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Trend Analysis of Some Meteorological Parameters in Benue State, Nigeria

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Abstract

This research work determines the trend analysis of some meteorological parameters in Benue state. This study examined the annual trend in temperature, relative humidity, precipitation and wind speed variation in Benue state Nigeria from 1982-2020 using Satellite data. In this study Microsoft-excel 2016 and other statistical tools were used to determine the annual temperature, relative humidity, precipitation and wind speed, seasonal temperature, relative humidity, precipitation and wind speed, cumulative seasonal temperature, relative humidity, precipitation and wind speed. Results indicate that maximum annual temperature of 27.22^{0}C occurred in 2019 and minimum of 24.67^{0}C occurred in 1984. It is also observed that annual relative humidity is high in 1982 with the value of 78.57% and low in 2017 with the value of 66.01%. Annual wind speed is high in 2015 with the value of 2.272m/s and minimum in 1987 with the value of 1.781m/s. while annual precipitation was high in 2000 with the value of 183.79mm and low in 1999 with the value of 68.08mm. The regression model of temperature and wind speed shows a positive slope trend (0.00388 and 8.44481E-5) which suggests that the monthly trend in the area of study is increasing over time. The regression model also shows a negative slope trend (-0.10062 and -0.0125) of precipitation and relative humidity which suggests that the monthly trend in the area of study is decreasing over time. The study therefore recommends that proactive measure like making accurate and appropriate weather and climate data available for economic planning should be encouraged by all, to mitigate these consequences especially on population whose livelihood depends on agriculture that is temperature sensitive.

Keywords: Trend Analysis, Meteorological Parameters, Annual Trend in Temperature, Relative Humidity, Precipitation, Wind Speed Variation

Introduction

A trend is a long-term change (increase or decrease) in a time series. A trend analysis is ordinarily used in climatology to know how the temperature for example, changes with time. In Africa temperature and precipitation are the two most studied parameters in terms of past, present and future trend because of the economy that is based mainly on agriculture [1, 2]. Regional temperature and rainfall over the West Africa region have changed with time and this has caused damages to the ecosystems and the interrelationships between them [3-5]. Trend analysis has been greatly carried on different parameters in many part of the world [6, 7].

In Nigeria, trend analysis has been done Akinsanola, and Ogunjobi [8]; statistical approaches have been directly used on the data such as the kurtosis and skewness coefficients to detect changes and variations in the temperature and rainfall values. Similarly, Oluwatobi, and Oluwakemi [9], did in the South West of Nigeria a study on trend and variability of temperature.

Weather is the state of the atmosphere at a given time at any given location [10]. It may also be referred to as the aspects of the atmospheric state which is visible and experienced, which affect human activities. The weather conditions of any given location is often described in terms of the meteorological elements which include the state of the sky, temperature, winds, pressure, precipitation, and humidity. These factors initiate and influence the atmospheric processes [11]. Whereas climate is the common average weather condition of a particular region over a long period of time (for example, over 35 years). The constituents of climate parameters include rainfall, temperature, relative humidity, atmospheric pressure, wind and solar radiation. The state of the atmosphere at a particular time and place occurs primarily in the troposphere, or lower atmosphere, and it's driven by energy from the sun and the rotation of the earth.

Weather forecasting is the application of current technology and science to predict the state of the atmosphere for a future time and at a given location. These are made by collecting as much data as possible of the current state of the atmosphere for a future time and at a given location.

Meteorological parameters affect the propagation of electromagnetic (EM) waves, however, the sources of these EM waves have their propagation frequencies, and these frequencies are directly linked to the extent at which the atmosphere affects their signal propagation (Particularly the temperature, humidity, evaporation, rainfall and wind) and using understanding of atmospheric processes (through meteorology) to determine how the atmosphere evolves in future [12].

Current climate variability is imposing a challenge by affecting productivity, tourism and the way plants grow due to high dependence on rain fed and how to predict and control the future behaviour of climate parameters to maximize the agricultural production.

The result obtained from the analysis of the meteorological parameters under study will provide the pattern and trend or variation of the rainfall, temperature and evaporation in Benue State. The information from the study can be used by agriculturist in planning their farming activities and taking necessary precautions with respect to the effect of change of these meteorological parameters having a thorough knowledge of the pattern of the weather condition of the place.

