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Research Article

CLIMATE IS CHANGING; TEMPERATURE AND RAINFALL PATTERN (VARIABILITY) IN JOS-METROPOLIS, PLATEAU STATE, NIGERIA

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Abstract: This study examines the temperature and rainfall patterns in Jos-Metropolis, Nigeria, over a 30-year period (1989-2018), utilizing instrumental records to assess climate variability. The research highlights significant climatic shifts, particularly from lower to higher temperature readings, as well as irregular rainfall patterns. Data were collected from the Nigerian Meteorological Agency's (NIMET) synoptic station at Heipang, Jos-Plateau, and analyzed using descriptive methods. A Pearson Correlation Coefficient (PCC) analysis at a 0.05% confidence level was applied to explore the relationship between temperature and rainfall. The results show a noticeable rise in temperature around 2010, with a period of stable high temperatures from 2010 to 2018. Rainfall, however, peaked in 1993, 1999, and 2018, indicating variability within the period under review. While no significant relationship was found between average temperature and rainfall, a strong relationship was observed between temperature and rainfall over different years. The findings suggest that climate change impacts, including temperature increases and varying rainfall patterns, are influencing the Jos-Metropolis region, with implications for agriculture and urban planning. Based on these results, recommendations were provided to stakeholders for managing climate-related challenges in the area.

Keywords: Climate variability, Temperature, Rainfall, Jos-Metropolis, Pearson Correlation Coefficient

Introduction

Climate variability, across both instrumental and pre-instrumental records, is critical for understanding the intricate dynamics of climate systems. These systems, influenced by natural and human-induced factors, have a profound impact on the environment, economies, and societies worldwide. Such variability is studied using data gathered over various temporal and spatial scales, providing crucial insights into the behavior of climate over time. According to Oguntunde et al. (2012), examining climate variability allows for a deeper understanding of the processes that contribute to both natural and anthropogenic climate changes. By identifying these processes, scientists can make informed predictions about regional and global climate variations, helping to assess the extent of human impact on climate systems and make projections about future climate trends. This understanding is essential not only for predicting climate patterns but also for addressing challenges posed by climate change, such as food security, water resources, and public health.

The need to examine climate trends is further emphasized by the fact that the majority of existing observational and numerical models are based on instrumental records that span roughly a century. These records primarily focus on understanding the natural variability of the climate system, which includes temperature, precipitation, and other climatic variables. However, these models have limitations, as they only offer a snapshot of climate behavior during the last century, without accounting for longer-term natural fluctuations. Understanding these fluctuations is critical, as the rates of climate change vary significantly across different regions. The global mean temperature, for example, has increased by approximately 0.7°C over the past century (IPCC, 2007). However, this increase is not uniform. Different regions of the world experience varying rates of climate change due to factors such as geographic location, land surface types, and local atmospheric dynamics. Land surfaces, for instance, influence climate patterns by affecting surface albedo, evapotranspiration rates, and the carbon cycle (Meissner et al., 2003; Snyder et al., 2004). These regional differences are significant because they contribute to the diversity of climate impacts on ecosystems and human activities.

The most apparent and observable consequences of global climate change are increasing temperatures and decreasing rainfall in various parts of the world. According to Wuyep and Daloeng (2020), the global rise in temperatures has resulted in widespread ecological shifts. In some regions, rising temperatures contribute to the melting of ice caps, leading to a rise in sea levels and intensifying coastal erosion. Conversely, in other regions, reduced rainfall exacerbates drought conditions, leading to agricultural failures and water shortages. These shifts in temperature and precipitation patterns are not only an environmental concern but also pose significant risks to food security, economic stability, and public health. The impacts of temperature changes on ecosystems are further exacerbated by human activities, particularly in urbanized areas where industrial emissions and urban heat islands enhance warming. Similarly, the hydrological cycle is disrupted, leading to altered rainfall patterns, which further aggravate climate-related challenges.

Rainfall and temperature are critical climatic parameters that influence various sectors, particularly agriculture. Temperature and rainfall jointly affect the rate of evapotranspiration and, consequently, the availability of water resources. The variation in these two parameters is vital for understanding agricultural productivity, as crops are highly sensitive to changes in temperature and precipitation. However, as noted by Akinsanola and Ogunjobi (2014), rainfall and temperature are inherently interdependent. This interdependence makes it challenging to model both parameters simultaneously, as their correlation varies depending on the region. In tropical regions, for instance, temperature and rainfall are often closely correlated, with changes in one parameter frequently influencing the other.

