

SPATIO-TEMPORAL ANALYSIS OF RAINFALL, TEMPERATURE AND WIND FOR EVIDENCE OF CLIMATIC VARIABILITY AND CHANGE IN JIGAWA STATE, NORTHERN NIGERIA (1981-2020)

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Abstract

Throughout the history of the earth, climates at all level be it (global, regional, and local) have never been static. The non-static natures are in various magnitudes ranging from variability through fluctuations, trends, and abrupt to gradual changes. The aim of this research is to analyze the climatic data and identify trends, in order to re-validate if climate change exist in the Sudano-Sahel Agro Ecological Zone of Northern part of Jigawa State. Climatic data of Temperature, Rainfall and Wind speed for the period of 1981-2020 (39years), obtained from. KNARDA, JARDA and NASA. Monthly, annual and seasonal trends in average temperature, total precipitation, and average wind speed data calculated by Mann-Kendall, linear trend and Sen's trend tests was used to analyze the data. The results indicated mixed results via the null hypothesis which states "there is no trend in the series" of the climatic variables (rainfall, temperature, and wind). Rainfall series was reject except for Kirikasamma and Sule-Tankarkar LGAs. Because the computed p-value is greater than the significance level $\alpha=0.05$. The H_0 for temperature series was accepted only for Kaugama LGA. Because the computed p-value is greater than the significance level $\alpha=0.05$. The H_0 for wind speed was accepted in all the LGAs except Sule-Tankarkar, Kirikasamma and Maigatari LGAs.. Rainfall trend only exist in two LGAs out of the seven LGAs. Temperature trend exist in only one LGA The result suggest that only variations exist rather than change in climate of the area, as deduced from the trend synthesis of the climate data for 39 years (1981-2020).

Keyword: Mann-Kendall, Climate Change, Trend, Variability, Jigawa

Introduction

Scientifically authenticated evidence is that the globe will face a temperature increase and changes in precipitation as well as wind patterns over the next decades (Republic of Turkey Ministry of Environment and Urbanization, 2011). Nigeria is already experiencing a range of impacts from Climate Change including more frequent heavy rainfall events, erratic rainfall, and unpredictable onset/retreat of rain, and increasing air temperature which is threatening the ecosystems, food production, livelihoods, and infrastructure (Babatolu and Akinnubi, 2016). These changes are not uniform in the country as some areas are severely impacted, and hence more vulnerable to climate change than others.

The inconstancy that local weather can have from one day to the other, from one season to the next, and between years, is one of the many challenges that a person faces when trying to distinguish between normal short-run variations and climate change manifestations (Hansen *et al.*, 2012).

Climate variability more especially rainfall is a major characteristic of the Sahelian climate, the last 40 years since 1969 have witnessed dramatic reductions in mean annual rainfall throughout the region (Diop, 1996; Le Barbe and Lebel, 1997; Ekpoh, 1999; Hulme, 2001; Camberlin and Diop, 2003; Gianniniet *al.*, 2003; Dai *et al.*, 2004). According to the Intergovernmental Panel on Climate Change, a rainfall decrease of 29 – 49 percent has been observed in the 1968 – 1997 period compared to the 1931 – 1960 baseline period within the Sahel region (IPCC, 2001).

A lot of researches were conducted on trend analysis of climatic variability; Ayugi *et al* (2016) analyze spatial and temporal patterns of rainfall variations in Kenya, Recha *et al*, 2016; Chung, *et al* (2018) Trend Analysis of Droughts during Crop Growing Seasons of Nigeria, Oguntunde, *et al* (2012) Spatial and Temporal Temperature Trends in Nigeria, 1901-2000; Bose *et al* (2019) "Rainfall Trend Detection in Northern Nigeria over the Period of 1970-2012," Mustapha *et al* (2020) Analysis of rainfall variation over northern part of Nigeria; Sawa and Buhari, (2011) Temperature Variability in Zaria, Northern Nigeria; Abaje and Oladipo (2019) analysis of temperature and rainfall data (1971-2016) in Kaduna state; Bose *et al* (2018) temperature and rainfall trend analysis 40 years (1971 - 2010) in Semiarid Zone of North-Eastern Nigeria; ; Olalere *et al*, (2021) Rainfall trend analysis in Northwestern Nigeria (NWN) The study used thirty years (30) rainfall data from 1987 to 2016; Ekpoh and Nsa (2011) Analysis of Rainfall Trends in north-western Nigeria Abubakar and Adesola, (2012), "Statistical and trend analyses of rainfall in Sokoto,"; Magawata and Aliero (2018) solar radiation, temperature and rain fall trend analysis in Birnin Kebbi; Ismail and Oke, (2012) Trend analysis of rainfall for a period of 1915- 2007 in Birnin Kebbi ; Ragatoa, *et al* (2018) A Trend Analysis of Temperature in Nigeria from 1981-2015; Abaje, *et al* (2014) rainfall trend in Kano from the period 1911 to 2010 (100 years); Shugaba, and Ahmed, (2019) Analysis of rainfall trends and Variability in the Sudan Savanna Zone, Jigawa State, Nigeria; Ezenwa *et al*, (2018) trend of climatic variability from 1984-2016 in Jigawa state.

