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Analysis of The Impact of Climate Change on Meteorological Time-Series Data in Uyo

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Abstract: *The annual trends of five meteorological variables were analysed for station in Uyo, the Akwa Ibom State capital, Nigeria, controlled by the Nigerian Meteorological Agency (NiMet) from 1972 to 2021. At the 5% statistical significance level, the non-parametric Mann-Kendall and Sen's slope estimator techniques were used to detect if there was a positive or negative trend and the magnitude of the trend in meteorological data. In this study, there was a significant statistically increasing (positive) trend in mean annual rainfall, maximum temperature, and minimum temperature. However, there was a significant statistically decreasing (negative) trend in average annual relative humidity, solar radiation. The magnitudes of the trends were 19.39mm/year, 0.0314^{o}C/year, 0.013^{o}C/year, -0.104%/year, and -8.78MJ/m^{2}/year, for annual rainfall, maximum temperature, minimum temperature, relative humidity and solar radiation, respectively. The rising trends in precipitation, temperature, and runoff in this research area show that this region is subject to climatic variability. The results of the Mann-Kendall and Sen's slope estimator statistical tests revealed the consistency of performance in the detection of the trend for the meteorological variables.*

Keywords: *Climate change; rainfall; Mann-Kendall test; trend analysis*

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1.0 Introduction

According to the international scientific community, climate change (CC) is occurring, and its impacts are already being seen in certain locations (Abbass, *et al*., 2022). It is presently viewed as one of the world's most pressing issues (Abbass, *et al*., 2022). CC includes changes in climate parameters such as rainfall, temperature, wind speed, humidity, sunshine, among others. Although climate change has occurred on a global scale, its impacts frequently differ from place to place (Mulune, 2021). Many researchers believe that the temperature of the Earth's surface air increased over the 20th century (Connolly *et al*., 2021). Because of an increase in greenhouse gases (GHGs), the atmosphere and seas have warmed, the amount of snow and ice on the land has reduced, and the sea level has risen. Both natural and manmade activities contribute to the rise in greenhouse gas (GHG) concentrations in the atmosphere. Global greenhouse gas concentrations have increased in recent decades, leading to global warming (Hansen *et al* 2023). Human activity has been identified as the primary cause of continuing global warming (Guo *et al*., 2023).

CC has caused a significant threat to all life on Earth, not just humans. Developing countries are vulnerable to climate change due to their inability to adapt to extreme events (Bedeke, 2023). CC affects temperature regimes in most places of the world. Temperature is a fundamental climatic characteristic, and variations in its pattern can have an impact on the earth's living components (Guo *et al*., 2021). Heat waves can occur when temperature increases, causing disease and death in less robust populations. Furthermore, temperature

variations can trigger changes in species of animals and plants [8]. Increased Earth temperature induces convectional current and boosts the rate of evaporation, resulting in cloud formation and increased precipitation (Fowler *et al*., 2021). Increases in precipitation patterns can also lead to a rise in the frequency of floods, affecting water quality. Almost all biosphere activities are impacted in some way by climate change events, and the effects of climate change on the environment and water resources are of particular significance in this regard (Fowler *et al*., 2021).

Various studies have been carried out in recent years to detect possible climate change trends and changes. However, most of these researches have only focused at trends in maximum, minimum, or mean temperatures and rainfall. Yunling and Yiping (2005) examined climatic change patterns and features at 19 sites along the Lancang River (China) from 1960 to 2000 using archival data from monthly air temperature and precipitation series. They observed temperature increases and precipitation decreases. Singh et al. (2008) used the Mann-Kendall statistical test to assess the trend and variability of seasonal and annual rainfall and relative humidity on a basin scale in the northwest and central parts of India. According to the findings of this study, the most of river basins in India have a rising trend in relative humidity on both seasonal and annual periods. Vincent et al. (2007) obtained similar results when they examined surface temperature and relative humidity trends in Canada from 1953 to 2005. Gocic and Trajkovic (2013) examined the annual and seasonal trends of seven meteorological variables for twelve weather stations in Serbia from 1980 to 2010. The non-parametric Mann-Kendall and Sen's methods were used to assess the statistical significance of positive or negative trends in meteorological data. Their findings revealed a significant agreement of performance in detecting trends in meteorological variables.

