Assessment of Climate Variability Trends in Nasarawa State, Nigeria

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Authors’ contributions

This work was carried out in collaboration among all authors. Author OSO designed and conducted this study under the supervision of authors MIJ and EAS helped prepare the charts and reviewed the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Changing global climate has emerged as one of the greatest environmental problems of mankind in the 21st century. However, there is still a dearth of information regarding the trends and patterns of climate variables at local and specific levels. It is against this background that this paper assessed climate variability trends in Nasarawa State, Nigeria over 21 years’ period (1997 – 2017). Daily data on climate variables for the State was obtained from the Nigerian Meteorological Agency and analysed using the linear trend function in Microsoft Excel. Pattern and course of the variables’ trend were determined using the trend/slope line and the trend equation. Out of the six investigated climatic parameters; maximum temperature, minimum temperature, total annual rainfall and dew points experienced the greatest fluctuation in Nasarawa State during the 21 years’ period (1997 – 2017). Also, while maximum and minimum temperature generally assumed an increasing trend, annual total rainfall and dew points alongside relative humidity and wind speed were generally decreasing. Policymakers in the various earth’s supporting systems such as agriculture, land and

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water, should employ the key findings of this study for advising some suitable adaptation and mitigation policies to cope with climate variability and change.

Keywords: Climate; change; climatic parameters; variability; trends.

1. INTRODUCTION

One of the greatest environmental problems that mankind has been faced with in this 21st century is the worldwide changing climate [1]. The extent of impact associated with the phenomena cannot be underrated considering that it possesses the tendency to affect the production systems of the earth [2,3,4]. The Evaluation Report of the Fifth Intergovernmental Panel on Climate Change (IPCC AR5) has powerfully pointed out that the changing climate has been “undisputable”, and “exceptional” since the mid-20th century [5]. The magnitude of the changing climate impact might have hastened the unsettled debate and research by researchers regarding the origins and penalties of the phenomenon as well as the necessity to develop adaptive strategies.

According to the World Meteorological Organization [6], variation in the mean state and other statistics of the prevailing climate variables on temporal and spatial states beyond normal weather is climate variability. It is used to denote changes in climatic variables over a given period of time as compare to long-term statistics of respective climatic variables. Through its chains of assessment reports in addition to the latest Fifth Assessment Report, the IPCC recognized that changes in the international climate is due to the collective anthropogenic forces resulting to Greenhouse Gases (GHG), which are emitted into the earth’s atmosphere. Although numerous GHG are present in the atmosphere, it is persuasively disputed that carbon dioxide has been one of the greatest anthropogenically generated greenhouse gases that results to atmospheric warming [7].

According to Tubiello [8], the yearly quantity of carbon dioxide that is released into the atmosphere is about 13-15 billion tonnes, and about 1/3 of the total emissions comes from anthropogenic activities. The existence of carbon dioxide in the atmosphere due to human activities (e.g. deforestation, burning of fossil fuels and bad farming practices such as slash and burn) absorbs the incoming short wave radiation and inhibits the outgoing long wave. Hence, carbon dioxide warms the atmosphere and subsequently affects the changing aspects of climatic variables such as temperature and precipitation.

As a result of the emissions of these GHG gases in the atmosphere, crop production has remained at the mercy of the rising temperatures and varying precipitation patterns with the aggregate effects of declined production and yield [9]. The forecasts of the IPCC [10] and studies at regional levels advocate that agricultural production could be impacted by changing climate. It can also have adverse effect on human health via climate introduced heat traumas and diseases as well as alter the hydrological cycle [10]. This implies that, if variations in climate continue to occur without the development of cutting-edge technologies to address the situation, food insecurity and poverty, especially among food/cereal crop farmers may arise.

Climate change is unequivocal and affecting every corner of the world [11]. However, information regarding the trends and patterns of climate variables are still lacking at local and specific levels [12]. Climate change due to anthropogenic factors has shown that the globe is warming [11,13]. Scientific accounts on global warming have indicated that the average global temperature has increased by around 0.7ºC (1.3°F) since the advent of the industrial era [14]. Studies have shown that the trend is accelerating such that the average temperature is rising at 0.2ºC every decade [11,15]. With the rising level in temperature globally, local rainfall patterns are changing, ecological zones are shifting, the seas are warming and ice caps are melting [11].

African countries and other developing countries have been termed to have been at disadvantage as the tropical areas stand to experience some of the most severe effects from climate change and agriculture which takes a significant part of employment and food provision in Africa is the most sensitive to climate variability. In order to deal with and adapt effectively to the associated problems of climate change/variability and achieve the Sustainable Development Goals (Goal 13: Take urgent action to combat climate change and its impacts), it is imperative to have adequate information regarding its trends and patterns of at local and regional levels. It is against this background that this paper assessed the climate variability trend in Nasarawa State, Nigeria.
2. MATERIALS AND METHODS