The major climatic variables of rainfall and temperature which are often analyzed as seen in many works by many scholars have been reviewed extensively over time. Other variables such as the combination of wind, rainfall, and temperature have not been explored. Therefore, this research seeks to carry out trend analysis on these variables so as to expose the existence of climate variability and change in Northern Nigeria.

Material and Method

The study area is situated in the north-western geopolitical part of the country within Latitudes 11⁰N to 13⁰N and Longitudes 8⁰E to 10.15⁰E. Jigawa State is one of the biggest states in Nigeria with an area of 24,742 Km². It is politically constituted by 27 local administrations and has a population of 4,361,002 inhabitants according to the National Bureau of Statistics (2012). The State shares borders with Kano and Katsina to the west, Bauchi State to the east, and Yobe State to the northeast. To the north, it shares an international border with the Zinder region of the Republic of Niger (National Population Commission (NPC) of Nigeria, 2009) as shown in Figure 1

The topography of the area is characterized by undulating land, with sand dunes of various sizes covering several kilometers in parts of the State. The southern part of Jigawa comprises the Basemen Complex while the northeast is made up of sedimentary rock of the Chad formation (Nigeria Galleria, 2021)

The climate of the state is controlled largely by the two dominant air masses. These are the dry, dusty, tropical-continental (cT) air mass (which originates from the Sahara Desert), and the warm, tropical-maritime (mT) air mass (which originates from the Atlantic Ocean). The interplay of these two air masses gives rise to two distinct seasons that are wet and dry seasons within the area. There are two main seasons during the year. Generally, from May to September and including October in recent years, the rainy season is caused by the humid southwesterly breezes from the Atlantic coast of West Africa. Annual rainfall is

estimated to be between 600mm to 1,000mm with an average of about 650mm over the last few years. (Abaje, *et al.* 212)

Rainfall in some parts of the state normally lasts an average of five months. Meanwhile, the rest of the year is dominated by a dry season (“Harmattan”) brought by the dusty northeasterly winds from the Sahara desert. Monthly mean temperatures are in the range of 19-35°C with a reported maximum of 42°C registered in the wet season and 13-33°C with a minimum of 10°C, registered during the night in the dry season (onlinenigeria,2003). There is also a substantial day/night temperature variation of nearly 15°C. Generally, Nigeria has high temperatures all year round. However, there are variations in temperature, especially during the very hot months. The mean monthly temperatures in the daytime on some occasion goes about 36°C and the monthly average temperatures at night sometimes fall lower than 22°C (Adelana, *et al.*, 2008). In addition to the aforementioned experience, the study areas also have four (4) different seasons namely; dry and hot (*bazara*), dry and cool (*rani*), dry and warm (*kaka*), and, wet and warm (*damina*) seasons as given by Olofin, (1987) The aim of this research is to analyze the climatic data and identify trends in order to re-validate if climate exist in the study area

