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Enquiries:

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Professor Kulomri J. Adogbo
ENVIRON Editor-in-Chief

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PART II: CREATIVE, INDUSTRIAL AND MATERIAL ARTS

PART III: GEO-SPATIAL AND URBAN PLANNING

EDITORIAL

Advancing the frontiers of knowledge and innovation is a prerogative of academic journal publications and this is clearly evident in ENVIRON Journal of Environmental Studies which aims to create an avenue for the dissemination of academic researches which cover the creation of built environments and landscapes that are designed to improve the artistic, natural, socio-cultural and physical quality of life and the natural environment.

ENVIRON is an inter-disciplinary scholarly peer reviewed publication and welcomes original articles exploring wide range of topics in the built environment discipline. This issue of the journal covers interesting and thought-provoking topics in Urban Management of transport systems, urban drainage system, land use, climate studies and building performance in educational institutions. The articles explored challenges and advancements in the field of construction project management, contract management, safety management and risk management. The trends in use of artistic and creative colour choices and materials are also explored with the view to capturing latest trends in the Fine Arts domains.

On behalf of the Editorial Board, I wish to express our profound gratitude to the distinguished academics who have sacrificed their time to review these articles. The Authors who conducted researches and submitted articles for publications have made this issue rich in content and we are most appreciative of your faith and trust in the Journal as a medium for disseminating your researches.

Moving forward, the Journal hopes to publish articles which explore ground-breaking research or projects on the importance of sustainable design/development, emerging technologies such as Industry 4.0/5.0; the application of Data analytics and Artificial Intelligence in the Built Environment, and perhaps touch on Industrial Design (Ceramics, Graphics and Textiles), Innovative Design Thinking and Quantity Surveying.

At ENVIRON Journal of Environmental Studies, we highly value your opinions and insights. We invite you to engage with us by sharing your feedback, comments, and suggestions on the articles published, the topics covered, and ideas for future research areas. Your thoughts are invaluable in shaping the future discourse of our Journal. We are committed to fostering knowledge exchange and innovation within the built environment community and we believe strongly that the articles in this, and future issues, will provide readers with relevant reference resources.

Professor Kulomri Jipato Adogbo
Editor-in-Chief

SPATIAL DISTRIBUTION OF CLIMATE PARAMETERS AND TREND PATTERN ANALYSES ACROSS THE SOUTH EASTERN PART OF NIGER STATE, NIGERIA

Baba, M[1], Akinpelu A. A[2], Faruna S.O[3], Olaniyi, A. M[4]
1,3,4. Department of Surveying and Geoinformatics,
Federal University of Technology, Minna, Niger State
2. Department of Building Technology,
Lagos State University of Science &Technology, Ikorodu, Lagos[2]
Corresponding email: Mahmud.baba@futminn.edu.ng

Abstract

The magnitude of climate variability varies according to location. Hence, examining the spatiotemporal dynamics of meteorological variables in the context of climate change which have influence on the agricultural, social economy activities of human lives is imperatives. This study thus seeks to present the spatial distributions of climate parameters (temperature, precipitation, surface pressure and wind speed) and trend pattern analyses across the nine local government areas (LGAs) in the eastern part of Niger state using Mann-kendell and Sen's slope statistical test. Merra2 meteorological dataset is processed directly from the National Aeronautical Space Administration (NASA) in affiliation with global modelling Assimilation office using the principles of retrospective analysis in refining earth data. The climate data (Merra2) covered the range of ten years (2010-2019), which was further filtered and sorted before been used. The Merra2 was validated using Nigeria Meteorology Agency (NiMET) dataset and it indicated that there was a strongly correlation with the climate parameters dataset apart from wind speed (WS) which had a poor correlation. The trend pattern analyses were computed for the ten years using Mann-Kendall and Sen's slope estimator statistical template at the 95% confidence level. Temperature (T), precipitation (P) and WS indicated a negative trend pattern while surface pressure (SP) indicated positive trend pattern for the study area. This might lead to unexpected changes in the weather conditions and subsequently have extended effect on the social and economic activities in the study area. Therefore, further study should be carried out to investigate such situation in order to provide adopted strategies to mitigate the extended effect.

