

Figure 1 Map of Jigawa state showing the Study Area
Source: Jigawa State Agricultural and Rural Development Authority 2020

The land in this area is characterized by rolling terrain, and in some places within the State, there are sand ridges of various dimensions that stretch over diverse kilometers. In the south of Jigawa lies the Basemen Complex, while sedimentary rock from the Chad formation is located in the northeast (Ujoh, 2014; Umar et al., 2025)

The climate of the area is controlled by dual main amount of air. They are desertic and sandy tropical-continental (cT) air mass from the Sahara Desert, as well as the warm tropical-maritime (mT) air mass that comes from the Atlantic Ocean. These two air masses intermingle to produce two distinctive seasons: the rainy and drier seasons in the area.

The year consists of two main seasons. Humid southwesterly breezes from the Atlantic coast of West Africa cause the monsoon season, which generally lasts from May to September and has included October in recent years. Mustapha et al. (2014) report that the estimated annual rainfall varies between 600 mm and 1,000 mm, with a recent average of around 650 mm.

In some regions of the state, rain is customary for roughly five months. For the rest of the year, a dry season called “Harmattan” dominates, driven by dusty winds from the Sahara desert coming in from the northeast. Umar & Bako (2019) report that average monthly temperatures range from 19 to 35ºC, with a peak of 42ºC throughout the monsoon season. In the dry season of year maximum and minimum varies between 33ºC and 13ºC respectively. The average monthly temperatures is between 36°C during the day, and 22°C at night (Umar, Umar, & Tukur, 2017). About four (4) distinct seasons are noticeable: the dry and hot (Bazara), the dry and cool (Rani), the dry and warm (Kaka), and the wet and warm (Damina) seasons (Umar, Ramli, Tukur, Jamil, & Zaudi, 2021).

This study utilized three sets of climatic data that were sourced. The initial set comprises noticed statistics gathered from the general stations of KNARDA (Kano State Agricultural and Rural Development Authority). Over the historical period from 1981 to 1991, eleven (11) zones of the meteorological stations were taken into account. The second data set was gathered from the synoptic stations of JARDA (Jigawa State Agricultural and Rural Development Authority) covering the historical period from 1992 to 2020.

The climatic data gathered from KNARDA and JARDA pertained to rainfall and temperature. To supplement the necessary data for this study, a third set of climatic statistics from MERRA-2 (Modern Era Reanalysis for Research and Applications Version 2) was sourced available at https://gmao.gsfc.nasa.gov/reanalysis/ MERRA-2/ from NASA (National Aeronautic and Space

Administration) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (Power).

Figure 1 provides a brief overview of their location. Data on rainfall, temperature, and wind speed were gathered monthly from NASA. Time series statistics were selected grounded in the standard of the statistics gathered from different stations. Nonetheless, only the National Aeronautics and Space Administration (NASA) offered comprehensive data on rainfall, temperature, and wind speed for the study area between 1981 and 2020. Data missing from observations have been completed with the cross-validation approach as per Ioannis (2017) (Ishaku, Umaru, Adebayo, Löwner, & Okhimamhe, 2024).

The analyses of this research were performed using the Non-parametric Test, Mann-Kendall Test with XLSTAT 2018, and Sen’s Slope Estimator under Time Series. The Statistical Package for the Social Sciences (SPSS) Version 29 software was utilized to process and analyze the statistics. Content analysis was applied to examine the connection between the climate data and the perception of respondents regarding climate variability and change.

3. Results and Discussion

3.1 Result for Rainfall Analyses

Table 1 illustrates the outcomes of the statistical analysis conducted on rainfall data from the study area covering the years 1981 to 2020. In Birniwa, the average annual rainfall amounted to 671.6 mm, with recorded values vary from a lowest of 316.8 mm to a highest of 989.5 mm. The rainfall data for Dutse between 1981 and 2020 shows that the average was 800.5 mm, with a minimum of 263.2 mm and a maximum of 1466.7 mm. The results from Kaugama show similar statistics, with a mean of 700.7 mm, a minimum of 260.9 mm, and a maximum of 1348.1 mm.