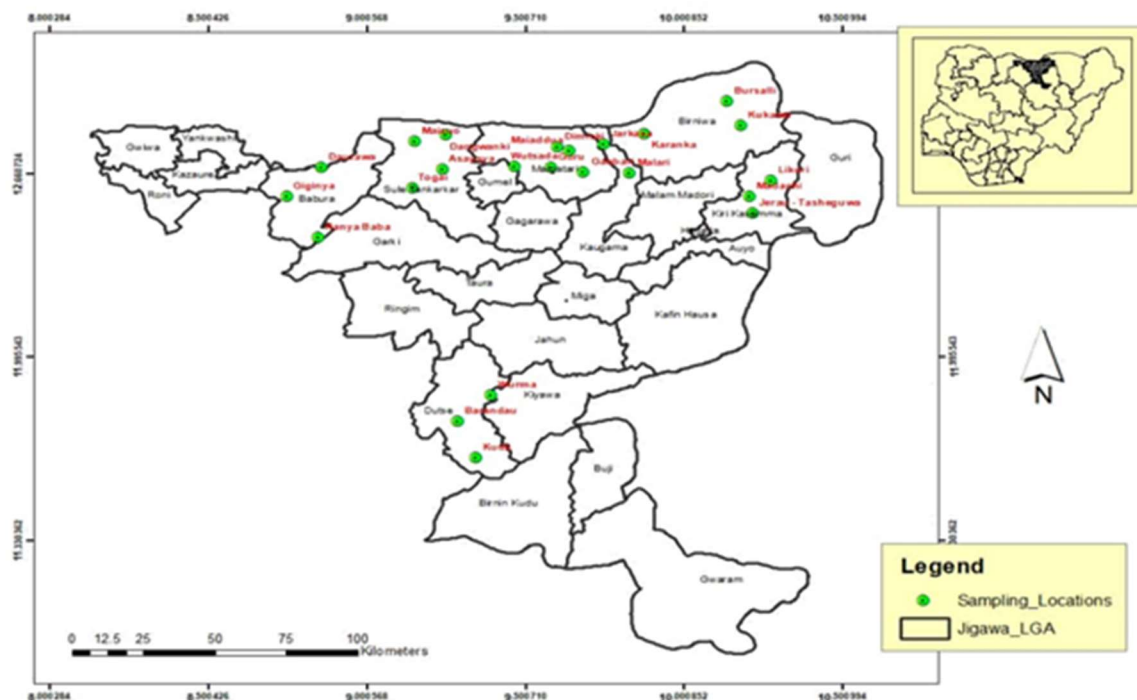


Figure 1 Map of Jigawa state showing the Study Area

Source: Jigawa State Agricultural and Rural Development Authority 2020 GIS Mapping at Geography Dept. FCE Kano.

Three sets of climatic data were sourced and used in this study. The first set consists of observed data collected from the synoptic stations of KNARDA (Kano State Agricultural and Rural Development Authority). Eleven (11) zones of the meteorological stations have been considered over the historical period 1981-1991. The second set of data was collected from the synoptic stations of JARDA (Jigawa State Agricultural and Rural Development Authority) over the historical period 1992-2020. The climatic data collected from KNARDA and JARDA were for rainfall and temperature. To complement the required, data for this study, the third set of climatic data grouping MERRA-2 (Modern Era Reanalysis for Research and

Applications Version 2) data available online at <https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/> was obtained from NASA (National Aeronautic and Space Administration) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (Power). The concise information on their location is presented in Figure 1. Rainfall data, Temperature data, and Wind speed data were collected at monthly scales from NASA. The selection of the time series data was based on the quality of the data collected from various stations. However, only the National Aeronautic and Space Administration (NASA) provided complete rainfall, temperature, and wind speed data for the study area from 1981 to 2020. Missing observed data have been filled in using the cross-validation method following Ioannis (Ioannis, 2017).

The analyses of this research work were undertaken by the use Non-parametric Test, Mann-Kendall Test using XLSTAT 2018, and Sen's Slope Estimator under Time Series was also used. The software is comprehensive and flexible statistical and data management tool, computed for simple descriptive statistics.

The data was further subjected to analysis using descriptive statistics, such as frequency distribution, percentage, and means. The data was processed and analysed using the statistical package for social sciences (SPSS) version 29 statistical software. Content analysis was used to compare the climatic data and perceptions of the respondents on climate variability and change.

Results and Discussion

Result for Rainfall Analyses

The results of the statistical analysis of the rainfall data in the study area for the period 1981–2020 are presented in this section, as shown in Table 3. It can be seen that the average annual rainfall data for Babura was found to be 804.2 mm, while the minimum and maximum rainfall were 351.9 mm and 1289.7 mm respectively. For Birniwa, the mean was found to be 671.6 mm, while the minimum and maximum were 316.8 mm and 989.5 mm respectively. Rainfall data for Dutse for the period (1981-2020) shows that the mean was 800.5mm, while the minimum was 263.2 mm and the maximum was 1466.7mm. Results for Kaugama show similar figures, with a mean value of 700.7mm, while the minimum was 260.9 mm with 1348.1 mm as the maximum. The mean value for Kirikasamma was 594.7mm, while the minimum was 357.2mm and the maximum was 969.2 mm. The results for Maigatari show the mean annual rainfall for the period was 512.1 mm, the minimum was 346.6 mm and the maximum was 935.0 mm. The results for Sule-Tankarkar revealed that the mean annual rainfall was 604.1 mm, whereas the minimum was 328.9 mm and the maximum was 1168.0mm.

Table 3. Mean Rainfall Data

Statistic	Babura	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule Tankarkar
Nbr. of observations	40	40	40	40	40	40	40
Minimum	351.9	316.8	263.2	260.9	357.2	346.6	328.9
Maximum	1289.7	989.5	1466.7	1348.1	969.2	935.0	1168.0
Range	937.73	672.60	1203.51	1087.22	612.01	588.440	839.13
Mean	804.2	671.6	800.5	700.7	594.7	512.1	604.1
Variance (n-1)	46103.40	35136.21	73884.61	51764.03	15491.94	14403.67	22280.72
Standard deviation	214.72	187.44	271.81	227.51	124.46	120.015	149.26
Variation coefficient	0.264	0.29	0.34	0.32	0.21	0.23	0.24
Skewness (Pearson)	-0.12	-0.164	0.006	0.230	0.850	1.379	1.326
Kurtosis (Pearson)	-0.64	-1.01	-0.52	0.14	1.021	2.395	3.661