Material and method

Material

Data, Microsoft office (Excel and word 2007), and Statistical Package for Social Science (SPSS) version 16.0

Study Area

Benue State lies within the lower river Benue trough in the middle belt region of Nigeria. Its geographic coordinates are Latitude 6° 25' to 8° 8' North and longitude 7° 47' to 10° 0' East (National Bureau of Statistics, 2012). The State shares boundaries with five other states namely: Nasarawa State to the north, Taraba State to the east, Cross-River State to the south, Enugu State to the south-west and Kogi State. The state has a total land area of 30,800 sq. km (National Bureau of Statistics, 2012). The total population is estimated to be 4,253,641 (National Bureau of Statistics, 2012). The State generally has about 5-7 months of rainfall. Temperatures are constantly high throughout the year, with average temperatures ranging from 23°C-32°C.

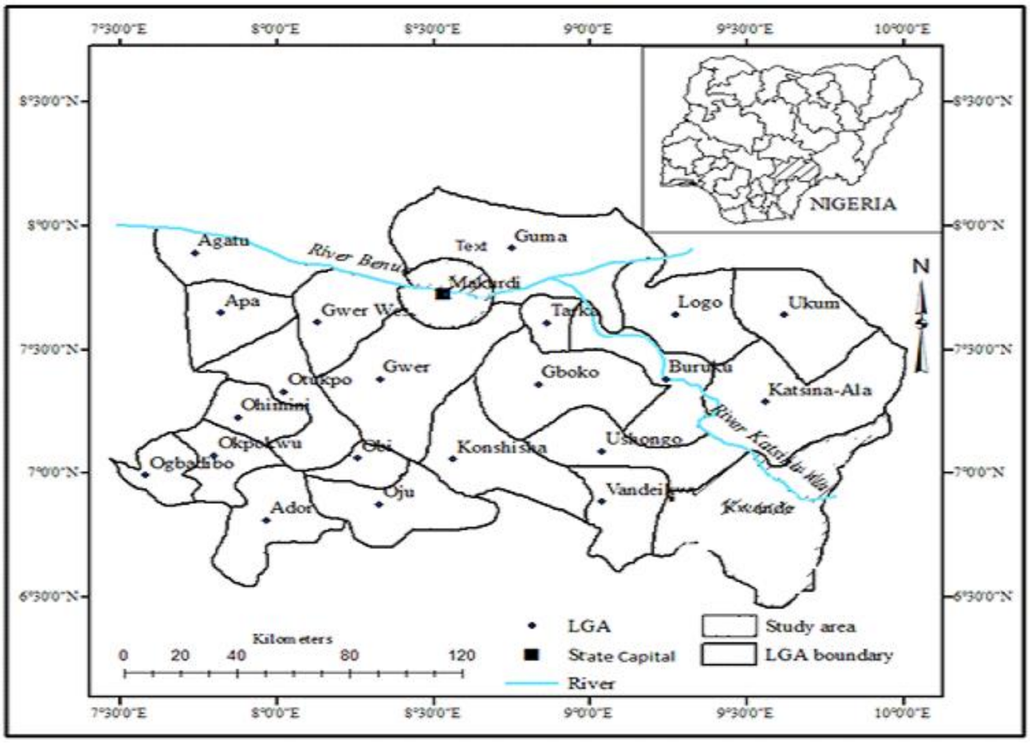

Fig 1: Map of Benue St

Data Collection

The data used in this research work were downloaded from Satellite Maps using the Modern Era Retrospective Reanalysis (MERRA 2) of the National Aeronautic and Space Administration (NASA). It spans from 1982–2020 and contains daily average of temperature (ºC), wind speed (m/s), precipitation (mm) and relative humidity (%).
https://climatedataguide.ucar.edu/climate-data/nasas-merra2-reanalysis

Methodology

The methodology applied for the study includes computation of mean monthly values, statistical analysis, application of trend detection and change point analysis for different climatic variables. In the analysis, different statistical tests were applied on maximum temperature, minimum temperature, evaporation and rainfall annual and seasonal (summer, rainy and winter) basis for determination of change point analysis and detection of trend for identification of climate change impact. Different statistical tests applied on meteorological parameters are described below.

