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RESEARCH ARTICLE

A MONOTONIC TREND ANALYSIS OF THE SURFACE AIR TEMPERATURE USING MANN-KENDALL TEST (MK) OVER NORTH-EASTERN REGION OF NIGERIA

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ABSTRACT

One of the key concerns addressed in the last 20 years was climate change, of which temperature is one of the indicating variables. According to the Nigerian National Petroleum Corporation (NNPC), hydrocarbon resources have been found at the Kolmani River II in the Northeast. The relative permeability of gas increases while the relative permeability of oil barely changes as temperature rises. Foamy oil responds well to thermal recovery at an intermediate temperature, but foamy behavior can be inhibited at much higher temperatures, which seems to offset the benefits of viscosity reduction. The goal of the current study was to examine the temporal variations in temperature during 41 years in North-eastern Nigeria (i.e 1981 to 2022). A non-parametric statistical technique called the Mann-Kendall test was used to examine trends in the yearly and seasonal temperature series. This test is useful for identifying patterns in data over time. In conclusion, the yearly mean temperature series appears to have a significant trend, as indicated by the statistically significant Mann-Kendall test statistics of 4.9864 and the associated 2-sided p-value of 0.0000006152. The dataset exhibits a positive trend, as indicated by the Sen's slope of 0.05625. This suggests that surface air temperature is rising in Nigeria. Majority of Nigerians depend on temperature-sensitive economic activities; hence the country is likely among those most vulnerable to the negative effects of global warming. As a result, the models created for this study may help to forecast temperatures over the areas it examined.

KEYWORDS

Mean temperature, Trend, Mann-Kendall test, Climate change, North-Eastern Nigeria.

1. INTRODUCTION

The operations, stability, and expansion of the petroleum industry are already being jeopardized by the far-reaching consequences of climate change (Katopodis and Sfetsos, 2019; Pathak et al., 2021). Climate change and extreme weather events, such as hurricanes, high winds, lightning strikes, storm surges, and floods, provide additional problems to the oil supply chain from upstream to downstream because oil infrastructure has lifetime forecasts that range decades. (Katopodis and Sfetsos, 2019).

Discussions at the worldwide conference centre on the problem of climate change. Regarding their potential long-term effects on sustainable economic growth, governments and environmental non-governmental organizations evaluate them as one of the major concerns across the globe (Starikova and Shamanina, 2021). Understanding the fluctuation of the climate is crucial in today's world. The Earth's climate is shifting, resulting in a rise in extreme weather occurrences such as droughts, floods, and unusually high or low temperatures (Lopes and Tenreiro Machado, 2014). Surface air temperature analysis is a crucial topic that can aid in our comprehension of climatic variability (Rahman and Lateh, 2015). Using this information, proactive measures can be developed to minimize the anticipated negative effects of global warming and temperature on the production of oil and gas as well as to prevent them altogether (Katopodis and Sfetsos, 2019; Nath and Behera, 2010).

According to the Nigerian National Petroleum Corporation (NNPC), hydrocarbon resources have been found at the Kolmani River II Well on the Upper Benue Trough in the Gongola Basin, located in the country's northeast (Ajiya, 2023). The relative permeability of gas increases while the relative permeability of oil barely changes as temperature rises. Foamy oil responds well to thermal recovery at an intermediate temperature, but foamy behavior can be inhibited at much higher temperatures, which seems to offset the benefits of viscosity reduction (Toby, 2021). Therefore, in other to address the problem there is need to examine the behaviour of the surface air temperature in other to obtain better result (Zhang et al., 2020).

Various approaches have been utilized in the examination of temperature time-series, such as: (Ofure et al., 2021). Used an artificial neural network to predict the air temperature across Nigeria. Using downscaling to the outputs from the Doubled CO_2 scenario, a group researchers determined the trend of surface air temperature at the Sylhet district (Ishaque et al., 2021). The Mann-Kendall Trend test and Sen's slope estimator were used to conduct the trend analysis. A group researchers determine the Yola, North Eastern Nigeria, Land Surface Temperature Using the Landsat-7 ETM+ Satellite Image (Alkasim et al., 2018). Determine how urban growth will affect Harare's future microclimate by employing Cellular Automata Markov Chain analysis to anticipate changes in land surface temperature, land use, and land cover in the future (Mushore et al., 2017).