Kirikasamma had an average of 594.7 mm, with a minimum of 357.2 mm and a maximum of 969.2 mm. According to the Maigatari results, the average annual precipitation for this timeframe was 512.1 mm, ranging from a low of 346.6 mm to a high of 935.0 mm. The Sule-Tankarkar findings indicated that the average annual precipitation was 604.1 mm, ranging from a minimum of 328.9 mm to a maximum of 1168.0 mm.

Table 1.Mean Rainfall Data

Statistic	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule Tankarkar
Nbr. of observations	40	40	40	40	40	40
Minimum	316.8	263.2	260.9	357.2	346.6	328.9
Maximum	989.5	1466.7	1348.1	969.2	935.0	1168.0
Range	672.60	1203.51	1087.22	612.01	588.440	839.13
Mean	671.6	800.5	700.7	594.7	512.1	604.1
Variance (n-1)	35136.21	73884.61	51764.03	15491.94	14403.67	22280.72
Standard deviation	187.44	271.81	227.51	124.46	120.015	149.26
Variation coefficient	0.29	0.34	0.32	0.21	0.23	0.24
Skewness (Pearson)	-0.164	0.006	0.230	0.850	1.379	1.326
Kurtosis (Pearson)	-1.01	-0.52	0.14	1.021	2.395	3.661

Source: Field Study 2023

3.2 Result for Temperature Analyses

The results of temperature data evaluation from 1981 to 2020 are presented in Table 2. The average annual temperature in Birniwa was 30.5°C, with a lowest of 29.3°C and a highest of 31.9°C. In Dutse, the temperature data indicated an average of 26.9°C, a lowest value of 25.5°C, and a highest value of 28.5°C. While in Kaugama's the mean temperature values is 25.2°C, maximum is 27.39°C, and minimum is 23.5°C. The average temperature value for Kirikasamma was 28.00C, with a minimum of 27.10C and a maximum of 29.10C. The temperature analysis results for Maigatari revealed the average yearly temperature as 27.9°C, with a lowest of 27.1°C and a highest of 28.9°C. In Sule-Tankarkar's average yearly temperature was 27.7°C, with a lowest of 26.7°C and a highest of 28.9°C.

Table 2. Mean Temperature Data

Statistic	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule-Tankarkar
Nbr. of observations	40	40	40	40	40	40
Minimum	29.3	25.5	23.5	27.1	27.1	26.7
Maximum	31.9	28.5	27.4	29.1	28.9	28.9
Range	2.702	2.991	3.93	2.022	1.833	2.251
Mean	30.5	26.9	25.2	28.0	27.9	27.7
Variance (n-1)	0.596	0.764	1.343	0.315	0.242	0.358
Standard deviation	0.772	0.874	1.159	0.561	0.492	0.599
Variation coefficient	0.025	0.032	0.045	0.020	0.017	0.021
Skewness (Pearson)	0.286	0.280	0.481	0.297	0.064	0.210
Kurtosis (Pearson)	-1.030	-1.149	-0.918	-0.769	-0.710	-0.859

Source: Field Study 2023

3.3 Result for Wind Speed Analyses

The results for wind speed from 1981 to 2020 are illustrated in Table 5. Starting with Birniwa, the average wind speed was 1.4 m/s, while the minimum and maximum recorded values were 1.3 m/s and 1.5 m/s, independently. For Dutse, the average speed measured was 1.7 m/s, ranging from a minimum of 1.6 m/s to a highest of 1.8 m/s. The results further revealed that for Kaugama with average atmospheric speed of 1.5 m/s, with a minimum of 1.4 m/s and a maximum of 1.6 m/s. In Kirikasamma's the wind speed mean values was 2.4 m/s, with a lowest of 2.2 m/s and a highest of 2.6 m/s. The average annual wind speed at Maigatari was 3.5 m/s, with a lowest of 3.2 m/s and a hightest of 3.7 m/s. Lastly, in Sule-Tankarkar an average yearly wind speed of 2.5 m/s, with a lowest of 2.2 m/s and a highest of 2.7 m/s was reported (Table 3).