Keywords: Climate change, Mann-Kendall, Precipitation, Surface Pressure, Temperature, Wind Speed

INTRODUCTION

Variability is a key innate feature of climate change and it occurs across all time spans. The current public and scientific interest in climate parameter variability, as well as the potential contribution of human activities to observed climate change, have been significant (Braganza *et al.,* 2003). Instead of analysing climate variability or extremes, global scale assessments of the influence of climate change on livelihood and economic aspects frequently rely on averages assumptions (Adams *et al.*, 1990). However, observations indicate that the influence of climate change on society is mostly due to extreme occurrences and their variability (Bernstein *et al.*, 2007). This is due to the fact that, climate variability including the frequency and intensity of extreme events is anticipated to rise in some places in the future (Bernstein *et al*, 2007). Some have suggested that climate extremes will affect agricultural yield more negatively than just climate averages (Tubiello *et al*., 2007).

The structure and dynamics of the Earth's climate system are studied by climatologists or climate science. Understanding the processes through which local, regional, and global climates are maintained, as well as how they change over time, is the goal of this discipline. The average weather over an extended period is referred to as the climate. The atmosphere interacts with a variety of different components, such as the sea ice, seas, land, and its characteristics, to create variations in the climate on the surface of the Earth (Jeremy *et al.*, 2018).

The Earth's rotation, the geometry surrounding the Earth and Sun, the Earth's orbital gradual perturbation, and solar radiation are examples of external forces that have an impact on climate (Kevin *et al.,* 2000). According to this notation, the parameters that make up the climate vary based on the associated factors. Climate comprises trends of temperature, precipitation (rain or snow), humidity, wind, and seasons, (Awade*t al.*, 2013). In a larger sense, the World Meteorological Organization (WHO) (2020) defined important climate variables (ECV) or parameters as physical, chemical, or biological variables, or a combination of related variables, that significantly influence how the Earth's climate is characterized. They determined that the atmosphere, land, and ocean are dependent on the region of the Earth. Surface and higher categories of the ECV atmosphere matrix were also considered (Howard, 2013).

Climate parameters in the surface atmosphere include Precipitation (Rainfall), Surface Pressure, Surface Radiation Budget, Surface Wind Speed and Direction, Temperature and Water vapour. Earth Radiation Budget, Lightning, Temperature (upper-air), cloud properties and Wind Speed and Direction (upper-air) were identified as elements of the upper-atmosphere ECV. ECV-Land matrix was associated with river discharge, lakes, groundwater, and soil moisture (Bernard *at al.,* 2022). While Ocean related essential climate, parameters include ocean surface heat flux, sea ice, sea surface salinity, sea surface temperature, subsurface currents, subsurface temperature and surface stress (Monjur, 2015). This study however is concerned with the atmospheric (surface) climatic parameters specifically temperature, rainfall, pressure, and wind speed.

One cannot overstate the importance of measuring and evaluating climatic factors due to their wide range of applications or their spatiotemporal variance. Humanity depends heavily on local weather conditions to survive, so it is crucial for both our economy and society to comprehend and predict what the upcoming winter might bring as well as how the climate will evolve over the next century (NCAS, 2019). Understanding and evaluating climatic characteristics is becoming more and more important. Concerns about the effects of climate change on food production have recently spread around the globe. Agriculture is constantly under risk from unfavourable weather and climatic changes. Weather and climate continue to be important variables in agriculture productivity even in the face of technological advancements like better crop types and irrigation systems (Jemma *et al.,* 2010).

The understanding of climatic parameter variation that represents climate change and its possible effects at the global, regional, and local scales has greatly improved (Takara *et al.,* 2009). The existence of satellites that observe environmental factors in space explains the relevance of remote sensing and its related geospatial approach. Since the introduction of the first meteorological satellite, TIROS (Television Infrared Observation Satellite), in 1960, satellite data have been utilized to estimate climatic parameters and have been recognized as a suitable replacement for point-based weather stations that are not always available (Thies & Bendix 2011)

Study Area

Niger is a state in the North Central region of Nigeria with the largest landmass in the country. Niger state is sub-classified into three geo-political zones namely zone A, B and C relatively based on thedominated tribe within the zone. Zone A is predominantly the Nupe speaking tribe, Zone Bis the Gbagyi speaking tribe while zone C is mostly dominated by the Hausa. The state is named after the RiverNiger (NSG, 2012). The LGAs in Zone B lie on latitude 2^0 $45^{'}$ to 4^0 $15^{''}$ north of the Equator, and on longitude10^0 50^0 to12^0 15’ east of the Greenwich Meridian, and occupy a total land mass area of about 16868.8km^2.