Similarly, a group researchers assessed how well the Model for Prediction Across Scales–Atmosphere (MPAS-A) predicted the Winter Surface Air Temperature in Week 2 (Li et al., 2022). Applied Sub-Seasonal Surface Air Temperature Forecasting using Super ensemble Methods: Pilot Studies

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across Northeast Asia in 2018 (Zhu et al., 2021). A group researchers reviewed Neural Networks for Air Temperature Forecasting (Tran et al., 2021). Forecasted soil temperature based on surface air temperature using a wavelet artificial neural network (Araghi et al., 2017). Applied three artificial neural network techniques to forecast the daily mean, maximum, and minimum temperature time series (Ustaoglu et al., 2008).

Moreover, some researchers explored the possibility of calibrating one-month surface air temperature forecasts for South Korea using Bayesian model averaging, employed pattern projection methods to statistically calibrate surface air temperature forecasts for East Asia (Kim and Suh,, 2013; Lyu et al., 2021). SARIMA was utilized to forecast the monthly mean surface air temperature in Ghana's Ashanti region (Asamoah-Boaheng, 2014). Used WRF to perform dynamic downscaling of near-surface air temperature at the basin scale: a case study in the Chinese Heihe River Basin (Pan et al., 2012). Examine the predictions of air temperature made with machine learning methods (Cifuentes et al., 2020). A group researcher created a cutting-edge hybrid intelligence model to forecast sun radiation globally over North Dakota dependent on air temperature (Tao et al., 2021).

Based on the literature, Mann-Kendall test is used to detect linear trend in time series data. It gives better predictions to the temperature data and most of hydrological data are data with non-seasonal effect (Zhu et al., 2021). However, application of Mann-Kendall test for the mean annual temperature time series has not yet been studied in literature in predicting the surface air temperature of the North-eastern region of Nigeria. This research work aims to apply and assess the performance of the models in the study area. This study's objective was to apply Mann Kendall test model to investigate the rise in local temperature in North Eastern region of Nigeria in order to suggest preventive measures for the oil and gas production, food industry, the tourism, and other sectors.

2. Materials and Methods

Mann-Kendall test (MK) was first developed by Mann in 1945 and then improved and modified by Kendall in 1975. The test is usually recommended when data from multiple locations are included in a single study (Nourani et al., 2018). The main advantage of the method is that it does not require the data to follow any specific statistical distribution; rather, it merely requires that the data be normally distributed (Nourani et al., 2015). Perhaps the most popular technique for analyzing trends in hydro-climatological variables across time is Mann-Kendall test.

For a given time series of n data points, the MK statistic (S) is defined as the sum of the positive differences minus the negative differences, where X_j is the data point at time j (Nourani et al., 2018).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(X_j - X_i) \tag{1}$$

$$sgn(X_j - X_i) = \begin{cases} 1 & if\ X_j - X_i > 0 \\ 0 & if\ X_j - X_i = 0 \\ -1 & if\ X_j - X_i < 0 \end{cases} \tag{2}$$

Where n = i, j = 1,2,3,…,n, and the sign function is denoted by $sgn(X_j - X_i)$. The magnitude of S indicates the degree of trend in the data. An upward trend is indicated by a very high positive value of S, and a downward trend is indicated by a very low negative value (Lornezhad et al., 2023). S very nearly resembles a normal distribution when there are more than eight observations, as proven by (Mann, 1945; Kendall, 1975). Its mean and standard deviation are determined by the relationships below:

$$E(S) = 0 \tag{3}$$

$$V(S) = n(n-1)(2n+5) - \frac{\sum_{i=1}^{n} t_i(t_i-1)(2t_i+5)}{18} \tag{4}$$

In the ith category, t_i represents the total number of identical data. Written as follows is Kendall's standardized Z statistic:

$$Z = \begin{cases} (S-1)/\sqrt{V(S)} & S > 0 \\ 0 & S = 0 \\ (S+1)/\sqrt{V(S)} & S < 0 \end{cases} \tag{5}$$

The Z statistic is a normal distribution-based standardized Mann–Kendall test with a mean of 0 and a variance of 1 (Nourani et al., 2018).