Table 3. Descriptive Statistics (Wind)

Statistic	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule_Tankarkar
Nbr. of observations	40	40	40	40	40	40
Minimum	1.3	1.6	1.4	2.2	3.2	2.2
Maximum	1.5	1.8	1.6	2.6	3.7	2.7
Range	0.207	0.218	0.218	0.351	0.517	0.446
Mean	1.4	1.7	1.5	2.4	3.5	2.5
Variance (n-1)	0.003	0.003	0.003	0.008	0.020	0.010
Standard deviation (n-1)	0.052	0.056	0.055	0.089	0.140	0.100
Variation coefficient	0.037	0.033	0.035	0.037	0.040	0.040
Skewness (Pearson)	-0.291	0.019	-0.231	-0.134	-0.228	-0.165
Kurtosis (Pearson)	-0.614	-0.596	-0.722	-0.721	-0.864	-0.285

Source: Field Study 2023

3.4 Trend Analysis

The Mann-Kendall (MK) test (Mann 1945, Kendall 1975, Gilbert 1987) is utilized to numerically assess provided the outcome variable has shown repetitive growth or reduce gradually. A monotonic movement, regardless of its direction, signifies that the variable frequently grows (or lessens) gradually, even if the trend is not straightforward. The MK test is best viewed as a tool for exploratory analysis, according to Hirsch, Slack, and Smith (1982). It's most appropriate uses are spotting stations with significant or substantial changes and measuring these changes.

Table 4. Mann-Kendall Trend Test Results

Location	***Variables***	**Kendall's Tau (Z)**	**S**	**Var (S)**	**P-Value**	**Sens' Slope**	**Hypothesis**
BIRNIWA	***Rainfall***	-0.274	-214.000	44.000	0.012	-7.432	H_0= Rejected
	Temperature	0.538	420.000	0.000	0.0001	0.048	H_0=Rejected
	Wind	-0.153	-119.000	73.667	0.169	-0.001	H_0=Accepted
DUTSE	***Rainfall***	-0.308	-240.000	44.000	0.005	-11.842	H_0=Rejected

	Temperature	0.494	385.000	7365.667	0.0001	0.052	H_0=Rejected
	Wind	44.000	-86.000	44.000	0.324	-7.206E-4	H_0=Accepted
KAUGAMA	***Rainfall***	-0.285	-222.000	44.000	0.009	-9.135	H_0= Rejected
	Temperature	-0.144	-112.000	0.000	0.197	-0.039	H_0=Accepted
	Wind	-0.183	-143.000	7365.667	0.098	-0.001	H_0=Accepted
MAIGATARI	***Rainfall***	-0.274	214.000	44.000	0.012	3.57	H_0= Rejected
	Temperature	0.241	188.000	0.000	0.029	0.018	H_0= Rejected
	Wind	-0.456	-143.000	7365.667	0.0001	-0.008	H_0=Rejected
KIRIKASAMMA	***Rainfall***	-0.062	-48.000	44.000	0.586	3.57	H_0=Accepted
	Temperature	0.379	296.000	0.000	0.000	0.028	H_0=Rejected
	Wind	-0.413	-322.000	44.000	0.000	-0.005	H_0=Rejected
SULE-TANKARKAR	***Rainfall***	-0.115	-90.000	44.000	0.302	-1.994	H_0=Accepted
	Temperature	0.372	290.000	0.000	0.001	0.028	H_0=Rejected
	Wind	-0.413	346.000	44.000	0.001	-0.005	H_0=Rejected

Source: Field Study 2023

This study utilized time series analysis of three meteorological parameters (Rainfall, Temperature, and Wind) over a 39-year period (1981–2020) in seven LGAs of Jigawa state to identify the trend and slope magnitude of the series. A statistical test (Mann-Kendall test) (Table 4) and Sen's Slope Estimator were utilized to analyze the trend. The results of Mann-Kendall's Tau and the size of Sen's Slope Estimator (see Fig. 2 a-f) indicated that the yearly trend analysis revealed both upward and downward trends for the variables across the LGAs.