Niger East is located at the south eastern part of the state, and it consist of nine local government areas namely Munya, Tafa, Gurara, Shiroro, Suleja Rafi, paiko, bosso and the state capital chanchaga (Minna). It houses one of the two of Nigeria's major hydroelectric power stations, the Shiroro Dam, along with the newly constructed Zungeru Dam located in Zone B. The main occupation of the people is farming, and the Gbagyi are known for yam cultivation and other cereals crops sorghum, maize etc. (NSG, 2012). Figure 1 depicts the map of the study area

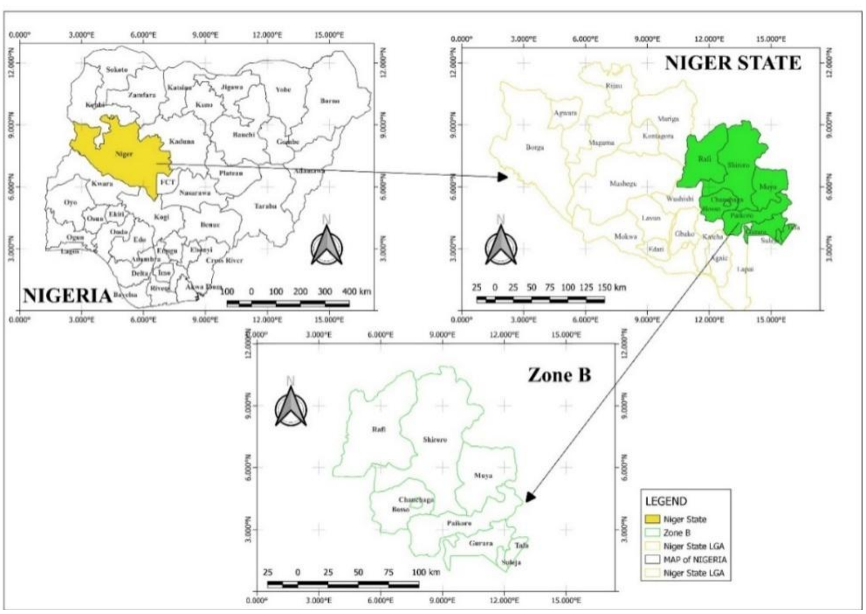

Figure 1. Map of study area: Top left; Map of Nigeria Showing Niger State, Top Right; Map of Niger State Showing the South Eastern Part, and Bottom; Study Location (Zone B)

METHOD

Data Acquisition

The MERRA-2 datasets were introduced to replace the MERRA-1 dataset due to the advances made in the assimilation system that enable assimilation of modern hyper-spectral radiance and microwave observations, along with GPS-Radio Occultation datasets. The spatial resolution is (0.5°×0.625° (latitude & longitude) or approximately 50 km) with temporal resolution up to hourly. The data downloaded was for the span of ten (10) years (2010-2019) which cut across the nine-local government of Niger state, Nigeria.

Data Processing

Merra2 data was processed directly from NASA in affiliation with global modelling Assimilation office. It uses the principles of retrospective analysis in refining earth data. The datasets were further reprocessed by Sorting and filtering, the telemetry data passed through a series of atmospheric reanalysis and adjustment before extraction. The Merra-2 daily data extracted from NASA/GMAO site comprises of four climate parameters (Temperature, Surface Pressure, Wind Speed, and Precipitation) The data was converted to monthly data for the whole of the nine (9) local government areas of Niger east, Nigeria. Mann-Kandel statistical template was used to determine the trend pattern of the data for the nine (9) Local Government Areas for the next ten years while quantum geographical information system (QGIS) software was used to plot the spatial distribution, the plot was divided into two phases at five years interval.

Mann–Kendall's Test

A Known statistical non-parametric tool used for analyzing trends in time series data from climatology and hydrology is the M-K test. The test was proposed by Mann (1945) mainly to evaluate environmental time series data, ever since it has been used to determine trend pattern of other factors. The usage of this test has two main edges over other methods.

i. It is a nonparametric test; therefore, the data do not need to be normally distributed.
ii. Inhomogeneous time series; the test is secondarily insensitive to sudden breaks.