3. Results and Discussion

The results from Mann Kendall test techniques are presented below to predict trend in the annual mean temperature of the northeastern region of Nigeria. Normality test was used to assess and examine the overall behaviour of the temperature data. The result shows slight level of variation as it was shown in figure 1, 2 and 3 respectively.

Table 1: Descriptive Statistics of the Mean Temperature Data of the north-eastern region of Nigeria

Descriptive Statistics of the Mean Temperature Data of the North-Eastern Region of Nigeria	
Mean	31.09225
Median	31.70000
Mode	35.70000
Maximum	38.70000
Minimum	22.70000
Std. Dev.	0.194479
Skewness	- 0.13348
Kurtosis	- 1.31176
Sum	15639.4
Sample Variance	19.02446
Observations	503
Confidence Level (95.0%)	0.382093

Table 1 presents the descriptive statistics of the mean monthly temperature data of the north-eastern region of Nigeria considered in this study. It has shown that the region has a mean temperature of 31.09225 °C, and standard deviation 0.194479 which is small indicating that the data points are relatively close to the mean and there is less variability. The distribution has the minimum temperature of 22.70 °C and maximum temperature of 38.70 °C respectively. The value for Skewness is - 0.13348 which indicate that the distribution is skewed to the left meaning that the data is more spread out towards the lower end of the scale and kurtosis is - 1.31176 which implies that the distribution is less peaked and has thinner tails compared to normally distribution. Therefore, the distribution is asymmetric and platykurtic. A histogram plot and a normality test for the temperature series is plotted in Figure 1.

The scatterplot of the temperature series in figure 2 described the behaviour of the temperature series which shows a little variation in the temperature series

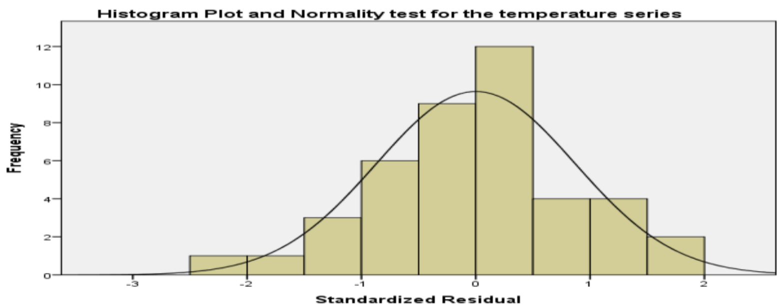

Figure 1: Histogram plot and normality test for the temperature series

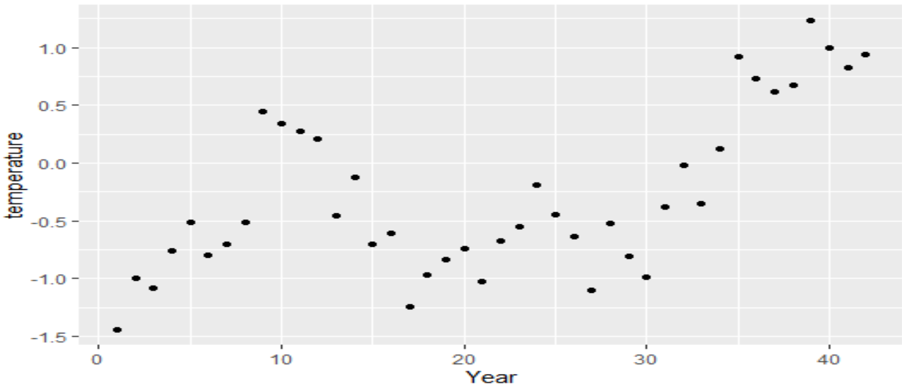

Figure 2: Scatter plot of the annual north-eastern temperature series

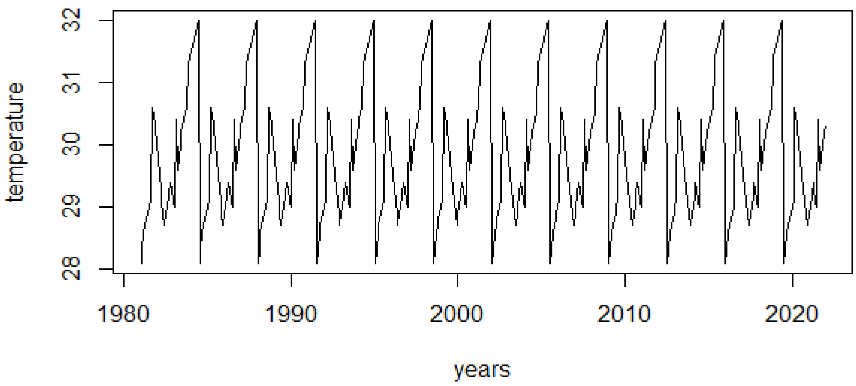

Figure 3: Time Plot for the Mean Monthly Temperature Data.