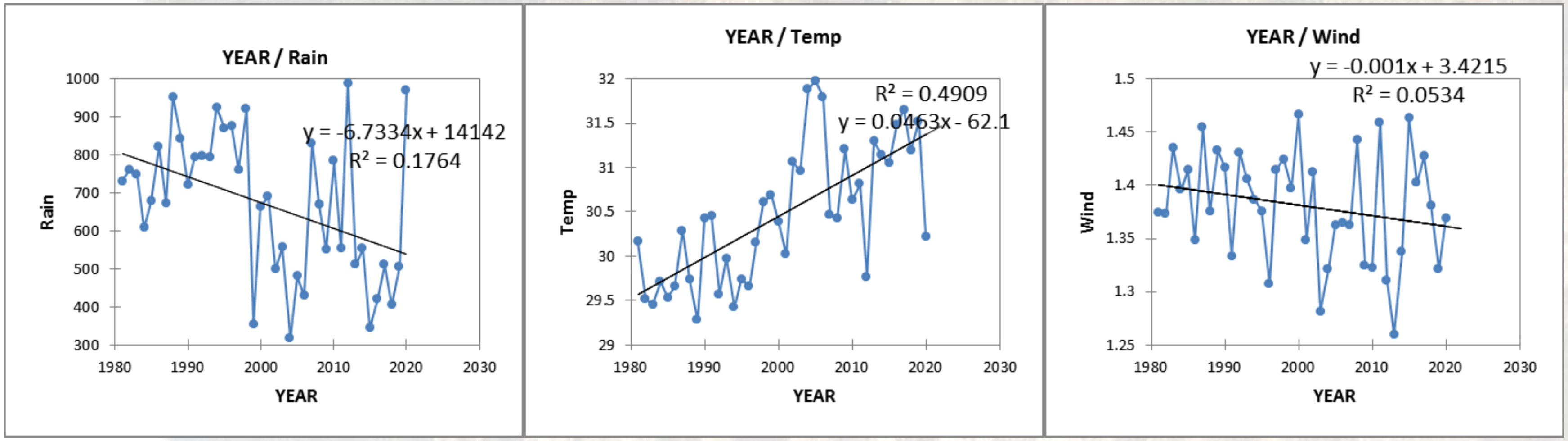

Fig. 2a: Sen's Slope for Rainfall, Temperature, and Wind (Birniwa)