When the test assumes that there is no trend, hence the null hypothesis is H_0, the alternative theory H_1, which indicate that there is a trend. Here is how to compute the M-K statistic:

$$S=\sum_{i=1}^{n}\sum_{j=1}^{i-1} sign(xi-xj) \qquad (1)$$

Where x_i and x_j are two generic sequential data values, n is the entire length of the data, and the following values are assumed for function sign $(x_i - x_j)$

Under this test, the statistic S is approximately normally distributed with the mean E(S) and the variance Var(S) can be computed as follows:

$$E(S) = 0 \qquad (2)$$

Where, n is the length of time series, and t is the extent of any given time and $\sum(t)$ denotes the summation of overall tie number of values. The standardized statistics Z for this test can be computed by the following equation (Gilbert 1987):

$$var(S) = \frac{1}{n}[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)] \qquad (3)$$

$$Z=\begin{bmatrix} \frac{s+1}{\sqrt{var\,(s)}} & if\ S > & 0 \\ 0 & if\ S = & 0 \\ -1 & if\ S < & 0 \end{bmatrix} \qquad (4)$$

If a data set of non-dependent variables with random distribution does not exhibit any trend with equally likely ordering, the null hypothesis H_0 is rejected in this test. Any value of the test statistic Z that is positive denotes a growing trend, whereas a value of Z that is negative may indicate a sequence of declining trends. In order to determine whether to accept or reject the null hypothesis and the significance of the trend, the computed absolute value of Z is compared with the standard normal cumulative value of Z(1-p/2) at p-% significance level (Partal & Kahya, 2006).Utilizing the XLSTAT 2017 program using NiMET dataset, this particular test was carried out, values that are extremely positive or extremely negative represent a growing or falling trend, respectively.

Sen's Slope Estimator Test

A non-parametric technique called Sen's estimator can be used to calculate the size of a trend in a time series (Sen, 1968). Sen's nonparametric technique is employed, and the test was run using the XLSTAT 2017 program, to determine the true slope of an existing trend, such as the amount of change per year. Sen's slope is a measure of the trend in a time series; a positive value indicates an upward or increasing trend and a negative value indicates a downward or decreasing trend (Hipel& McLeod, 1994).

Nigeria Meteorological Agency (NiMET) Data

Due to scarcity of climate stations in the study area, Niger State is housing only two climate (NiMET) stations which are located in Borgu LGA and Minna the state capital of Niger State. The NiMET datasets are the primary data used for the validation of the data generated from NASA/GMO (MERRA-2 datasets). It was possible to obtain NiMET datasets for Minna station for a period of ten (10) years (2010 to 2019). Climatic data (NiMET) were carefully processed for missing values and the data quality checked before using them for any analysis.

RESULTS AND DISCUSSION

Figure 2, depicts the spatial distribution of climate parameters for the first phase of five years (2010-2014). Figure 3, depicts the spatial distribution of climate parameters for the second phase (2015-2019) while Table 1 shows values of the highest and lowest climate parameters for the nine LGAs of Niger Zone B.