Source: Field Study 2022

Result for Temperature Analyses

The results of the statistical analysis of the temperature data for the period of 1981 – 2020 are presented in Table 4. The average annual temperature for Babura was found to be 26.5 °C, while the minimum and maximum temperatures were 25.1°C and 28.0°C, respectively. For Birniwa, it was found that the mean temperature was 30.5°C, while the minimum and maximum were 29.3°C and 31.9°C, respectively. In the temperature data for Dutse, the mean was 26.9°C, while the minimum was 25.5°C, and the maximum was 28.5°C. Results for Kaugama were mean temperature values of 25.2°C, as minimum, 23.5°C, and 27.39°C as maximum. The mean value for Kirikasamma was 28.0°C, while the minimum was 27.1°C, and the maximum was 29.1°C. The result for Maigatari shows the mean annual temperature as 27.9°C, the minimum was 27.1°C, and the maximum was 28.9°C. Sule-Tankarkar had a mean annual temperature of 27.7°C, whereas the minimum was 26.7°C and the maximum was 28.9°C.

Table 4. Mean Temperature Data

Statistic	Babura	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule-Tankarkar
Nbr. of observations	40	40	40	40	40	40	40
Minimum	25.1	29.3	25.5	23.5	27.1	27.1	26.7
Maximum	28.0	31.9	28.5	27.4	29.1	28.9	28.9
Range	2.872	2.702	2.991	3.93	2.022	1.833	2.251
Mean	26.5	30.5	26.9	25.2	28.0	27.9	27.7
Variance (n-1)	0.639	0.596	0.764	1.343	0.315	0.242	0.358
Standard deviation	0.800	0.772	0.874	1.159	0.561	0.492	0.599
Variation coefficient	0.030	0.025	0.032	0.045	0.020	0.017	0.021
Skewness (Pearson)	0.265	0.286	0.280	0.481	0.297	0.064	0.210
Kurtosis (Pearson)	-1.105	-1.030	-1.149	-0.918	-0.769	-0.710	-0.859

Source: Field Study 2022

Result for Wind Speed Analyses

The results for Wind speed for the period of 1981 – 2020 are presented in Table 5. The average annual Wind speed for Babura was found to be 2.2m/s, while the minimum and maximum were 2.1 m/s and 2.3 m/s, respectively. For Birniwa, the mean wind speed was 1.4 m/s, while the minimum and maximum were 1.3 m/s and 1.5 m/s respectively. For Dutse the mean value was 1.7 m/s, while the minimum was 1.6 m/s, and the maximum was 1.8 m/s. Results for Kaugama shows a mean wind speed of 1.5 m/s, minimum of 1.4 m/s, and a maximum of 1.6 m/s. The mean values for Kirikasamma were 2.4 m/s, the minimum was 2.2 m/s, and the maximum was 2.6 m/s. For Maigatari, the mean annual wind speed for the period was 3.5 m/s, the minimum was 3.2 m/s and the maximum was 3.7 m/s. For Sule-Tankarkar revealed a mean annual wind speed of 2.5 m/s, whereas the minimum was 2.2 m/s and the maximum was 2.7 m/s.

Table 5. Descriptive Statistics (Wind)

Statistic	Babura	Birniwa	Dutse	Kaugama	Kirikasamma	Maigatari	Sule_ Tankarkar
Nbr. of observations	40	40	40	40	40	40	40
Minimum	2.1	1.3	1.6	1.4	2.2	3.2	2.2
Maximum	2.3	1.5	1.8	1.6	2.6	3.7	2.7
Range	0.245	0.207	0.218	0.218	0.351	0.517	0.446
Mean	2.2	1.4	1.7	1.5	2.4	3.5	2.5
Variance (n-1)	0.004	0.003	0.003	0.003	0.008	0.020	0.010
Standard deviation (n-1)	0.065	0.052	0.056	0.055	0.089	0.140	0.100
Variation coefficient	0.029	0.037	0.033	0.035	0.037	0.040	0.040
Skewness (Pearson)	0.324	-0.291	0.019	-0.231	-0.134	-0.228	-0.165
Kurtosis (Pearson)	-0.979	-0.614	-0.596	-0.722	-0.721	-0.864	-0.285

Source: Field Study 2022

Trend Analysis

The purpose of the Mann-Kendall (MK) test (Mann 1945, Kendall 1975, Gilbert 1987) is to statistically assess if there was a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (or downward) trend means that the variable consistently increases (or decreases) through time, but the trend may or may not be linear. Hirsch, Slack and Smith, (1982) indicated that the MK test is best viewed as an exploratory analysis and is most appropriately used to identify stations where changes are significant or of large magnitude and to quantify these findings.

In this study, the time series analysis of three (3) meteorological parameters (Rainfall, Temperature and Wind) for 39 years (1981 – 2020) in seven LGAs of Jigawa state were used to identify the trend and slope magnitude of this series. To analyze the trend, a non-parametric test (Mann-Kendall test) (table 6) and Sen's Slope Estimator were used.