Understanding this relationship is crucial for making accurate climate predictions and informing policy decisions on climate adaptation.

Temperature, as one of the key parameters influencing climate systems, plays a pivotal role in the manifestation of climate change. Bryan et al. (2010) argue that temperature fluctuations are largely influenced by the interaction between incoming solar energy and outgoing long-wave radiation. These variations in temperature are not isolated events; rather, they are part of larger atmospheric patterns influenced by both natural and anthropogenic factors. Local temperature variations, for example, can be influenced by urbanization, as the conversion of natural landscapes to urban environments alters the surface energy balance and leads to localized warming (Roy et al., 2009). Additionally, climate change induces changes in cloud cover and alters the nature and intensity of rainfall patterns. For instance, increasing temperatures can enhance evaporation rates, which in turn can increase the likelihood of more intense rainfall events. Conversely, in arid regions, rising temperatures may lead to higher rates of evaporation, resulting in less rainfall and drier conditions.

Rainfall patterns, similarly, exhibit significant variability across different regions and time scales. The global trend in rainfall is influenced by both natural climatic variability and human-induced changes, with varying impacts in different parts of the world. In some regions, rainfall is increasing, while in others, it is decreasing or becoming more erratic. The global distribution of rainfall trends has been a topic of significant concern, with recent studies indicating that while there is a small overall positive trend in rainfall, many regions are experiencing negative trends. Notably, extreme rainfall events have increased globally, with records showing a 12% increase in such events from 1981 to 2010 compared to natural climate variability (Lehmann et al., 2015). These extreme events, characterized by heavy rainfall and flooding, have been attributed to global warming and have been shown to be more intense in areas where human influence is most prominent (Fischer and Knutti, 2014). Furthermore, the changing dynamics of the atmosphere are expected to amplify future rainfall extremes, making it crucial to monitor and understand these trends in order to better predict and mitigate climate-related risks.

In Nigeria, rainfall variability is particularly pronounced, with both temporal and spatial fluctuations influenced by the changing climate. Studies, such as those by Ayansina et al. (2009), have shown that seasonal rainfall patterns in the Guinea Savannah region of Nigeria are becoming more variable, reflecting broader climate change trends. Wuyep and Doloeng (2020) also emphasize the increasing variability of rainfall in Nigeria as a key manifestation of climate change. In addition to rainfall, temperature fluctuations in Nigeria, especially in urban areas, have been shown to influence local microclimates and contribute to the broader effects of climate change. Temperature changes in urbanized areas often lead to heat island effects, which exacerbate local warming and influence the overall climate of the region.

The relationship between temperature and rainfall is complex and region-specific. While some studies suggest that higher temperatures may lead to decreased rainfall, other studies argue that increased temperatures can contribute to higher evaporation rates and increased precipitation in certain areas. In the case of Jos-Metropolis, which typically experiences a relatively low temperature environment with adequate rainfall, recent climate changes have resulted in noticeable shifts in both temperature and rainfall patterns. Understanding how these variables have changed over the past few decades is essential for developing effective climate adaptation strategies for the region. Observing temperature and rainfall records over a 30-year period will help clarify the extent to which climate variability has impacted Jos-Metropolis and offer insights into the broader trends of climate change in the region.

As climate change continues to evolve, it is critical to monitor and understand the underlying trends in temperature and rainfall variability. These parameters are crucial for understanding the broader impacts of climate change on ecosystems, agriculture, and human livelihoods. This study, therefore, aims to analyze the spatial changes in temperature and rainfall in Jos-Metropolis over the past 30 years, providing a comprehensive understanding of climate variability and its implications for the region. By doing so, this research contributes to the broader scientific discourse on climate change and its impacts, particularly in developing regions like Nigeria. Understanding these trends is vital for informing climate policy, guiding urban planning, and ensuring the sustainability of local ecosystems and human activities in the face of changing climatic conditions.