A review of the available literature revealed that this study has not been conducted in the region. As a result, a regional or local scale study of historical trends in hydro-meteorological variables is required. However, the purpose of this paper is to analyse the, annual trends for five meteorological variables in Akwa Ibom State, Nigeria, from 1972 to 2021. Furthermore, the objectives of this study are: (i) to analyze and discuss the trend characteristics of meteorological variables in detail; (ii) to quantify the magnitude of trend and significance of change by using the Mann-Kendall test and the Sen's slope estimator in the time series.

2.0 Materials and Methods

2.1 The Study Area

The research was conducted in Uyo local government areas, Akwa Ibom State, Nigeria. Uyo is the capital of Akwa Ibom State (Fig. 1). The study area has a latitude of 5.037740 and a longitude of 7.912795. The GPS coordinates for the area are 5° 2' 16" N and 7° 54' 46" E. It is located at an elevation of 64.122 metres above sea level over a massive underlain conglomerate sedimentary stratum. The region has a tropical rainforest climate with two distinct seasons: a short dry season from December to February that has daytime temperatures of 34 to 38 degrees Celsius and lower nighttime temperatures of 23 to 25 degrees Celsius. The months of June and July typically have the highest annual precipitation rate, which ranges between 60 and 70 percent.

2.2 Data Collection

The data used in this research were obtained from the Nigerian Meteorological Agency (NiMet), Abuja. The daily meteorological datasets (rainfall, maximum and minimum temperatures, relative humidity and solar radiation) were obtained from NitMet's meteorological station situated in the study area. The graphical position of the selected station in the Akwa Ibom State map is shown in Fig. 1. The location was chosen based on

three criteria: (1) high-quality datasets; (2) reliable datasets; and (3) datasets with sufficient record duration. Seasons were defined as follows: dry season = December, January and February; rainy season = March, April, May, June, July, August, September, October and November.

2.3 Trend Analysis Methods

Parametric and non-parametric approaches can be used to conduct tests for the identification of significant trends in meteorological and hydrological time series. Non-parametric trend tests just need independent data, but parametric trend tests need independent and properly distributed data. Two non-parametric techniques (Mann-Kendall and Sen's slope estimator) were employed in this study to determine trends in the hydro-meteorological data.

2.3.1 Mann-Kendall trend test

The Mann-Kendall (MK) test, is a non-parametric test technique that is frequently used to identify patterns in datasets and is recommended by the World Meteorological Organization (WMO). It may be used to analyse data having non-normal distributions, including hydrologic and meteorological datasets. Recent research has made extensive use of the MK technique to analyse trends in time series of temperature, rainfall, runoff, and water quality. This study employed the MK test approach to evaluate the trends of time series data from the study region, including annual rainfall, annual mean temperature, relative humidity (RH), and sun radiation (SR).

2.3.2 Sen's slope estimator

Sen (1998) developed the non-parametric approach for estimating the slope of trend in the sample of N pairs of data. A positive value of shows an increasing trend, whereas a negative value shows a decreasing trend in the climatic time series data.

2.4 Data Processing

To examine time series trend analysis, the Mann-Kendall test was used. To analyse the variations of these parameters, graphs were plotted using the Minitab 17 software, and the Mann-Kendall Test was performed using "XLSTAT," an inbuilt tool in Excel used for statistical analysis. The data was analysed to see whether there were any climatic changes. The data was logically analysed, and basic tables and graphs were used. The hydro-meteorological data were used to analyse the trends that have occurred in Akwa Ibom State during the last 50 years. XLSTAT 2022 was used for the Mann-Kendall (MK) test and Sen's slope statistical test to determine whether or not there are any statistically significant trends in the datasets, as well as the magnitudes of such trends. The null hypothesis (H_0) assumes that there is no trend in the data, whereas the alternative hypothesis (H_1) assumes that there is an increasing or decreasing trend over time.

2.0 Results and Discussion

The trend, slope and coefficient of variation analyses of rainfall, average maximum and minimum temperatures, relative humidity, and solar radiation were carried out for the data collected from the meteorological and hydrological stations on a monthly, seasonal, annual and decadal basis during 1972-2021.