Table 6. Mann-Kendall Trend Test Results

<i>Location</i>	<i>Variables</i>	<i>Kendall's Tau (Z)</i>	<i>S</i>	<i>Var (S)</i>	<i>P-Value</i>	<i>Sens' Slope</i>	<i>Hypothesis</i>
BABURA	Rainfall	-0.238	- 186.000	44.000	0.031	-7.427	H ₀ = Rejected
	Temperature	0.521	406.000	0.000	0.0001	0.050	H ₀ =Rejected
	Wind	0.030	23.000	7363.667	0.798	2.197E-4	H ₀ =Accepted
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 2022

The annual trend analysis showed both increasing and decreasing trends for the variables across the LGAs because of the values of Mann- Kendall's Tau and the magnitude of Sen's Slope Estimator obtained (Table 6).

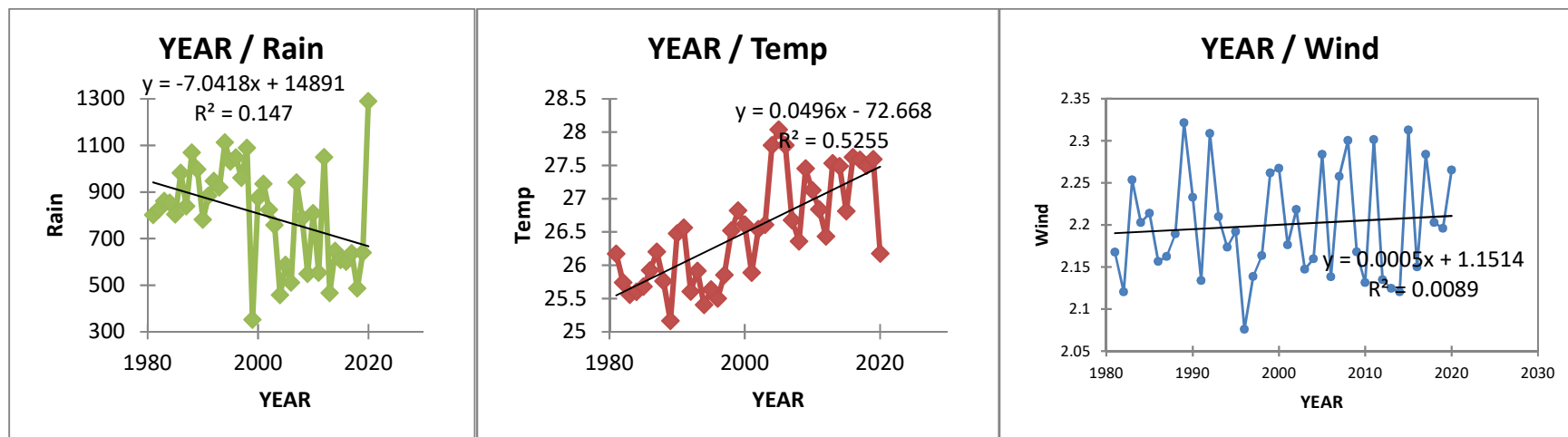


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (BABURA)

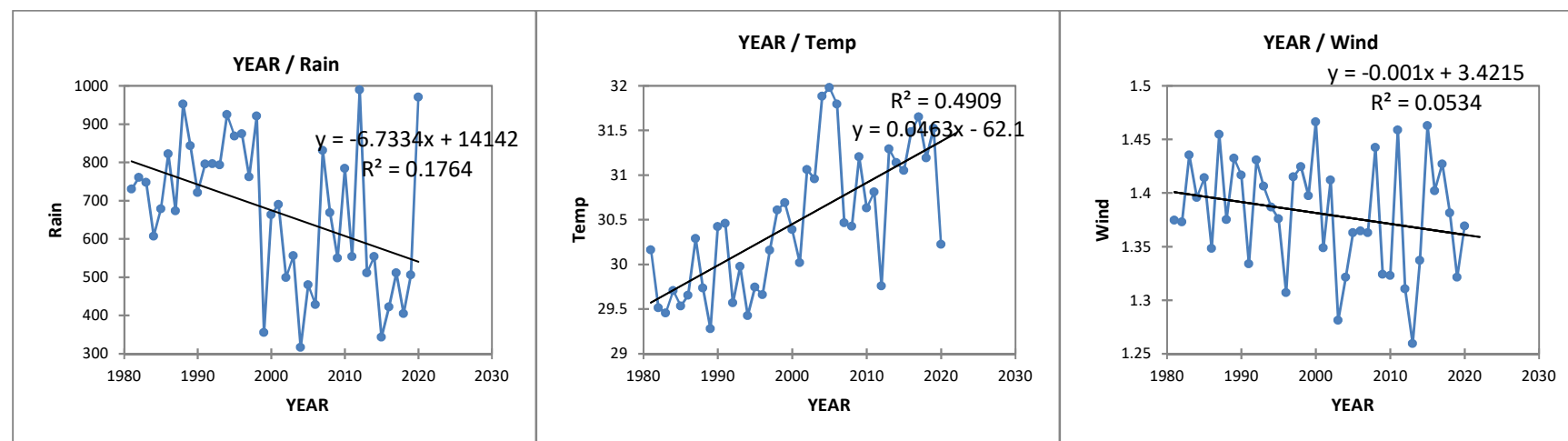


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Birniwa)