Methodology

Jos metropolis is located between latitudes 9° 54' N and 10° l0' N and longitudes 48' E and 9° 30' E (see figure 1) of Jos South and Jos North local Government Areas. Jos-metropolis from north to south is 18km while from east to west is about 18,5 km on an elevation of 1,250m above sea level with Shere Hills having the highest peak of 1,777Km(square) above sea level with an area of 1002.19 Km^2 (Jidauna, et al, 2013; Gajere, Adigun and Folayan, 2010). Jos-metropolis experiences AW climatic type and falls within the Koppens AW climatic sub-region. Generally, weather conditions are warmer during the rainy season (April – October) and colder during hammattan (December – February) (Ariyo , 2000). The mean annual temperature in the city ranges between 20°C and 26^{o}C.These temperature ranges are as the result of the influences of rainfall, relief and cloud cover at different periods and seasons in the year.(Nyong, et al 2008). Rainfall on the Jos metropolis is within a average of 70cm to 100cm at the peak period with a wet season of 8-9 months while dry season is between 3-4 months. The climate is affected by altitude and changing position of Inter-Tropical Convergence Zones (ITCZ) or Inter-Tropical Discontinuity or Inter-Tropical Front (ITF). Rainfall is high (1,305 mm) and characterize with two distinct season (wet and dry), with temperature range of 32^o C to 18^o C respectively (Eziashi, 2005).

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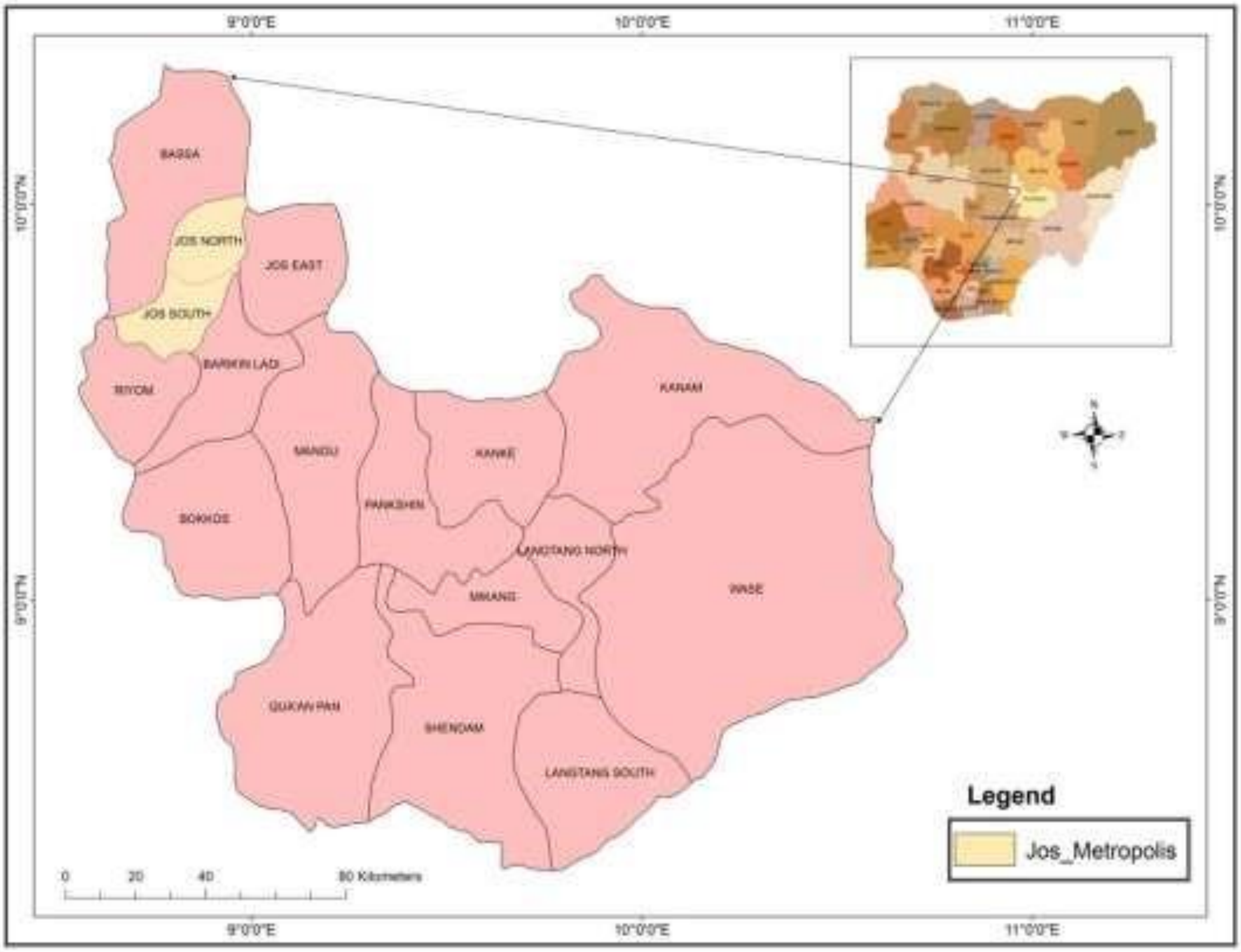