Tests for Trend Analysis

The trends in historical series of meteorological data have been assessed using linear regression and Mann-Kendall tests, as given below:

Linear Regression Test

In linear regression test, a straight line is fitted to the data and the slope of the line may be significantly different from zero or not. For a series of observations x_i, i = 1, 2, 3,…n, a straight line in the form of y = a + bx is fitted to the data and then the test statistics (t) can be computed as:

$$a = \bar{y} - b\bar{x} \quad \text{(i)}$$

$$b = \frac{\sum(x_i - \bar{x})(y_t - \bar{y})}{\sum(z_i - z)^2} \quad \text{(ii)}$$

$$\sum \varepsilon^2 = \sum(y - \bar{y})^2 - b\sum(x - \bar{x})^2 \quad \text{(iii)}$$

$$S_b = \frac{\varepsilon_t^2}{(n-2)\sum(x - \bar{x})^2} \quad \text{(iv)}$$

$$t = \frac{b}{S_b} \quad \text{(v)}$$

Where, a, b are the intercept and slope of fitted line, respectively, $\sum\varepsilon^2$ is the sum of squares of residuals or errors and S_b is the standard error of b. The hypothesis in this test is confirmed using students t-test.

Mann-Kendall Test

Mann-Kendall test is a non-parametric test which does not require the data to be normally distributed; this test has low sensitivity to abrupt breaks due to inhomogeneous time series [13]. This test has been recommended widely by the World Meteorological Organization for public application [14]. Furthermore, Burn and Elnur [15], Yue *et al.* [16] and many more have used this test for evaluating the trend in climatic, hydrological and water resources data. In this test, each value in the series is compared with others, always in sequential order. The Mann-Kendall statistic can be written as:

$$S = \sum_{i=1}^{n}\sum_{j=1}^{i-1} sign(x_i - x_i) \quad \text{(vi)}$$

Where, n is the total length of data, x_i and x_j are two generic sequential data values, and function sign (x_i –x_j) assumes the following values

$$Sign(x_i - x_j) = \begin{cases} 1, if\ (x_i - x_j) > 0 \\ 0, if (x_i - x_j) = 0 \\ -1, if\ (x_i - x_j) < 0 \end{cases} \quad \text{(vii)}$$

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

$$E(S) = 0 \quad \text{(viii)}$$

$$Var(S) = \frac{1}{n}[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)] \quad \text{(ix)}$$

where, n is the length of time series, and t is the extent of any given tie and Σt denotes the summation over all tie number of values. The standardized statistics Z for this test can be computed by the following equation:

$$Z = \begin{cases} \frac{S+1}{\sqrt{Var(S)}},\ if\ S > 0 \\ 0, \qquad if\ S = 0 \\ -1, \qquad if\ S < 0 \end{cases} \quad \text{(x)}$$

In this test, the null hypothesis H_0 is confirmed if a data set of independent randomly distributed variables has no trend with equally likely ordering. Any positive value of test statistic Z indicates a rising, while a negative value may conclude a declining trend in series. The computed absolute value of Z is compared with the standard normal cumulative value of Z (1-p/2) at p % significance level obtained from standard table to accept or reject null hypothesis and ascertain the significance of trend.

Results

Table 1: Annual analysis of precipitation, wind speed, relative humidity and temperature from 1982 - 2020

Year	Annual Precipitation(mm)	Annual wind speed(m/s)	Annual Temperature (0C)	Relative Humidity (%)
1982	160.63	1.914	24.74	78.57
1983	156.43	2.127	24.87	75.25
1984	129.27	1.854	24.67	77.39
1985	107.46	1.877	24.93	75.36
1986	119.95	2.046	25.23	76.09
1987	110.37	1.781	25.98	73.22
1988	129.50	1.881	25.72	75.71
1989	131.96	2.103	24.73	73.78
1990	100.89	1.921	25.67	74.89