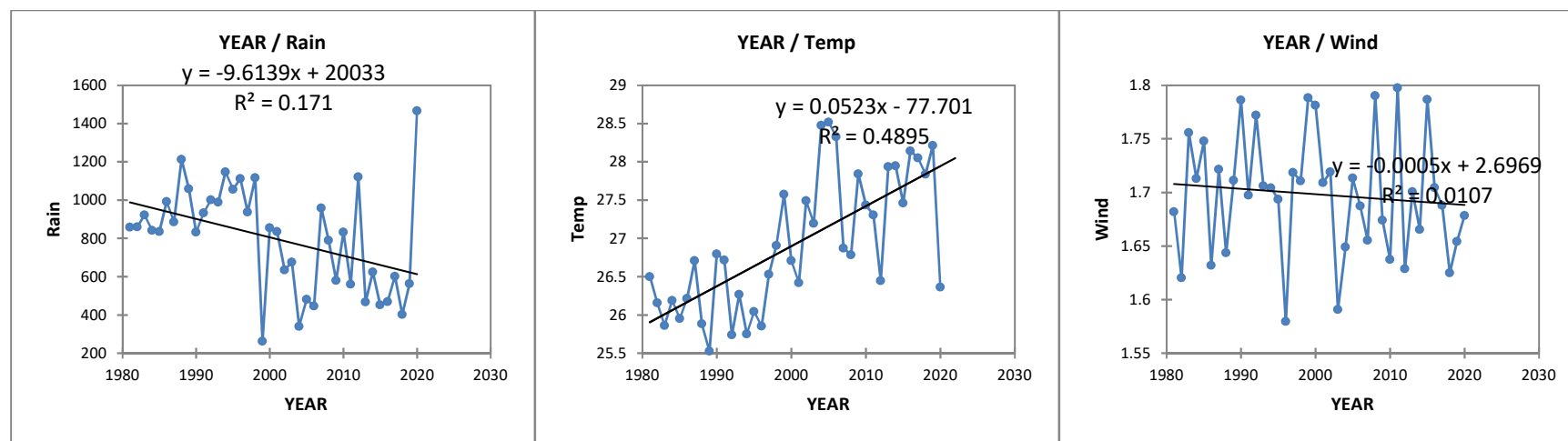


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Dutse)

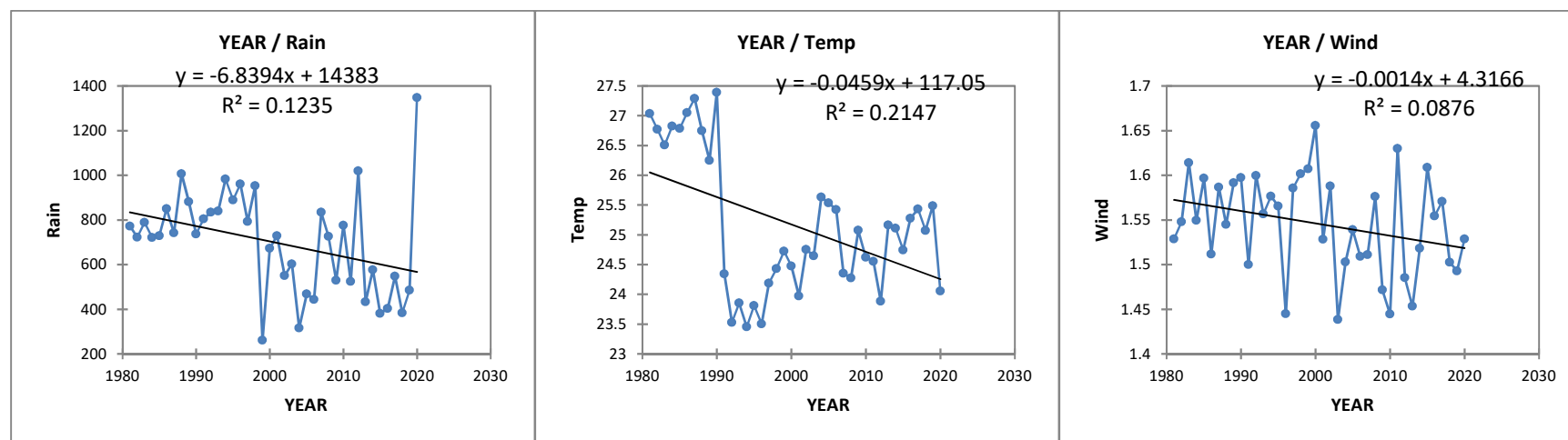


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Kaugama)