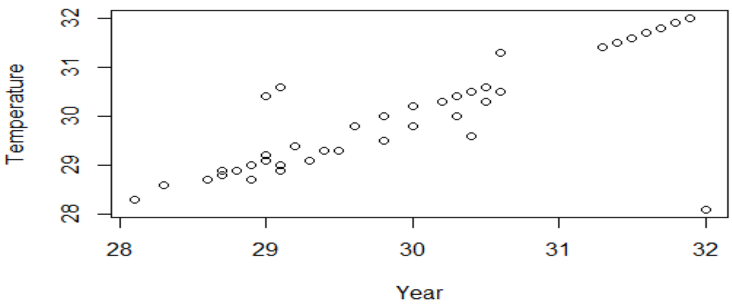

Figure 4: Scatter plot of the north-eastern temperature series

The plot of the series in figure 3 shows a random walk indicating cycles in the data, and also shows a pattern of seasonality in the series at level. It is therefore important to confirm seasonality and assess whether there is overall trend in the data over time in other to understand the long-term behaviour of the variable. A scatter plot in figure 4 displays the relationship between the variables. The plot shows a positive correlation since the values of both variables increase together. The points form a pattern that slopes upwards from left to right. In addition the plot also provides the strength and direction of the correlation suggesting a strong correlation. To confirm seasonal, cyclical, and trend in the series data, we plot a residual ACF and PACF as shown in figure 4 and 5 respectively. The ACF and PACF plot is used to capture the temporal structure of the time series accurately in other to improve the forecasting accuracy.

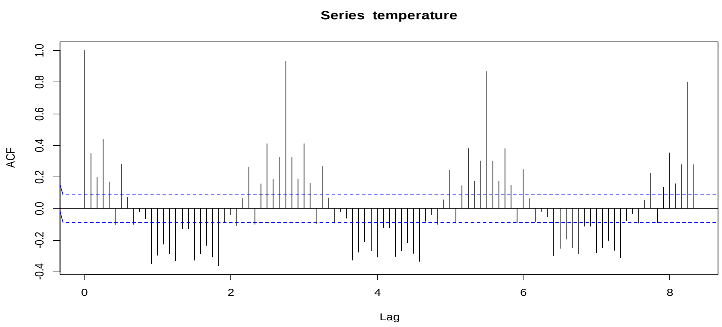

Figure 5: Residual ACF Plot

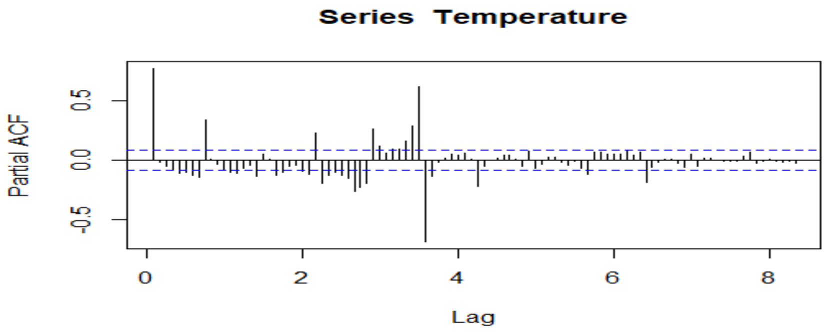

Figure 6: Residual PACF Plot

The plot of the residual ACF in figure 5 above shows correlation coefficients at various lags, taking into account the seasonal components. In this plot, you can typically see significant spikes at the seasonal lags, the significant spikes occurs at lag 12 suggesting a seasonal pattern with an annual cycle. While the plot of the residual PACF in figure 6 shows partial correlation coefficient at various lags, controlling the intermediate lags including the seasonal lags. This indicates the presence of seasonal autocorrelation and partial autocorrelation.