A descriptive research method was applied for the study of which data were collected from a synoptic station of the Nigerian Meteorological Agency (NIMET), Heipang, Jos Plateau for two parameter (Temperature and Rainfall) ranging from 1989-2018) of 30years were used to seasonal and annual variability.. NIMET is federal government established agency to monitor and regulate climate activities in the nation. Therefore, data were available and reliable for usage. Statistically, the parameters data were presented descriptive statistics of line graphs and analytically, using the Pearson Correlation Coefficient (PCC) is a statistical measure used to test the relationship between the temperature and rainfall parameters using data between the periods of 2008 to 2018 monthly averages of the two parameters. However, the relationship could be positive or negative at 95 confidence level. The Product Correlation coefficient (PCC) is represented by the following:

$$r = \frac{\sum(X-\overline{X})(Y-\overline{Y})}{\sqrt{\sum(X-\overline{X})^2}\sqrt{(Y-\overline{Y})^2}}$$

Where, $\overline{X}$ = mean of X variable

$\overline{Y}$ = mean of Y variable

Thus, ΄ϒd = cross correlation coefficient

d = delay

X = Mean of Temperature range

Y= Mean of Rainfall range

Xi = raw temperature

Yi-d = delayed raw rainfall range

N = total number of values

I = ith term in series

However, the findings of the analysis was discussed in the result of the research

RESULTS AND DISCUSSIONS

The results of the finding in figure 2 revealed the Monthly Average Temperature (MAT) of JosMetropolis from 1989-2018 i.e periods of 30years that there are increase in the temperature from January (26.2^0C) MAT till it reached April (28.9^0C)MAT and began a gradual reduction until it was at August (24.2^0C)MAT that it began to increase before finally dropped in the month of December (25 ^{0}C)MAT. This shows fluctuations in the temperature within the period of 30years to the fact that climatic changes was occurring. In figure 3 shows an average yearly temperature ranging from 1998 to 1998 where increase was noticeable between 1989- 1992 with a decrease in 1993 and a sharp increase in 1993 that proceeded to 1996. In 1997, temperature for Josmetropolis decrease but increase in 1998. By implication, the 10 years between 1989-1998 temperatures has been instable which signifies climate change with the period.