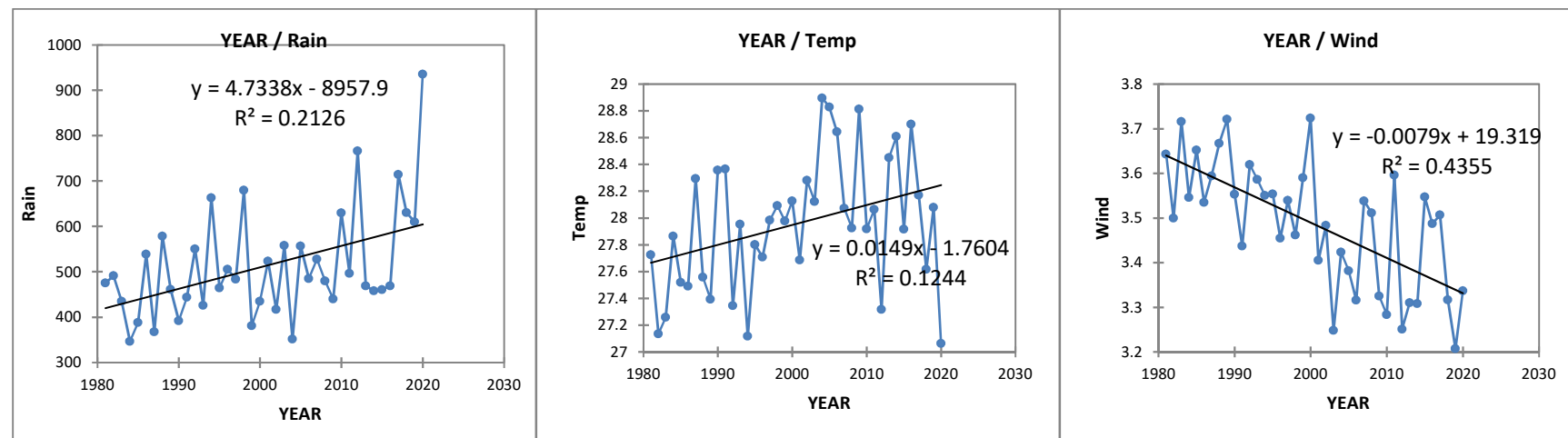


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Maigatari)

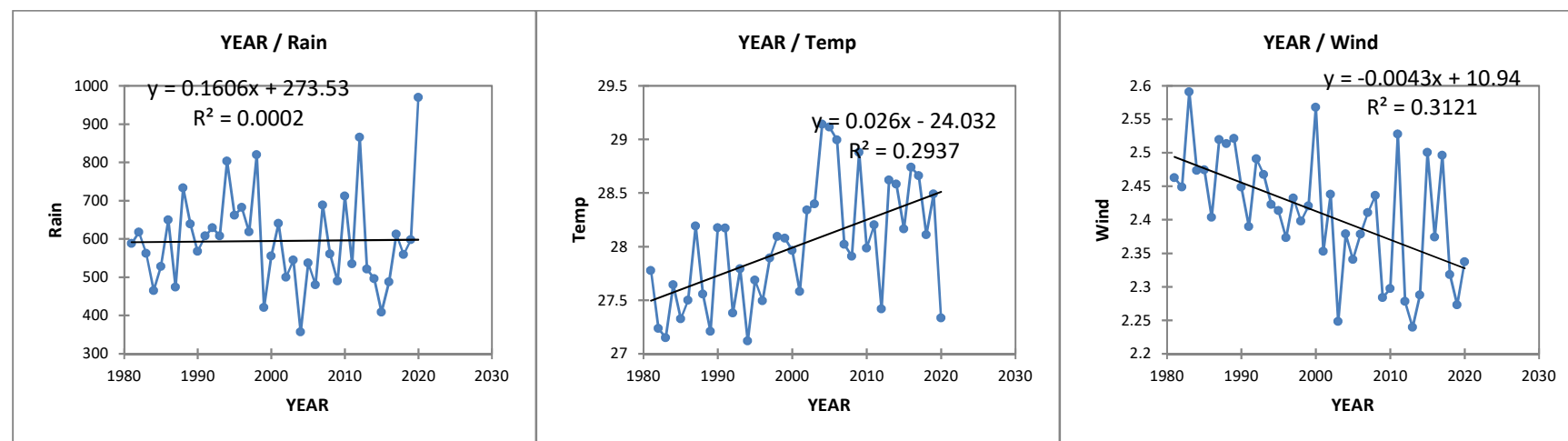


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Kirikasamma)