3.1 Analysis of Rainfall

The annual trend of rainfall obtained by Mann-Kendall test and Sen's slope estimator are shown in Fig. 1. According to these results, the significant increasing trend in the annual rainfall series was detected at the 5% significance level. The Sen's slope rate of mean annual rainfall increase was 19.39 mm/y.

3.2 Analysis of Maximum and Minimum Temperatures

The MK trend test and Sen’s slope estimator were used to assess the average annual maximum and minimum temperatures. Results of applying statistical tests for data series over

the period 1972 to 2021 are presented in Figs .2 and 3. The MK test showed a statistically significant increasing trend in the maximum temperature of annual basis. The increasing trends in air temperature series have been caused by several factors, such as global warming, increased urbanization and changes in atmospheric circulation. For the minimum temperature, significant increasing trends were also witnessed in the annual datasets at a 95% confidence level. The Sen's slope rate of average annual maximum temperature increase was 0.0314 degrees Celsius per year.

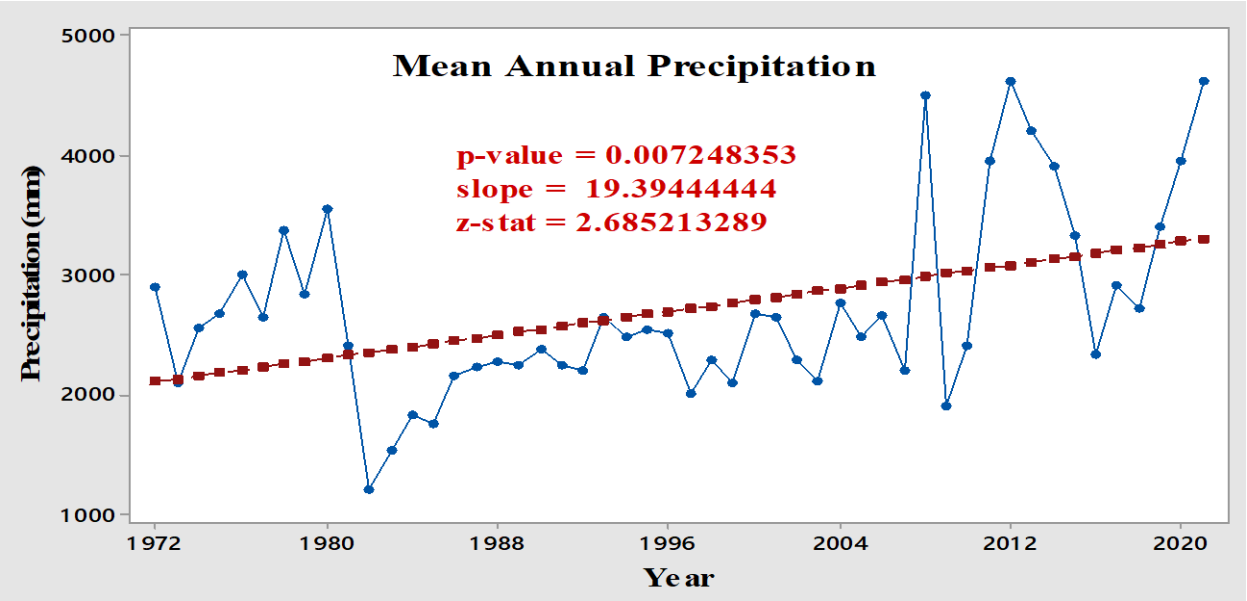

Fig. 2: Mann-Kendall trend test for mean annual rainfall

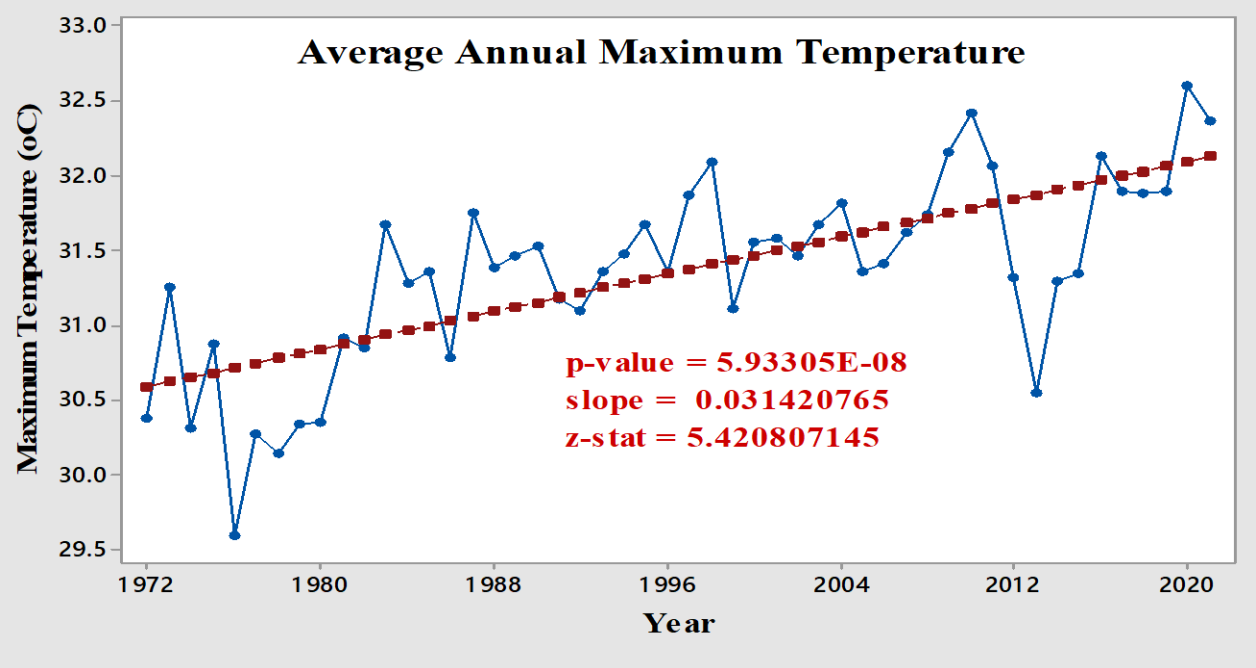

Fig. 3: Mann-Kendall trend test for average annual maximum temperature

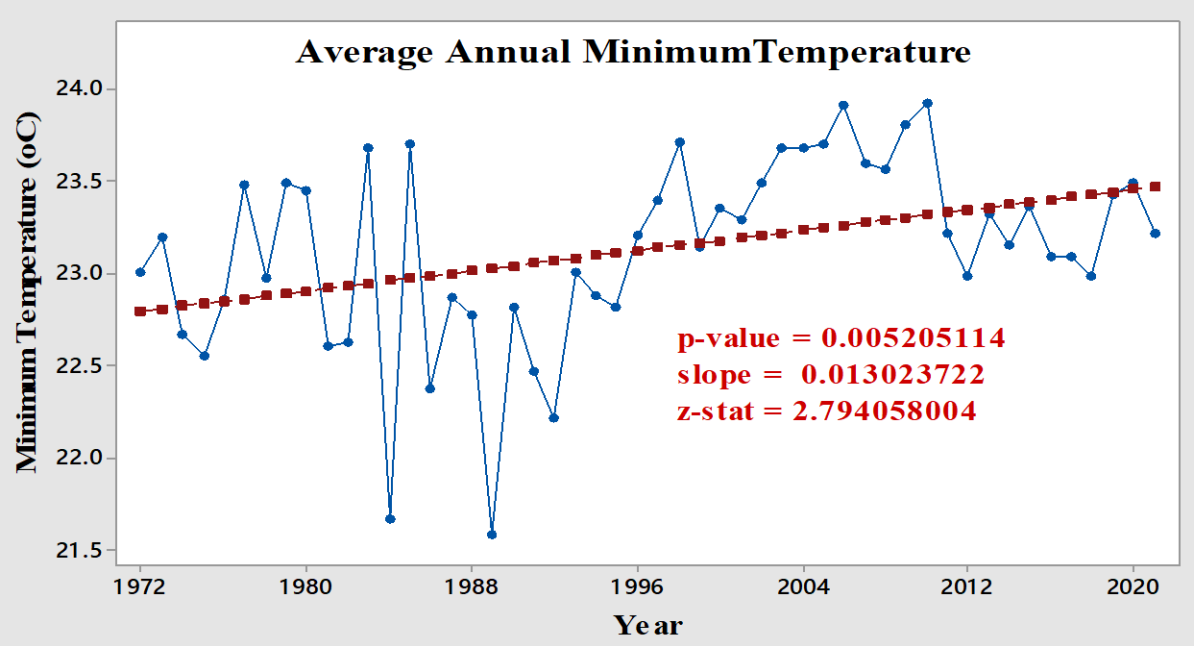

Fig. 4: Mann-Kendall trend test for average annual minimum temperature

3.3 Analysis of Relative Humidity

The output of the analysed relative humidity series is summarised in Fig. 4. The MK test for relative humidity showed a significant decreasing trend in the average annual datasets at a 95% confidence level. The significant decreasing trend in the annual relative humidity series was found to be -0.104% per year. Gocic and Trajkovic (2013) attributed a decreasing trend in the annual series of relative humidity to an increase in atmospheric temperature.