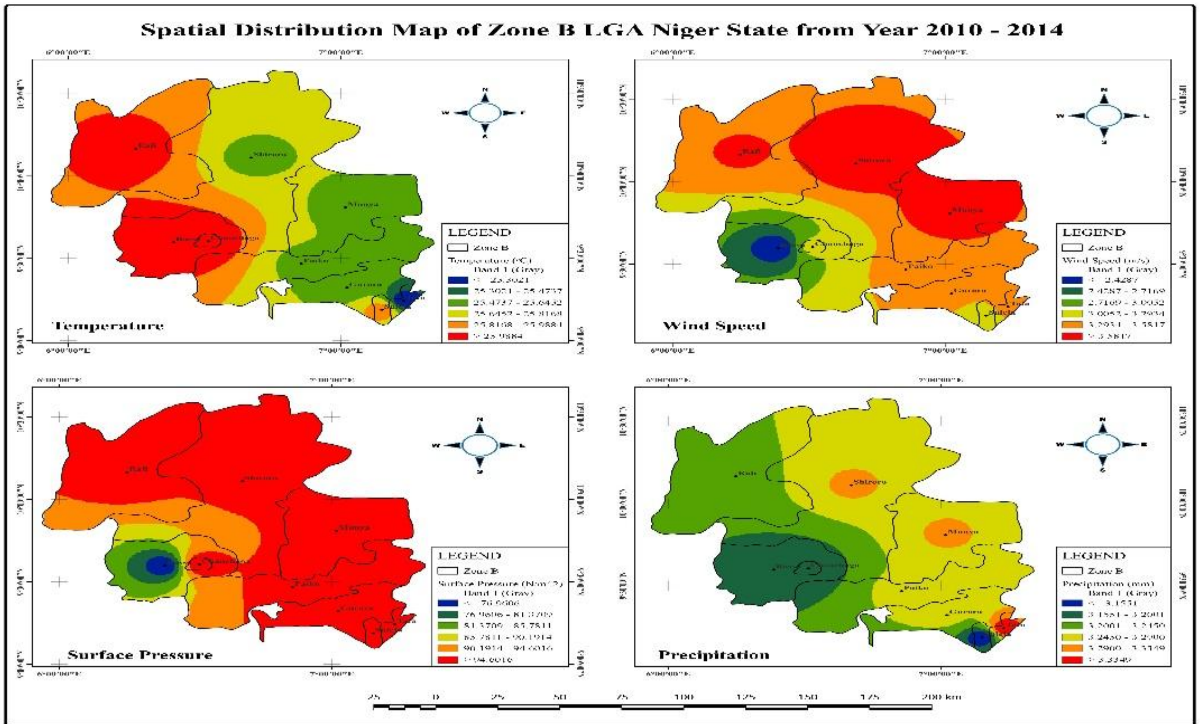

Figure 2. Spatial distributions of climate parameters between 2010 and 2014

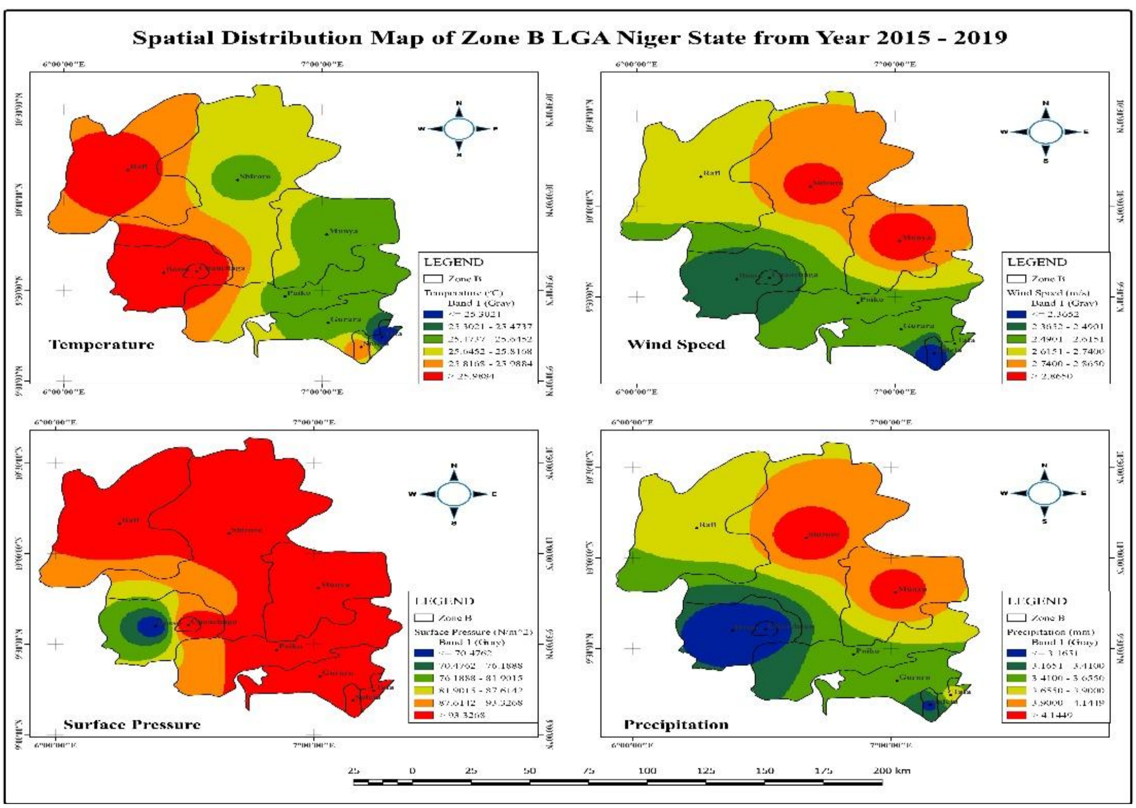

Figure 3.Spatial distributions of climate parameters between 2015 and 2019

Table1.Highest and lowest value of climate parameters in Niger east LGAs

Climate Parameters	Bosso LGA	Gurara LGA	Munya LGA	Paiko LGA	Rafi LGA	Shiroro LGA	Suleja LGA	Tafa LGA	Chanchaga LGA
Temperature (MAX) (℃)	28.05℃	26.93℃	26.46℃	26.93℃	27.08℃	26.45℃	27.93℃	26.14℃	2 8.05℃
MIN (℃)	25.4	24.92℃	24.74℃	24.92℃	25.48℃	24.73℃	25.09℃	24.47℃	25.40℃
Surface Pressure MAX(KPa)	99.08	97.21	97.21	97.1	98.23	96.46	98.12	95.19	99.07
MIN(KPa)	98.98	97.1	97.1	96.46	98.11	96.34	98.06	94.99	98.84
Precipitation MAX (mm)	4.13	4.27	4.27	4.27	4.33	4.7	4.01	4.52	4.14
MIN (mm)	2.16	2.21	2.21	2.22	2.01	2.21	2.21	2.21`	2.17
Wind Speed MAX(m/s)	2.57	2.79	2.79	2.79	2.9	3.19	2.79	2.8	2.48
MIN(m/s)	2.1	2.41	2.41	2.37	2.46	2.68	2.11	2.45	2.10

Variability analysis of meteorological parameters is of great importance for researchers and policy makers in their decision making as climate parameters (temperature, precipitation, surface pressure, wind velocity and relative humidity) play dominant role in deciding the variability of climate and weather conditions in the local government areas. Firstly, Bosso LGA houses the Federal University of Technology, which share close boundary with the state capital Minna. The LGA has the highest average value of temperature recorded for the span of ten (10) years when compared to other LGAs. It recorded about 13.40% of the total temperature across the whole of the zone B, the highest value was observed in the year 2016. The volume of precipitation recorded was 11.83% for the period in view, the surface pressure was 12.75%, and the wind speed recorded was 11.16%.