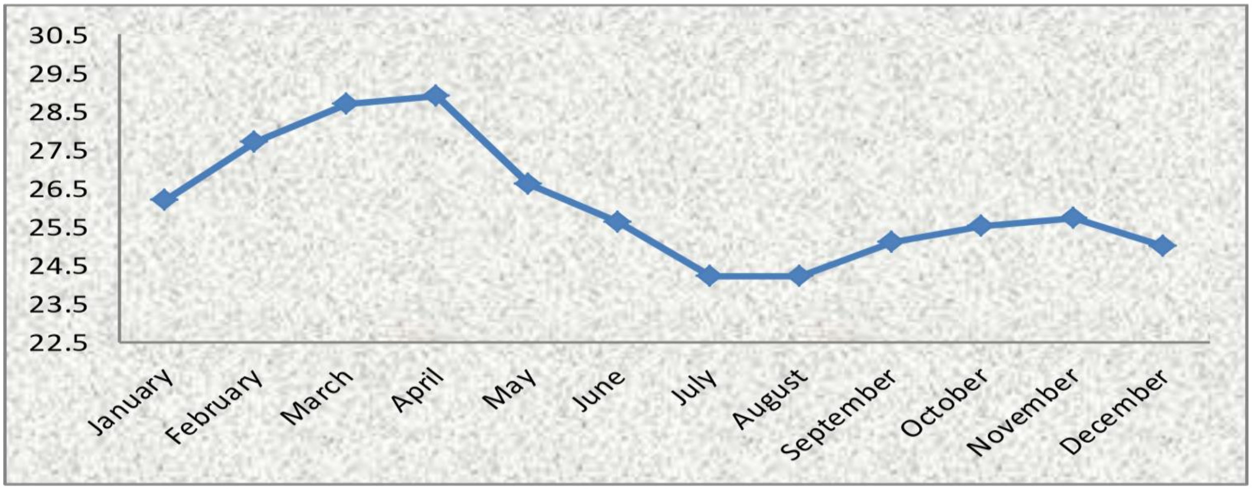

Figure2 Monthly Total Average Temperature ^{0}C (1989-2018) of Jos-Metropolis

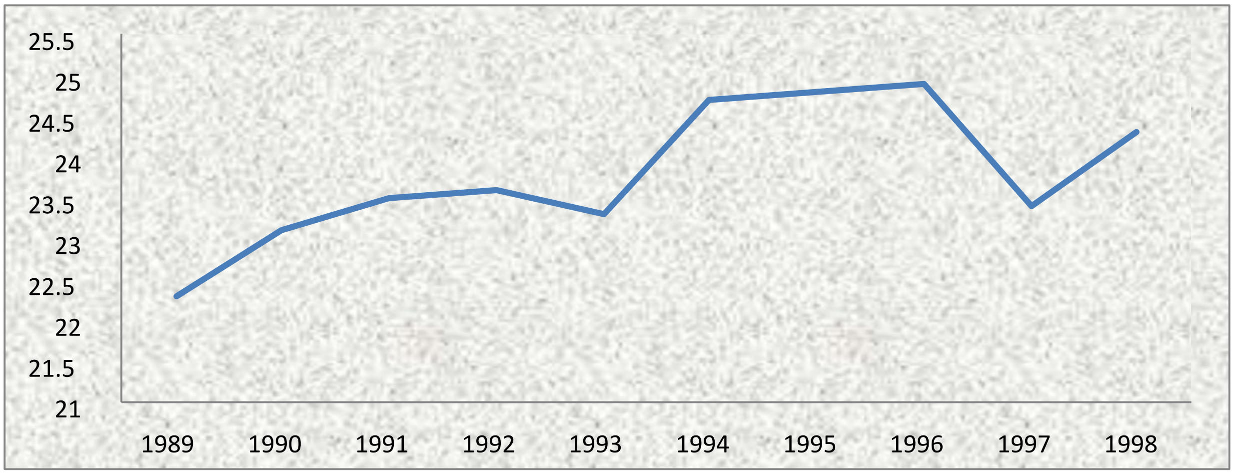

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Figure 3 Average Temperatures (1989-1998) of Jos-Metropolis