1991	106.69	1.973	25.49	76.19
1992	133.18	2.161	25.00	73.40
1993	129.32	2.044	25.11	76.97
1994	136.51	2.025	24.92	77.35
1995	155.21	1.908	25.02	77.94
1996	134.26	1.850	25.09	78.17
1997	138.81	1.879	24.95	77.06
1998	118.75	1.896	25.70	75.37
1999	68.08	1.983	26.22	72.45
2000	183.79	2.118	25.84	69.99
2001	115.97	1.866	24.89	75.93
2002	177.34	2.019	25.50	74.70
2003	97.72	1.810	25.70	75.80
2004	80.69	2.009	26.19	71.79
2005	87.32	2.138	26.61	72.21
2006	101.44	1.981	26.16	73.91
2007	142.99	1.999	25.56	74.58
2008	92.40	1.824	25.38	75.33
2009	90.43	1.815	26.13	75.58
2010	106.56	1.964	26.30	74.49
2011	88.32	2.001	25.85	73.37
2012	2992.53	1.961	25.77	75.54
2013	81.30	1.996	26.44	74.52
2014	78.14	1.967	26.85	69.72
2015	71.13	2.272	26.84	66.01
2016	109.38	2.043	26.58	70.19
2017	103.24	1.790	26.32	72.91
2018	78.67	2.109	26.53	70.46
2019	83.63	2.063	27.22	67.74
2020	101.86	2.040	26.50	69.17

Table 2: Seasonal analysis of precipitation, wind speed, temperature and relative humidity

Month	Seasonal Precipitation(mm)	Seasonal Wind Speed (m/s	Seasonal Temperature(0C)	Seasonal Relative Humidity (%)
Jan.	8.24	2.21	23.97	51.69
Feb.	9.05	2.16	26.32	53.21
Mar.	35.21	2.37	27.98	64.96
Apr	101.04	2.49	27.96	75.18
May	162.75	2.09	26.99	81.68
Jun	192.86	2.04	25.96	84.59
Jul	202.36	2.14	25.08	86.25
Aug	248.33	2.10	24.90	87.01
Sep	228.80	1.65	25.15	87.14
Oct	155.99	1.35	25.50	85.44
Nov	21.91	1.27	25.24	72.98
Dec	2.37	1.82	23.63	58.83

Table 3: Cumulative Seasonal analysis of precipitation, wind speed, temperature and relative humidity

Month	Cumulative Seasonal Precipitation(mm)	Cumulative Seasonal Wind Speed (m/s)	Cumulative Seasonal Temperature (^{0}C)	Cumulative Seasonal Relative Humidity (%)
Jan.	8.24	2.208	23.97	51.69
Feb.	17.28	4.367	50.29	104.89
Mar.	52.49	6.734	78.27	169.86
Apr	153.53	9.227	106.22	245.03
May	316.28	11.317	133.22	326.71
Jun	509.14	13.362	159.18	411.31
Jul	711.51	15.506	184.26	497.55
Aug	959.83	17.609	209.16	584.56
Sep	1188.63	19.262	234.30	671.70
Oct	1344.62	20.610	259.80	757.14
Nov	1366.54	21.880	285.04	830.12
Dec	1368.91	23.695	308.67	888.95