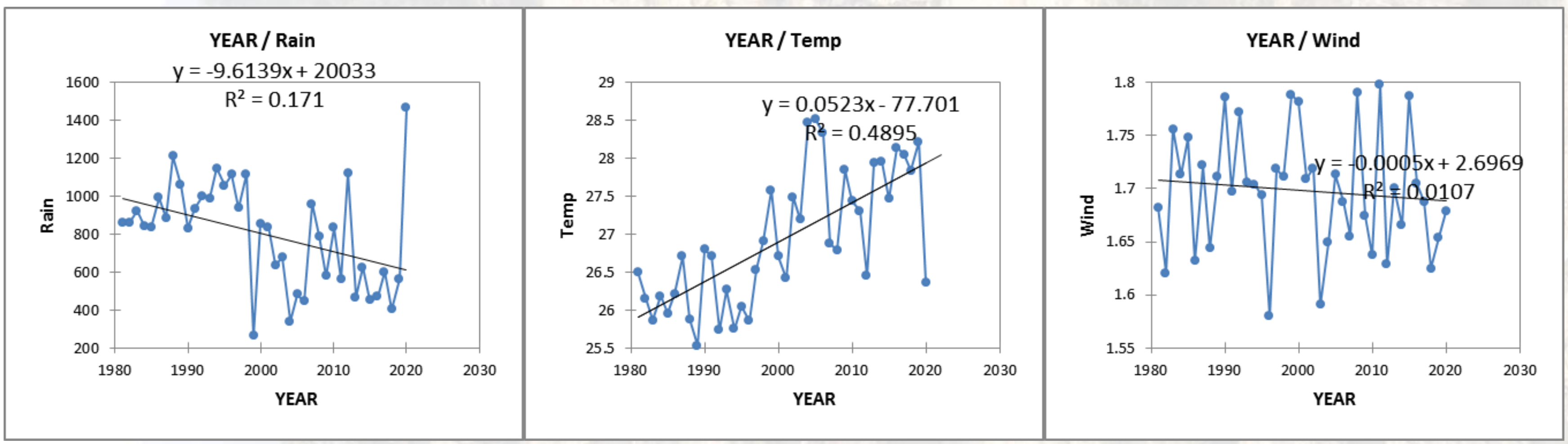

Fig. 2b: Sen's Slope for Rainfall, Temperature, and Wind (Dutse)

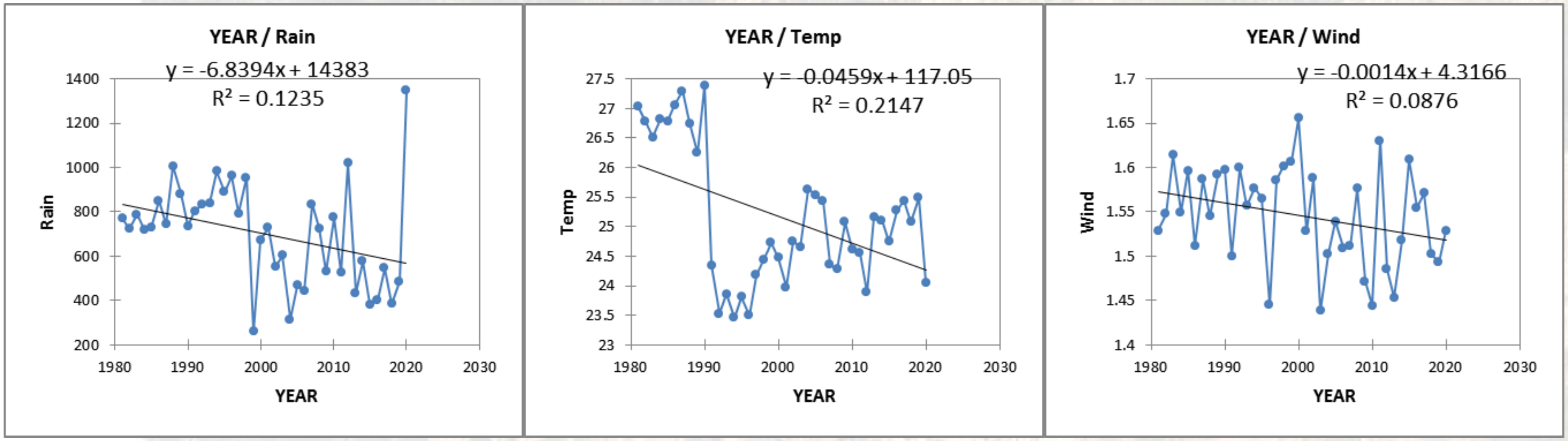

Fig. 2c: Sen's Slope for Rainfall, Temperature, and Wind (Kaugama)