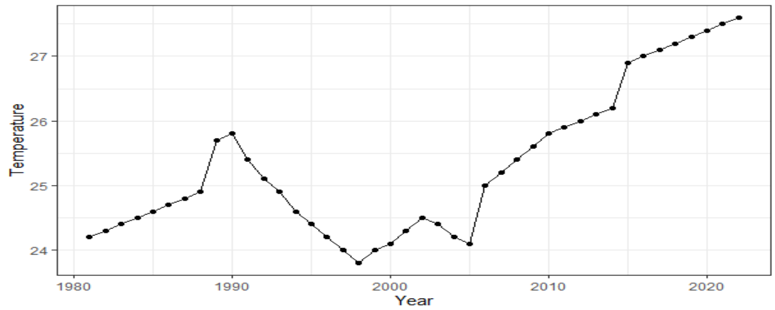

Figure 7: Plot of the annual temperature series

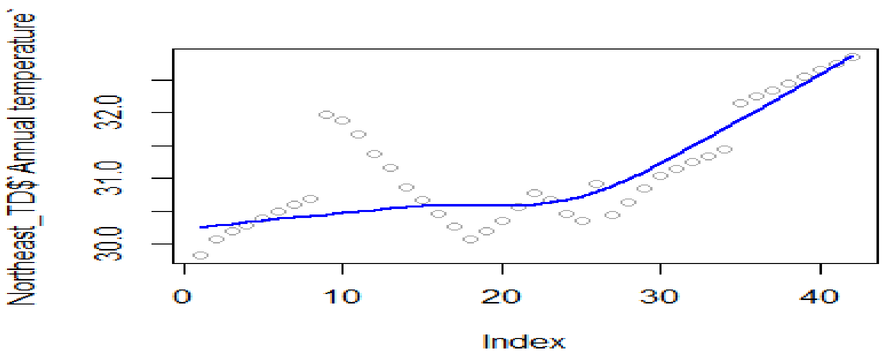

Figure 8: Graphical representation of the Mann-Kendall trend test

The plot in Figure 7 reveals the behaviour of the series over the period of interest. The graphical representation of the Mann-Kendall trend test in Figure 8 reveals the underlying upward trend present in the data more clearly: This refers to a consistent increase in average temperatures over a period of time, usually on a global or regional scale.

Table 2: Mann-Kendall trend test	
Mann-Kendall Test for the temperature data	
Tau (Kendall tau statistic)	0.536672
p-value	6.152e-07
S (Kendall score)	461.000000
Var (variance of Kendall score)	8510.333333
Z	4.9864000
N	42

alternative hypothesis: true S is not equal to 0

The Mann-Kendall test from table 2 shows that the test statistics is 4.9864 and the corresponding 2-sided p-value is 0.0000006152 Since the p-value is less than the level of significant (i.e p-value = 0.0000006152 < 0.05) then our data satisfies the criteria for p-value, the p-value associated with the Mann-Kendall test is statistically significant, suggesting the presence of a statistically significant upward trend in the annual mean temperature series. Therefore, we reject the null hypothesis of the test and conclude that a trend is present in the data. The Sen's slope is 0.05625 indicating a positive trend in the dataset.

4. Conclusion

Time series analysis is an important tool for understanding trends and patterns in data. Mann Kendall's test was specifically used in this study to determine if there is a consistent upward or downward trend in a time series dataset. Mann Kendall's test was successfully applied to identify an upward trend in this study. This analysis provides valuable insights into the behaviour of the variable. Mann Kendall's test is widely used in climate science and other fields to analyze trends in temperature data. By applying this test, we identify a significant upward trend in temperature over a specific period of time. This provides valuable information for predicting future temperature patterns and climatic changes. The Mann Kendall's test fails particularly when the time series have nonlinearity. This condition causes the time series to have unpredictable turning points that the model cannot accurately match. Therefore, this study recommends potential extensions or variations of the Mann Kendall's test model, such as modified Mann Kendall's test, seasonal Mann Kendall's test or hybrid approaches in other to enhance the problem of nonlinearity in time series analysis.

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