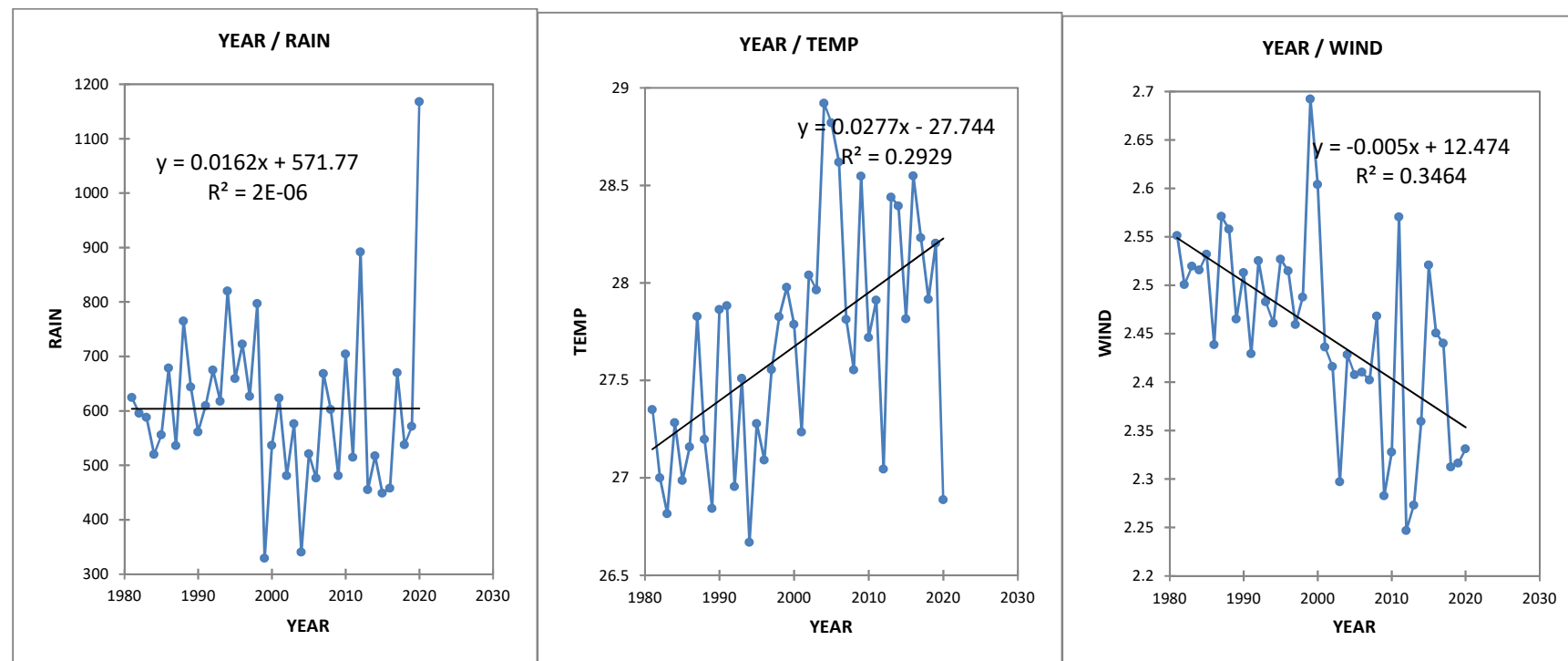


Fig. 4.1 Sen's Slope for Rainfall, Temperature, and Wind (Sule-Tankarkar)

The results of the Mann-Kendall (MK) test indicated mixed results via the null hypothesis which states “there is no trend in the series” of the climatic variables (rainfall, temperature, and wind) under investigation. The hypothesis, for example, was rejected for the rainfall series except for Kirikasamma and Sule-Tankarkar local government areas. However, the null hypothesis for the temperature series was accepted only for Kaugama local government area. Conversely, the null hypothesis for wind speed was accepted in all the local government areas except Sule-Tankarkar, Kirikasamma, and Maigatari local government areas. The fact that the rainfall trend only exists in two local government areas out of the seven and the temperature trend exists in only one local government suggests that only variations exist rather than change in the climate of the area, as deduced from the trend synthesis of the climate data for 39 years (1981-2020). This may be corroborated by Salam *et al.*, (2021), who indicated that the climate of Jigawa state has shown a considerable temporal and spatial shift in its variability and change from 1990-2020. Climate variability can be regarded as the variations in the means state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events (Akinalona and Agunjobi, 2014). Climate change can be a natural process where temperature, rainfall, wind, and other elements vary over decades or more (IPCC, 2018).

Conclusion

It thus concluded that the study area faces challenges of increased rainfall irregularities associated with increased climate variability. Evidence was manifested from the statistically significant spatial variations in the rainfall, temperature, and wind speed though at different scales. Generally, the results displayed a magnitude of spatial and temporal inclination of rainfall, temperature, and wind speed, thus, temporal variability is more discernible than the spatial changes. This however does not suggest overlooking the spatial variations, since spatial variations will accordingly affect the farmers’ livelihoods in the area. Precipitation is very determinative in climate change studies, but temperatures and wind are also very important in terms of influencing evaporation and transpiration which are the parameters of climate change (Keskin *et al*, 2018; Zeleke, *et al*, 2022).

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