Gurara LGA shares boundary with Suleja LGA and Abuja to the north while Paiko LGA to the south. It recorded maximum average temperature of about 12.47%, average surface pressure recorded for the span of 10 years was 12.51%, and theaverage wind speed recorded was 12.11% while the precipitation was 12.22%. The observed climate parameters of the LGA have justified the reason for the high yield of agriculture products cultivated in the LGA.

Munya LGA shares boundary with Kaduna state to the south, Shiroro and Rafi LGAs to the southeastern part of the state. The maximum average temperature recorded in Munya LGA for the year in-view was 12.47%, the surface pressure recorded was 12.51%, The volume of precipitation recorded was 12.22% and the wind speed recorded was 12.11%. The result is an indication of the high yield of cereals crop in the LGA. The main agriculture products are maize, sorghum, soya beans, yam, guinea corn etc.

Paiko LGA shares border with the state capital east and Shiroro LGA to the south part of the state. The maximum average temperature recorded for the period in review was 12.47%, the volume of rainfall recorded was 12.40% while the surface pressure recorded was 12.38%. The wind velocity of Paiko LGA for the period in-view was 12.11% while the relative humidity percentage recorded was 12.69%. The results show agricultural potential ofNiger east (zone B) LGAs should have. According to food and agriculture (FAO) of the United Nations in 2018, with the expansion in population in Nigeria, there is need for the country especially Niger state with a vast land area and amazing climate condition to adequately harness its agriculture potential, for if well harnessed it can feed the whole of the country. Shiroro LGA recorded average maximum temperature of about 12.25%, the surface pressure and precipitation recorded were 12.42% and 13.45% respectively. This account for the highest values recorded compared to other LGAs. Wind speed recorded about 13.85%.