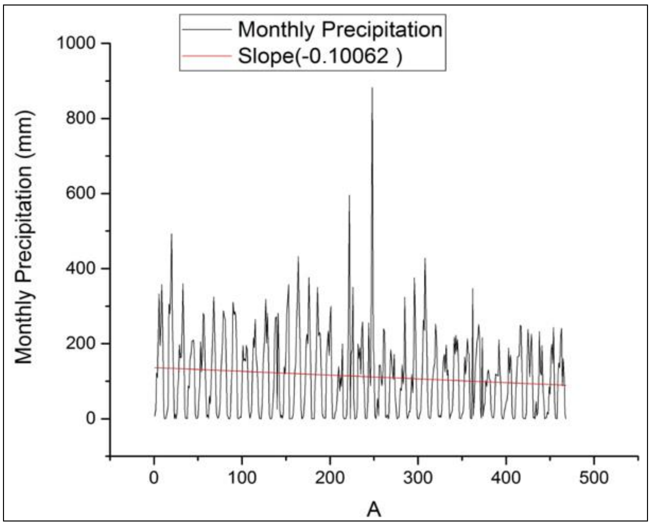

Fig 2: Precipitation Time series from 1982-2020

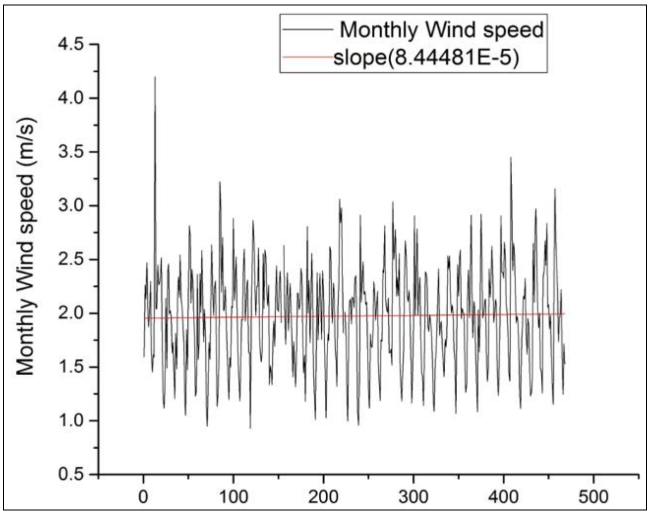

Fig 3: Time series plot monthly wind speed from 1982-2020

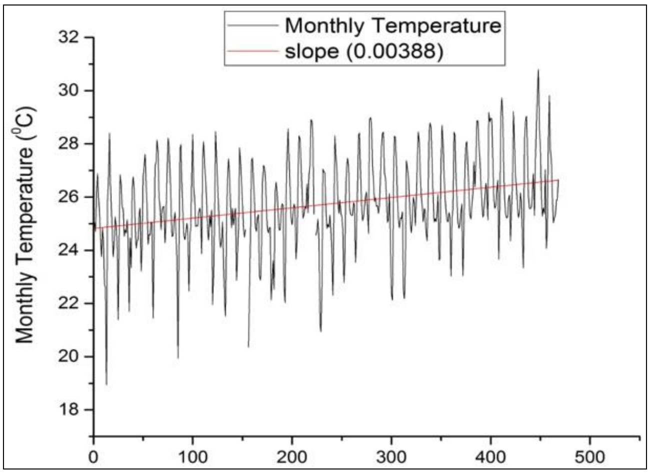

Fig 4: Monthly Time Series Plot of Temperature from 1982-2020

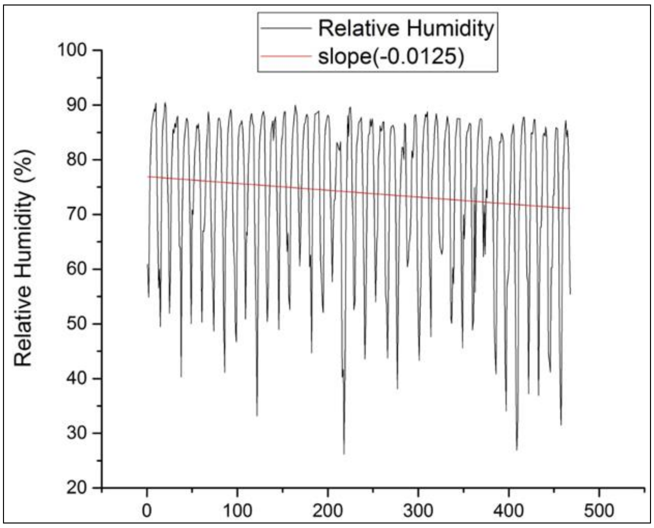

Fig 5: Time Series Plot of Relative Humidity from 1982-2020

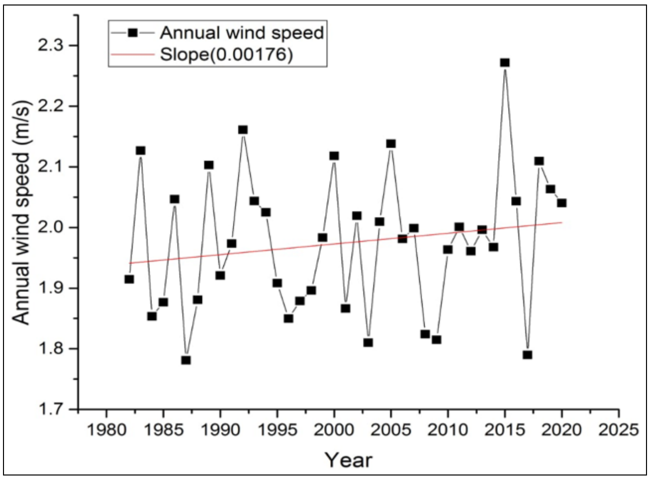