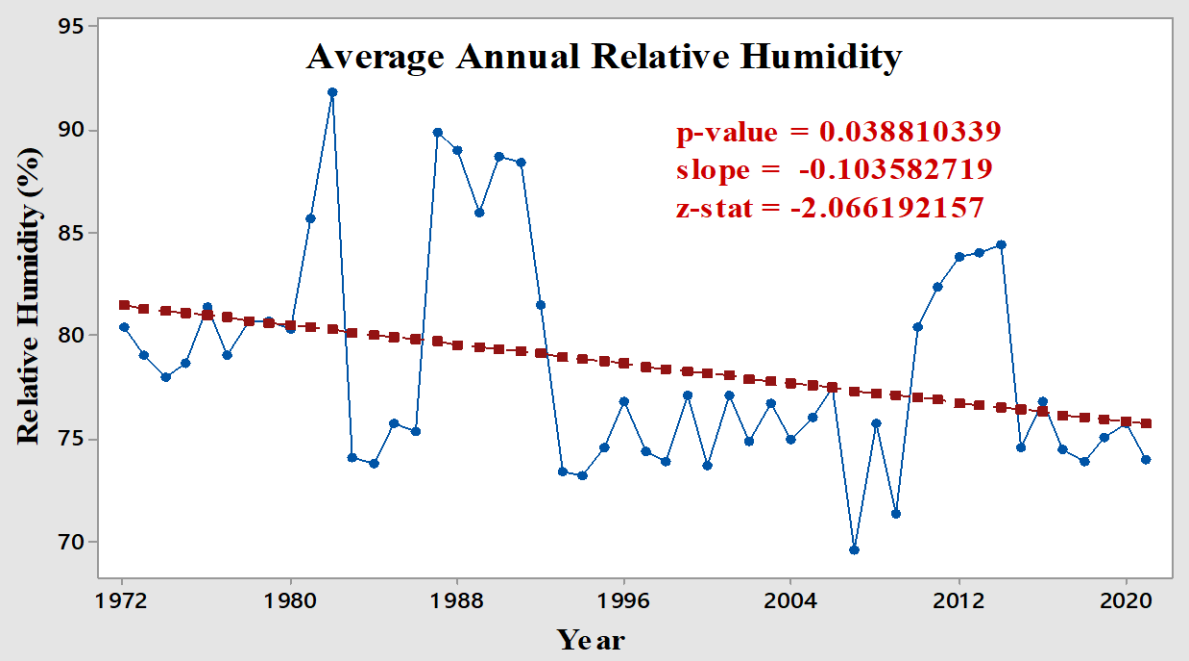

Fig. 5: Mann-Kendall trend test for average annual relative humidity

3.4 Analysis of Solar Radiation

Solar radiation is another important climate parameter that was considered in this study. The results of the MK test and Sen's slope estimate for solar radiation of decade, annual and monthly data series are presented in Fig. 5. The MK test for solar radiation revealed a significant decreasing trend of mean annual datasets. The significant decreasing trend in mean annual solar radiation was -8.78 MJ/m^2 per year. According to Sarkar *et al.* (2022), significant decreasing trend in solar radiation is likely due to atmospheric changes when increases in cloudiness, precipitation, heavy fog, and aerosol concentration occur.