Suleja LGA and Tafa LGA are positioned at the fringes of the state sharing boundary with the country's capital, Abuja. Suleja LGA recorded average maximum temperature of about 12.92%, surface pressure of about 12.63% and precipitation of about 11.74%. The wind speed recorded was 12.11%. Tafa LGA recorded average maximum temperature of about 12.11%, surface pressure of about 12.24% and precipitation of about 12.94%. The wind speed recorded was 12.16% of the total for the span of ten (10) years.

In order to measure the degree of closeness of Merra2 dataset, validation procedure was carried out using the Nigeria Meteorological (NiMET) dataset for Minna station. Niger state has two NiMET station, Minna station and the second located at Ibi town in Borgu LGA of Niger state. Figure 4 depicts the scatter plots for Merra2 and NiMET dataset for the span of ten years based on correlation analyses.Table 2present the relationship between Merra2 and NiMET climate datasets.

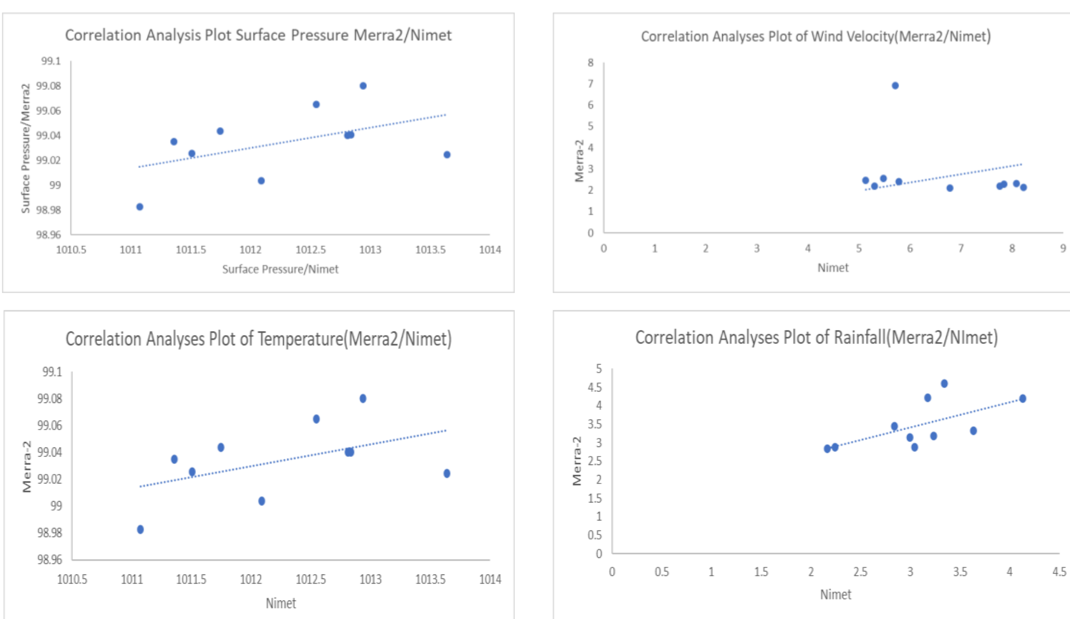

Figure 4. Correlation analyses index of NiMET dataset and Merra2 dataset

Table 2. Relationship Between Meera2 and NIMET climate dataset

s/n	Climate parameters	Correlation	Remark
1	Precipitation	0.6	Strongly correlated
2	Surface pressure	0.7	Strongly correlated
3	Temperature	-0.3	Poorly correlated
4	Wind speed	0.6	Strongly correlated

The result of Table 2 depictsthe degree of closeness of Merra2 data and NiMET climate dataset, which indicates that surface pressure, precipitation, and temperature showed strong correlation index with the NiMET data while wind speed indicates a poor correlation index with the NiMET data. However, the above outcomes depict that the Merra2 data can be used to measure the climate parameter of a place where there is no coverage of primary means except for wind velocity which requires more verification.Table 3 presents the results of quantitative statistics based on the Mann-Kendell analyses to determine the trend pattern of the climate parameters in view in Minna, the state capital, while Figures 3 (a-d) present Mann-Kendall trend tests/two-tailed tests for temperature, precipitation, surface pressure, and wind speed, respectively.