Fig 6: Annual Variability of Wind speed from 1982 – 2020

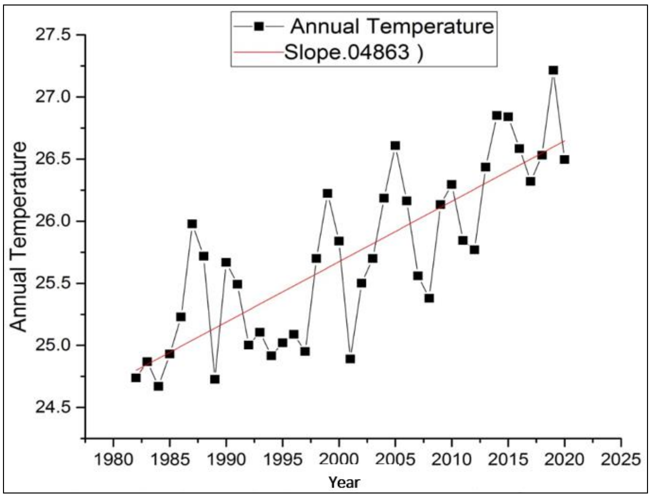

Fig 7: Annual Variability of Temperature from 1982 – 2020

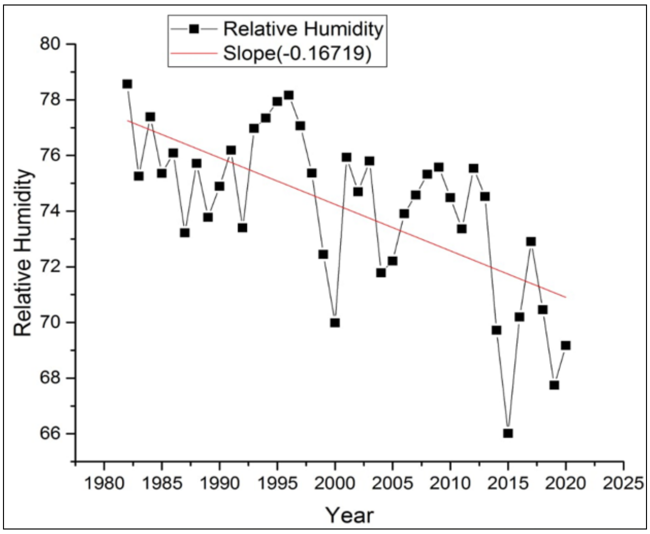

Fig 8: Annual Variability of Relative humidity from 1982 – 2020

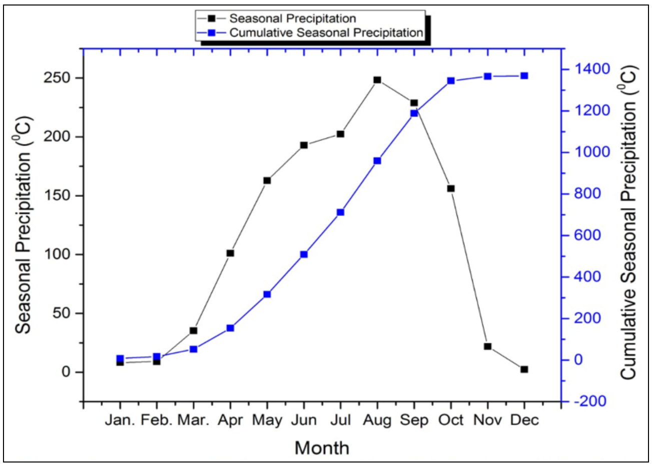

Fig 9: Seasonal Characteristics of Precipitation from 1982 – 2020

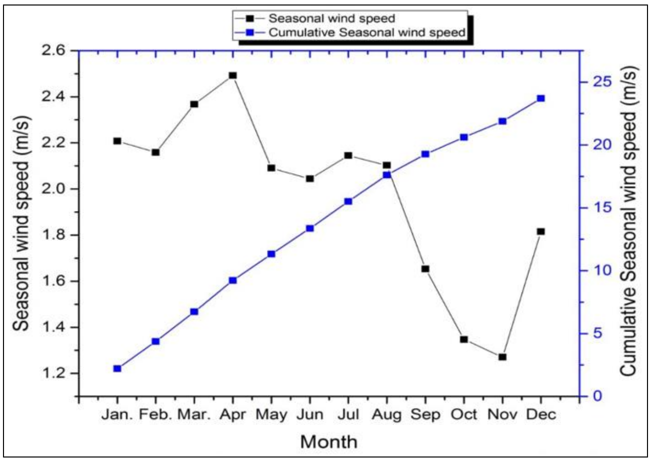