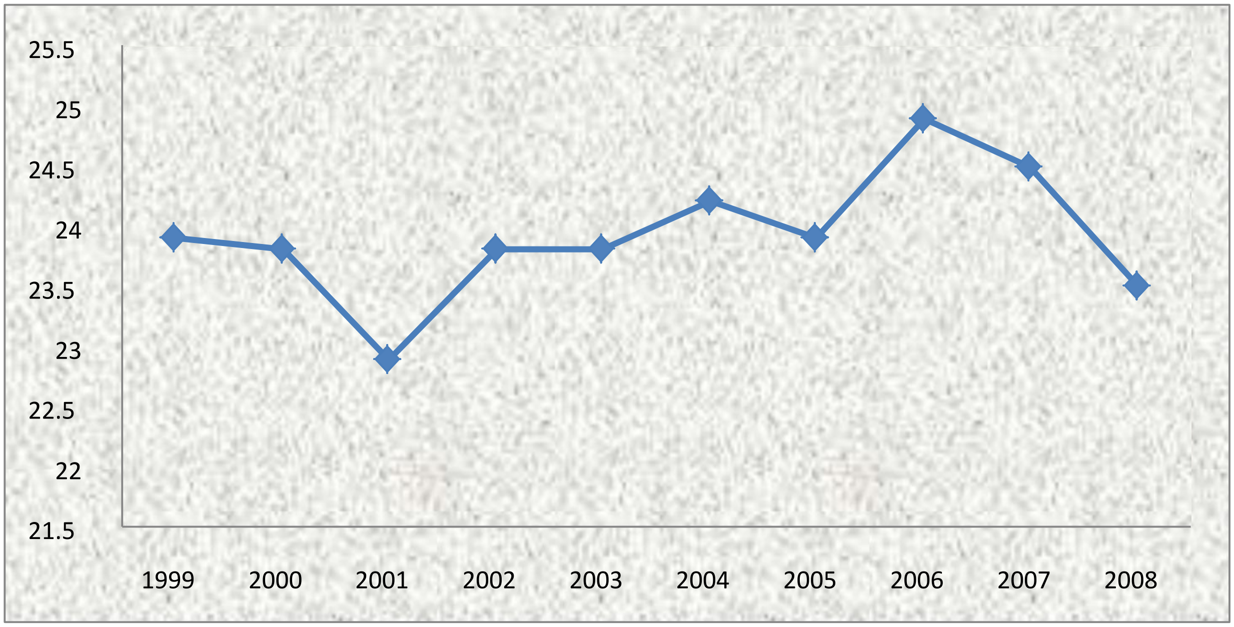

Figure 4 Average Yearly Temperatures in 0C (1999-2008)

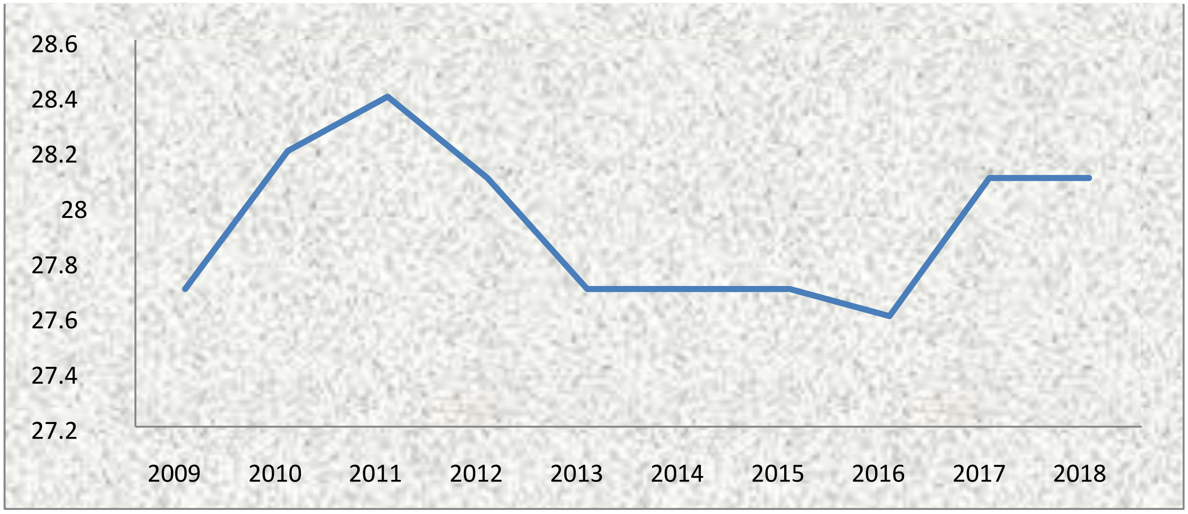

Figure 5 Average yearly Temperature in 0C (2009-2018)