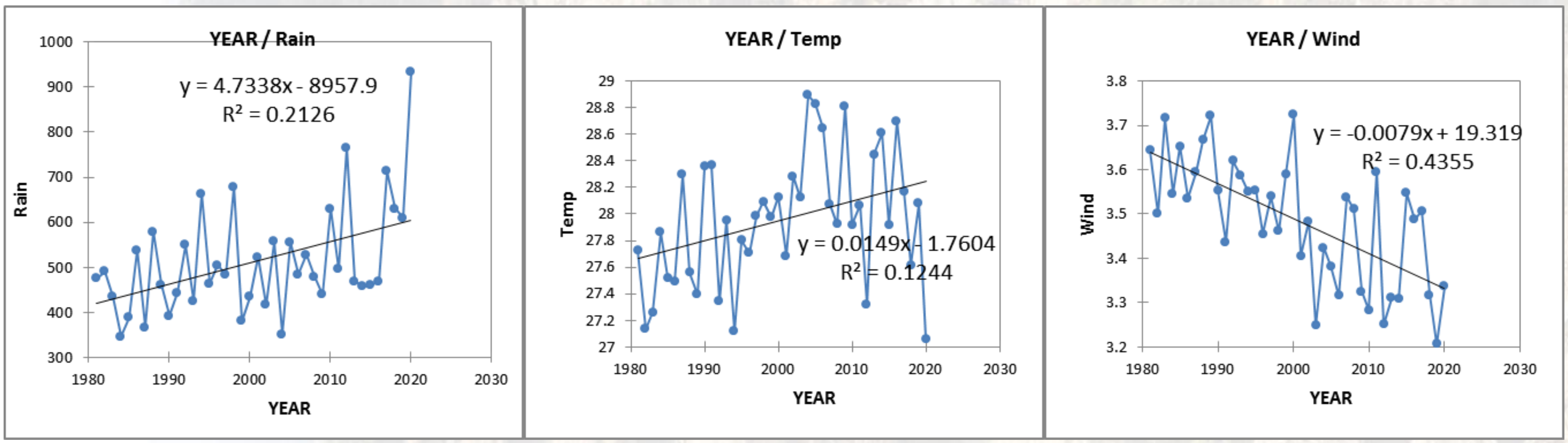

Fig. 2d: Sen's Slope for Rainfall, Temperature, and Wind (Maigatari)

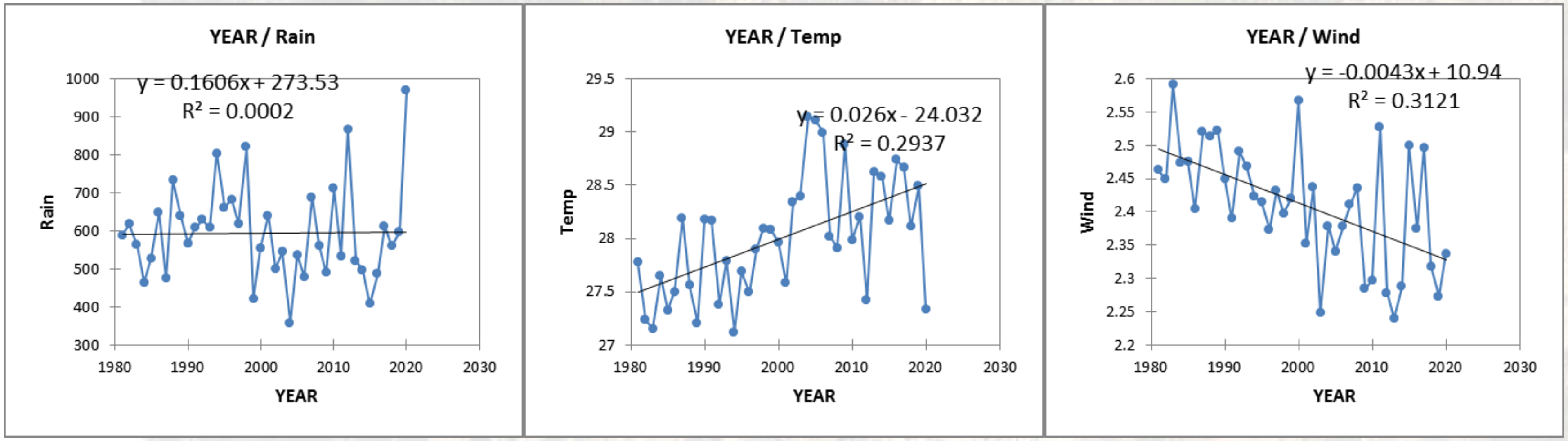

Fig. 2e: Sen's Slope for Rainfall, Temperature, and Wind (Kirikasamma)