Nasarawa State is located in the basement complex of Nigeria’s central between longitudes 6°45' 03” and 9°45'03” of the Greenwich, and latitude 7°45’ 00’ and 9°35' 00” of the Equator. The state has an area of approximately 26,385.04 square kilometers, and stands at an altitude of 400 meters above sea level [Fig. 1]. It shares geographic boundaries with Kaduna state in the north, Federal Capital Territory (FCT) in western part, Kogi and Benue, in the south, and Taraba and plateau to the east. The proximity of Nasarawa State to the federal capital Territory has caused it to experience rapid growth in population and development of infrastructure. This has altered its natural ecological state and by extension, resulted varying climate condition. The climate of Nasarawa State is typical of a tropical sub-humid climate having two distinctive seasons. The rainy season sets in from about the beginning of May and last until October. The dry season is experienced between November and April. The Yearly rainfall amount range between 1100 mm to roughly 2000 mm. About 90% of the rain in the State falls from May to September, with the highest amounts being recorded in the months of July and August. High temperatures are generally recorded in the State during the day time, particularly between the months of March and April. The mean monthly temperatures in the State ranges between 20°C and 34°C [16].

Daily records of Nasarawa State’s climatic variables: Rainfall (Millimetre); mean temperature (Degree Celsius); maximum temperature (Degree Celsius); minimum temperature (Degree Celsius); relative humidity (Percentage); wind speed (Meter per seconds) and dew point (Degree Celsius), for the period of 21 years (1997 – 2017) were obtained from the Nigerian Meteorological Agency (NIMET). The data was collected for the period of time that the State has been in existence, that is, 21 years. The daily rainfall data was converted to annual totals using the SUM function in Microsoft Excel while the daily data for the rest variables were converted to monthly averages using the AVERAGE function. Linear trend function as well as line chart were used to analyse the variables’ trend over the period of 21 years. The line chart, trend line and trend equation were used to determine the nature and course of the trend of the investigated climatic variables.

Fig. 1. Administrative map of Nasarawa State
Source: Geography Department, Nasarawa State University, Keffi
3. RESULTS AND DISCUSSION


Fig. 2 presents the trend of maximum temperature over the period of 21 years in Nasarawa State. The trend equation \( y = 0.0526x + 31.362 \) and the trend line generally show an increasing trend which indicates that maximum temperature in the area has been on the increasing path since the year 1997. However, there were declines in year 2000, 2001, 2006, 2007, 2008, 2012 and 2016. Maximum temperature in the study area mostly oscillated during the first decade with two periods of sharp increase and one period of a sharp decrease. Conversely, during the second decade, maximum temperature showed mostly a gently increasing trend and a single sharp decline. The degree of variation \( R^2 = 0.6187 \) shows that the variability in mean maximum temperature in the study area is approximately 1 and indicates good fit for prediction purpose.

The trend graph showed that sharp increases were mostly recorded between 1997 and 1999, 2001 and 2005, 2012 and 2015 while a sharp decrease in maximum temperature occurred between the years 2005 and 2008. The highest mean maximum temperature \((33.24^\circ C)\) was recorded in the year 2005 while the least value \((30.02^\circ C)\) occurred in 1997. This finding corroborates that of Hansen et al., [17] who asserted that more warming conditions would be experienced in the 21st century than the preceding decades. Furthermore, Sarker [18] observed higher variability in mean maximum temperature between 1985 and 2009 period compared to the 1952 and 1984 period.


Generally, the trend equation \( y = 0.049x + 21.173 \) and the trend line for the minimum temperature indicated a rising trend for most of the study period. The degree of variation \( R^2 = 0.8394 \) shows that the variability in mean minimum temperature in the study area is approximately 1 and indicates good fit for prediction purpose. Fig. 3 shows that average minimum temperature in Nasarawa State started with an upward trend from \(20.82^\circ C\) in the base year (1997) to \(21.84^\circ C\) in 1999. This rise was immediately followed by a downward trend which

![Graph showing mean maximum temperature trend in Nasarawa State (1997 – 2017)](image)
saw the minimum temperature drop to 20.59°C in 2001. The upward trend in minimum temperature was most noticeable in the study area between 2001 and 2005 during which the highest (22.51°C in 2005) and lowest (20.59°C in 2001) average minimum temperature was recorded. This was also followed by another downward trend which declined from 22.51°C to 21.00°C in 2008. Another rise was observed from 2008 to 2010, followed by a decline in 2011 and sharp increase in 2012 through to 2014. The minimum temperature trend in the study area for the 21-years period ended with a gentle decline in 2015 through to 2017.

This finding agrees with Dontwi et al., [19] who found that maximum and minimum temperatures increased by 2.5°C and 2.2°C respectively, along the coast of Ghana between 1960 and 2001. Recent climatological studies have also shown an increase in global surface air temperature by 0.76°C from 1850 to 2005 [20].