Table 3. Statistics of Climate Parameters from The Mann-Kendell Analyses

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
temperature	10	0	10	25.393	28.049	26.849	0.912
Precipitation	10	0	10	2.167	4.133	3.081	0.588
Surface pressure	10	0	10	98.983	99.080	99.033	0.029
wind speed	10	0	10	2.106	6.929	2.764	1.471

Table 3a:Mann-Kendall trend test/Two-tailed test (Temperature)

Kendall's tau	0.422
S	19
Var(S)	125.000
p-value (Two-tailed)	0.107
Alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:

H_0: There is no trend in the series
Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.221	-0.059	0.395
Intercept	-419.368	-593.822	-136.279

Table 3b, Mann-Kendall trend test / Two-tailed test (Precipitation):

Kendall's tau	0.067
S	3
Var(S)	125.000
p-value (Two-tailed)	0.858
Alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:
H_0: There is no trend in the series
Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.027	-0.199	0.172
Intercept	-50.649	-197.630	176.182

Kendall's tau	0.378
S	17
Var(S)	125.000
p-value (Two-tailed)	0.152
Alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:
H_0: There is no trend in the series

Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.005	-0.003	0.012
Intercept	89.662	81.954	97.197

Table 3d. Mann-Kendall trend test / Two-tailed test (Wind speed):

Kendall's tau	0.289
S	13
Var(S)	125.000
p-value (Two-tailed)	0.283
Alpha	0.05

An approximation has been used to compute the p-value.

Test interpretation:

H_0: There is no trend in the series

Ha: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0.

The continuity correction has been applied.

Sen's slope:

	Value	Lower bound (95%)	Upper bound (95%)
Slope	0.023	-0.075	0.045
Intercept	-43.134	-65.378	55.363

CONCLUSION

The capital of Niger state is susceptible to climate variability and all the local government areas in Zone B are also experiencing the same. Fluctuations in climatic parameters which have an extended effect on climatic and weather conditionsare a recurring phenomenon in the studied local government areas. The effects of climate variability exacerbate existing social and economic activities across the LGAs, because people here are mainly reliant on resources that are sensitive to climate variability such as agricultural practices. Improved capacity to cope with future climate variability extremes can lessen the extent of economic, social and human loss. However climatic parameter such as rainfall, temperature, surface pressure, wind speed and relative humidity are relevant variables that define the weather and climatic condition of an area. The present study analyzed the meteorological data extracted from NASA Merra2 dataset and the Nigeria Meteorological station in Minna, Niger state Nigeria. The analysis of the time series dataset was carried out using non-parametric M–K test and Sen's slope estimator, which are widely used tests for conducting trend analysis. The trend pattern was computed at 95% confidence level which indicated that in Rafi LGA, it recorded a positive Sen’s slope of 0.013 for temperature, Sen’s slope 0.097 for precipitation and Sen’s slope (0.006) for surface pressure. Munya LGA recorded negative Sen’s slope of - 0.060 for temperature, positive Sen’s slope0.156 for pressure, Sens’s slope of 0.007 for surface pressure, Sens’s slope of 0.015 for wind speed. Bosso LGA recorded positive Sen’s slope 0.0223 for temperature, Sen’s slope of 0.027 for precipitation, Sen’s slope 0.003 for surface pressure, Sen’s slope 0.030 for wind speed. Gurara LGA recorded positive trend pattern of Sen’s slope 0.089 for temperature, Sen’s slope 0.049 for precipitation, Sen’s slope 0.005 for surface pressure, Sen’s slope 0.011 for wind speed. Tafa LGA recorded positive trend pattern of Sen’s slope 0.080 for temperature, Sen’s slope 0.024 for precipitation, Sen’s slope 0.007 for surface pressure, Sen’s slope 0.007 for wind speed. Suleja LGA recorded positive trend pattern of Sen’s slope 0.192 for temperature, Sen’s slope 0.016 for precipitation, Sen’s slope 0.005 for surface pressure, Sen’s slope 0.014 for wind speed. Hence, the correlation of Meera2 dataset and Nimet dataset have indicated a high reliability on Meera2 data except for wind velocity. Therefore, it can be concluded from both Mann-Kendall and Sen’s Slope have indicated both positive and negative trend relative to the climate parameter in review. This could be due to impact of climate change. However, if caution is not taken, it may lead to weather and climate extremes in the study area. It is therefore recommended that the variability of the climate parameters should be monitored in order to minimize its effects on human activities.

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