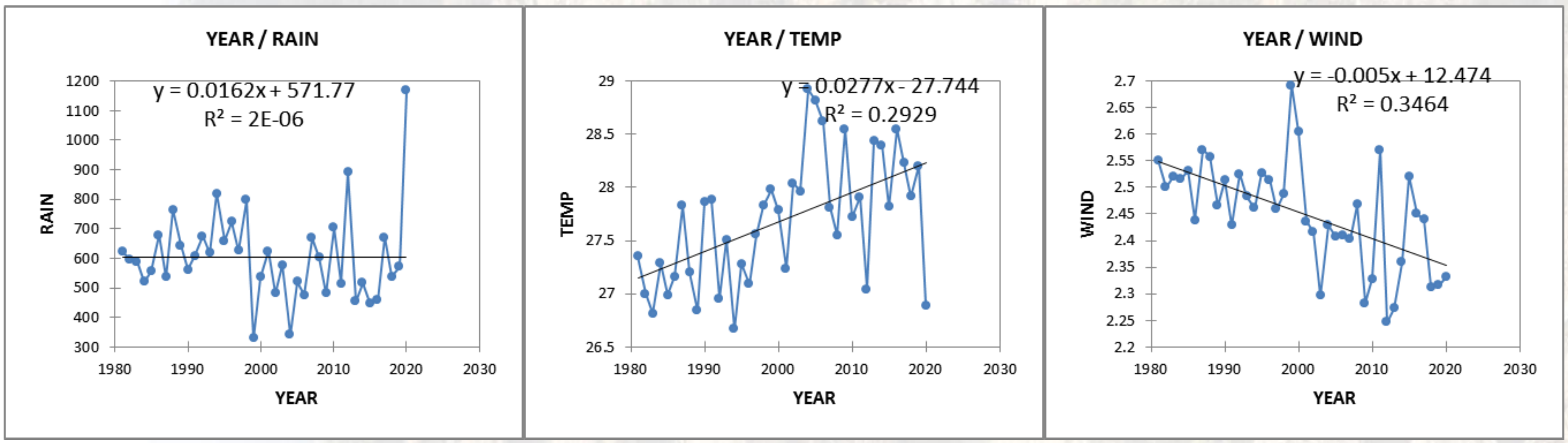

Fig. 2f: Sen's Slope for Rainfall, Temperature, and Wind (Sule-Tankarkar)

The Mann-Kendall (MK) test results showed mixed outcomes regarding the null theory, which asserts that “there is no trend in the series” of the climatic variables (rainfall, temperature, and wind) being studied. For the rainfall series, with the exception of Kirikasamma and Sule-Tankarkar local government areas, the hypothesis was rejected. The null hypothesis for the temperature series was accepted solely for Kaugama local government area. On the other hand, in all local government areas except for Sule-Tankarkar, Kirikasamma, and Maigatari, the null hypothesis regarding wind speed was accepted. The rainfall trend is observed in only two out of seven local government areas, and the temperature trend is present in just one. This indicates that there are only variations, not changes, in the area's climate, as concluded from the synthesis of climate data over 39 years (1981–2020). Salam et al. (2021) corroborated this by indicating that from 1990 to 2020, the climate of Jigawa state exhibited significant earthly and geographical transfer in its deviation and alteration, which according to Akinsalona and Agunjobi (2014) is the changes in mean states and other statistical measures (like standard deviations, frequency of excessive, etc.) of the climate across all earthly and geographical scales yonder those of single climate phenomena (IPCC, 2018).

4. Conclusion

It reached the conclusion that the study area is challenged by irregularities in rainfall that are linked to heightened climate variability. Evidence was shown through the statistically significant spatial variations in rainfall, temperature, and wind speed, albeit at different scales. Overall, the findings exhibited a degree of spatial and temporal inclination for rainfall, temperature, and wind speed; therefore, the temporal variability is more evident than the spatial changes. This does not imply that spatial variations should be ignored, as they will have an impact on the livelihoods of farmers in the area. While precipitation portrays a significant part in climate change studies, temperatures and wind are also significant as they affect evaporation and transpiration, which are key parameters of climate change.

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