The line graph of rainfall variability trend over the study period is presented in Fig. 4. The degree of variation (R² = 0.5214) shows that the variability in the total annual rainfall of the study area is approximately 1 and indicates good fit for prediction purpose. The trend equation (y = -15.262x + 1627.2) and the trend line revealed that annual rainfall pattern has been decreasing at an unsteady rate in the study area between 1997 and 2017. The trend line depicts a downward trend with the highest amount (1817.70 mm) recorded in 2006 and the least (950.43 mm) in 2017. A downward trend was recorded between 1997 and 1998 followed by an increase in 1999. The years 2000 and 2001 experienced a gentle decline followed by an increase in 2002. The annual rainfall declined again in 2003 and 2004 with a difference of 9.03mm between both years. The variation in annual rainfall continued as the amount increased again from 2005 (1459.31 mm) to 2006 before assuming a sharp declining posture from 2007 to 2008. Further increase was witnessed in 2009 through to 2010 before a sharp decline in 2011 which was also followed by a sharp increase in 2012. Through the period of 2013 to 2017, annual rainfall in the study area maintained a relatively stable rising and declining pattern.

![Fig. 3. Average minimum temperature trend in Nasarawa State (1997 – 2017)](image-url)
This finding is in agreement with Ideki et al. [21] who analysed rainfall variability in North Central Nigeria using Remote Sensing and GIS and found a downward rainfall trend in plateau, Nasarawa, Benue and Niger states. The result further lends credence to previous studies by Anufurom [22] which found that rainfall is generally retreating in parts of the North Central Region of Nigeria. It also corroborates Jidauna et al., [23] who found that the quantity and duration of rainfall pattern experienced over the years in Nigeria remarkably decreased by 78.6 percent while the intensity of the rains experienced in the rainy season also decreased by 77.3 percent. The decreasing rainfall trend in this study also confirms the case of Ghana where research has revealed that the annual rainfall in the country is highly variable on inter-annual and inter-decadal timescales, making identification of long-term trends difficult [24].


The average relative humidity of the study area generally showed a gentle decreasing trend for the study period with a trend equation; \( y = -0.1763x + 67.5 \) and 48.1% degree of variation \( (R^2 = 0.6187) \). The line trend in Fig. 5 showed that the average relative humidity sharply decreased from 1997 to 1999 and then maintained a gentle undulation from 2000 up until 2015 which experienced slightly sharp fall before rising to an average percent of 65.56% in 2016 and 2017. The highest value (72.5%) was recorded in 1997 while the least (58%) was recorded in 2014.

This finding failed to comply with that of Syed et al., [25] who investigated trends and variability of annual minimum, maximum and mean temperatures, relative humidity and rainfall of Peshawar-Afghanistan, using annual meteorological parameters for 30-years (1981-2010) and observed an increasing trend for relative humidity. This could be due to the difference in climatic type/zone of both study areas. Conversely, the finding on the trend of relative humidity affirmed that of Eludoyin et al.,[26] who observed a decreasing trend for relative humidity in their study of air temperature, relative humidity, climate regionalization and thermal comfort of Nigeria.
Fig. 5. Relative humidity trend in Nasarawa State (1997 – 2017)

Fig. 6. Average wind speed trend in Nasarawa State (1997 – 2017)

The variability trend of average wind speed in the study area for the period of 1997 to 2017 is presented in Fig. 6. The degree of variation ($R^2 = 0.0084$) shows that the variability in annual rainfall in the study area is less than 1 percent. Furthermore, the trend graph shows that there were relatively no much variations in the wind speed as most of the data points were located on or close to the trend line. The trend equation ($y = -0.0017x + 2.6601$) indicated a very gentle downward/decreasing trend beginning with a gentle rise in value from 1997 to 1998 and ended with a relatively sharp decline from 2015 through to 2017. The highest (2.92 m/s) and lowest (2.43 m/s) values of average wind speed were recorded in 2015 and 2009 respectively. This finding corroborates Jacob and Anil [27] who found a slightly decreasing trend in wind speed during their study of long term weather trends in Phaltan, Maharashtra Indian State of India.


Fig. 7 depicts the variability trend of the average dew point in Nasarawa State during the study period. It revealed that average dew point declined from 19.03°C in 1997 to 16.58°C in the year 2000 before it rose to 18.03°C and continued in the same undulating pattern to 2017. The highest amount of dew point (19.12°C) was recorded in 2013 while the least amount (16.57°C) occurred in 2015. The degree of variation ($R^2 = 0.0027$) shows that the variability in annual rainfall in the area is less than 1 percent. The trend equation ($y = -0.0063x + 18.243$) and the trend line of dew point show that average dew point over the study period has been decreasing at almost a steady rate. Average dew point explains the water condition of an area [28].

4. CONCLUSION

In line with the findings of this study, it was concluded that out of the six investigated climatic parameters; maximum temperature, minimum temperature, total annual rainfall and dew points experienced the greatest fluctuation in Nasarawa State during the 21 years’ period (1997 – 2017). Also, while maximum and minimum temperature generally assumed an increasing trend, annual total rainfall and dew points alongside relative humidity and wind speed were generally decreasing. This condition could result in drier climate and impact negatively on life supporting
systems such as; agriculture, natural vegetation, ground and surface water, if adequate measures are not devised through further research on how the present trends affect these life supporting systems, followed by policy formulation and implementation to combat climate change in the State. Hence, the main findings of this study may be helpful to water resource managers and agricultural development programmes' coordinators for planning and managing water resources and farm operations on a seasonal and annual basis and to policymakers for advising some suitable adaptation and mitigation policies to cope with anticipated climate variability and climate change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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