Fig 10: Seasonal Characteristics of Wind from 1982 – 2020

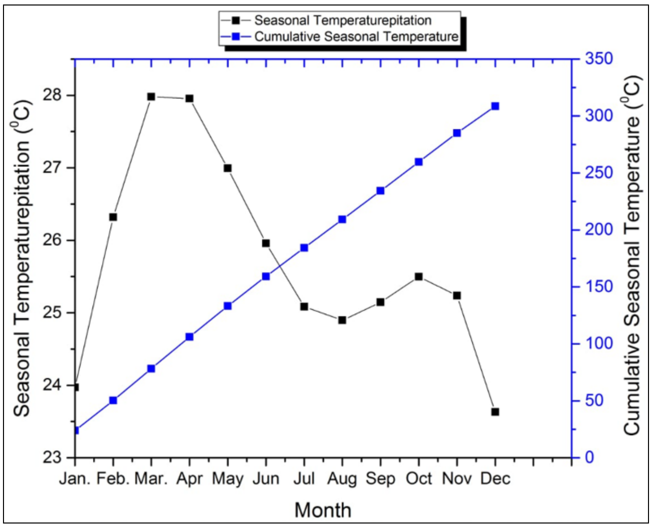

Fig 11: Seasonal Characteristics of Temperature from 1982 – 2020

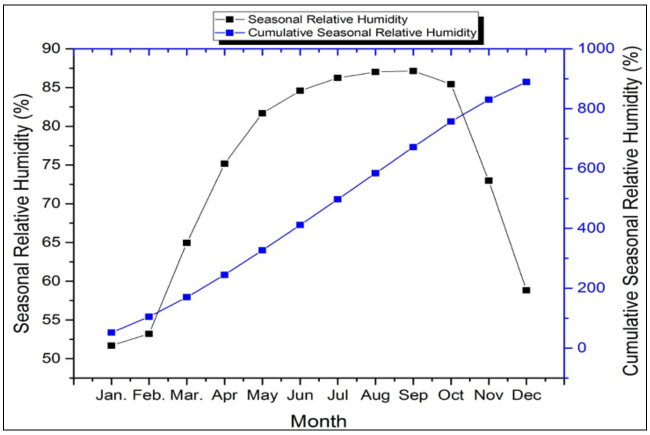

Fig 12: Seasonal Characteristics of Relative humidity from 1982 – 2020

Discussion

Results of statistical analysis performed on the temperature dataset over the region for the period of 38 years ranging from 1982-2020 are shown in figures 2 to 12.