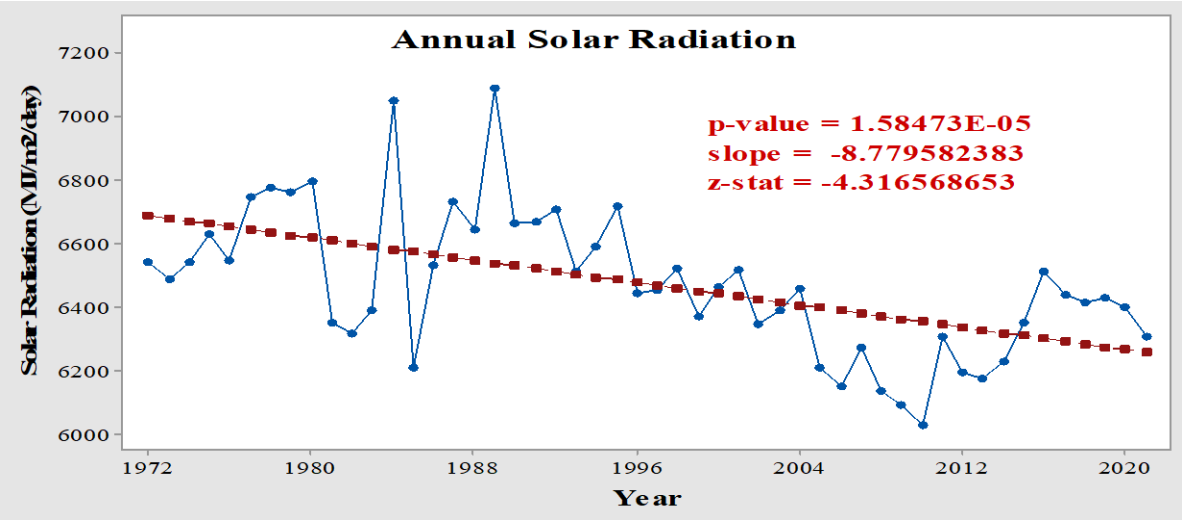

Fig. 6: Mann-Kendall trend test for mean annual solar radiation

3.0 Conclusion

The variability of the climate has not been properly investigated in Nigeria. Because of that, the aim of this study was to perform an analysis of the annual trends and coefficients of variation of seven hydro- meteorological variables in Akwa Ibom State, Nigera, from 1972 to 2021. The analysis was obtained by applying the non-parametric Mann- Kendall and Sen's slope estimator methods to the time series.

The results of Mann-Kendall and Sen's slope analysis reveal a significant statistically increasing (positive) trend in average annual rainfall, maximum temperature, and minimum temperature. However, a significant statistically decreasing (negative) trend was observed in average annual relative humidity, and solar radiation. The magnitude of the trends was 19.39mm/year, 0.0314^{o}C/year, 0.013^{o}C/year, -0.104%/year, and -8.78MJ/m^2/year, for annual rainfall, maximum temperature, minimum temperature, relative humidity, and solar radiation, respectively. The increasing trends in precipitation, temperatures and runoff in this study area indicate that this region faces climate variability.

In general, the results of using Mann-Kendall and Sen's slope estimator statistical tests pointed out the agreement of performance that exists in the detection of the trend for the meteorological variables. Changes in atmospheric temperature and rainfall amounts will have significant impacts on water resource structures, biodiversity and food security in Nigeria. Therefore, substantial reductions of heat-trapping gas emissions and adaptation strategies are crucial in Nigeria. Besides, further research comparing Mann-Kendall with

another trend identification test is recommended. Finally, additional meteorological stations should be established in the catchment area by the authorities concerned in order to carry out an attribution study of meteorological trends in specific locations and analyse the spatial distribution of trends.

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Compliance with Ethical Standards

Declaration

Ethical Approval

Not Applicable

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Authors' Contribution

All aspects of the work were done by the author, SEU