Table 1 shows annual analysis of precipitation, wind speed, relative humidity and temperature from 1982 - 2020. It is observed that maximum or peak annual temperature from 1982-2020 is 27.22^{0}C (2019), while the minimum or lowest trends occur in 1984 with 24.67^{0}C. It can also be seen that relative humidity is high in 78.57% (1982) and low in 66.01% (2017). Table 4.1 also shows that annual wind speed is high in 2015 (2.272m/s) followed by 1992 (2.161m/s), while the minimum occur in 1987 with 1.781m/s followed by 2003 with 1.810m/s. The annual precipitation from 1982-2020 is high with 183.79mm in 2000 followed by 177.34mm in 2002 and low with 68.08 in 1999 followed by 71.13mm in 2015. Table 4.2 show the Seasonal analysis of precipitation, wind speed, temperature and relative humidity which implies that seasonal relative humidity is high in the month of September (87.14%) and low in January (51.69%). It is also observed that seasonal temperature high at 27.98^{o}C in March while low at 23.63^{o}C in December. Seasonal wind speed occurs high in April at 2.49m/s while low in November at 1.27m/s. it can also be seen in Table 2 that seasonal precipitation is high in August (248.33mm) and low in December (2.37mm). Table 3 show the Cumulative Seasonal analysis of precipitation, wind speed, temperature and relative humidity, it is observed that cumulative seasonal relative humidity is high in the month of December (888.14%) and low in January (51.69%). It can be seen that Cumulative seasonal temperature is high at 308.967^{o}C in December while low at 23.97^{o}C in January. Cumulative seasonal wind speed occurs high in December at 23.695m/s while low in January at 2.208m/s. it can also be seen in Table 3 that seasonal precipitation is high in December (1368.91mm) and low in January (8.24mm).

Figure 2 shows precipitation time series from 1982 – 2020. The linear regression model shows a negative trend which is an indication that the trend over the study region decrease as time goes. Figure 3 represent time series plot for monthly wind speed from 1982 -2020, here the linear regression model shows a positive trend which is an indication that the trend over the study region increase as time goes. Figure 4 shows the monthly time series plot of temperature form 1982 – 2020 which indicates that the linear regression model shows a positive trend which is an indication that the trend over the study region increase as time goes. Figure 5 shows time series plot of relative humidity from 1982 – 2020. The linear regression model shows a negative trend which is an indication that the trend over the study region decrease as time goes. Figure 6**:** Annual Variability of Wind speed from 1982 – 2020 shows that, the maximum wind speed occurs in 2015 at 2.3m/s while the minimum is in 1985 at 1.75m/s, this implies that wind speed varies at different stages and years due to its location. It can be observed that the higher and lower annual temperature occurs in the year 2020 and

1983 a point 27.2 and 24.8 respectively as shown in figure 7, this is because different locations has different temperature due to the weather condition. In Figure 8, the lowest and highest relative humidity of 66% and 79% occurred in years 2015 and 1980.

Figure 9 show Seasonal Characteristics of Precipitation from 1982 – 2020. This implies that cumulative seasonal precipitation has it minimum in January and February (0°C) and increases simultaneously to its maximum point in October (1300°C) while seasonal precipitation has its minimum in December (0°C) and in maximum in August (250°C). It can also be observed that cumulative seasonal and seasonal precipitation has the same level of precipitation in the months of January and February respectively. From Figure 10, cumulative seasonal wind speed has it minimum in January (2.5m/s) and it maximum in December (24m/s), this shows that cumulative seasonal wind speed raise continuously from lower point (January) to higher point (December) without dropping throughout the year. Seasonal wind speed raises and drops at different stages throughout the year but it makes it maximum and minimum in April (2.5m/s) and November (1.3m/s). Seasonal Characteristics of Temperature from 1982 – 2020 shows that, cumulative seasonal temperature increases constantly from on January to December at 25°C and 325°C respectively without decrease at any stage. The cumulative temperature is not static, it raises and fall at different months as shown in figure 11, it lower and higher points are obtained from the months of December (23.5°C) and March (28°C) respectively. In figure 12 cumulative seasonal relative humidity also increases constantly from January to December at 100% and 900% respectively while seasonal relative humidity increases from January (52%) to its maximum at September (87%) and decreases back to December making a curve as shown in figure 12.

Conclusion

The study examined trends of some meteorological parameters in Benue State, Nigeria from 1982-2020. Results revealed that there is significant increase (positive trend) in temperature with the highest temperature recorded in 2019 and the lowest in 1984, relative humidity is high in 1982 and low in 2017, wind speed high in 2005 and low in 1987 while precipitation is high in 2000 and low in 1992. Positive and the negative anomalies are the years of excess and deficit temperature, relative humidity, precipitation and wind speed respectively. It is also revealed that seasonal and cumulative seasonal precipitation, temperature, relative humidity and wind speed in Benue state varies in different months depending on the locations. April and August were the months of extremely dry and wet seasons respectively. Evidence has showed that middle belt, Nigeria is particularly vulnerable to climate extremes because of its physical and socioeconomic characteristics..

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