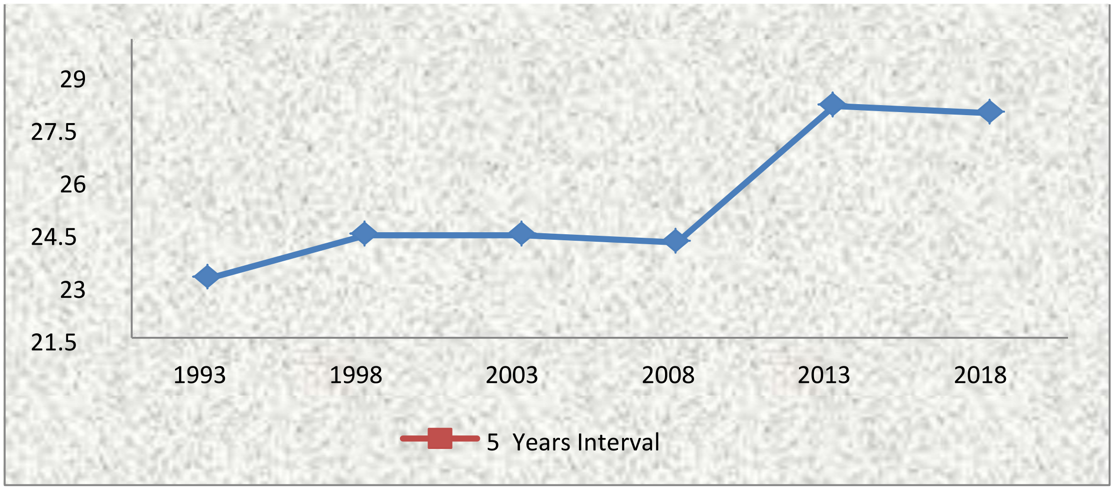

Figure 6 Average Yearly Temperatures ^{0}C Five (5) year Intervals

Figure 4 revealed a decrease in temperature from 1999 -2001, an increase from 2002, slide decrease in 2003 with increase in 2004 and then decrease in 2005 and increase in 2006. The temperature gradual decreases in 2007 -2008. The temperature fluctuates from 1999-2001 was on a consistence level beyond the year 1989-1998 which means there are more factors influences climate change. In Fig 5 high temperature increase was experience between 2009-2010 and fall in between 2011-2013 while it maintains a constant temperature from 2013-2014, less in 2016 then increases and remain stable from 2017-2018. An interval of five (5) temperature data observed for the period of 30years in fig 6 which indicated that temperature increases between 1993-1998 with slight decrease from 1998 -2008 and a sharp increase between 2008-2013 while temperature was less from 2013-2018 and such fluctuation were indication of temperature variability. However, Fig 7 revealed yearly average temperature for 30 years (1989-2018) with increase and decrease (zigzags) from 1989-2008, sharp increase in 2010 and stable high temperature from 2010-2018. According to the study Tingneyuc Sekac, et al, (2020) Temperature increasing trends were found to be more significant than decreasing trend which was the experience in Jos-metropolis.

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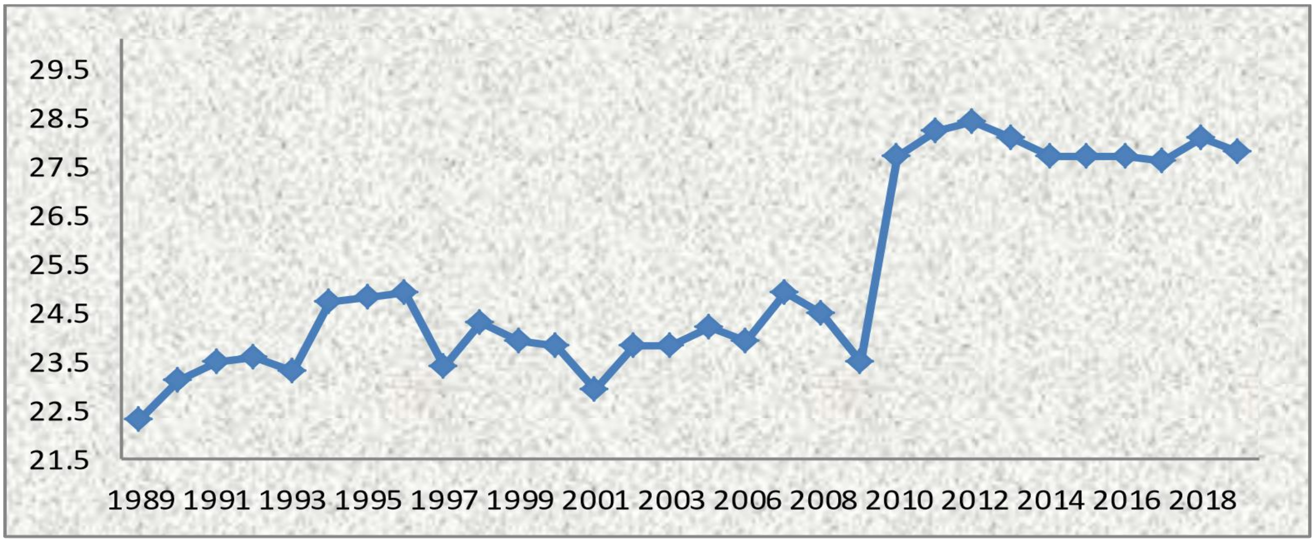
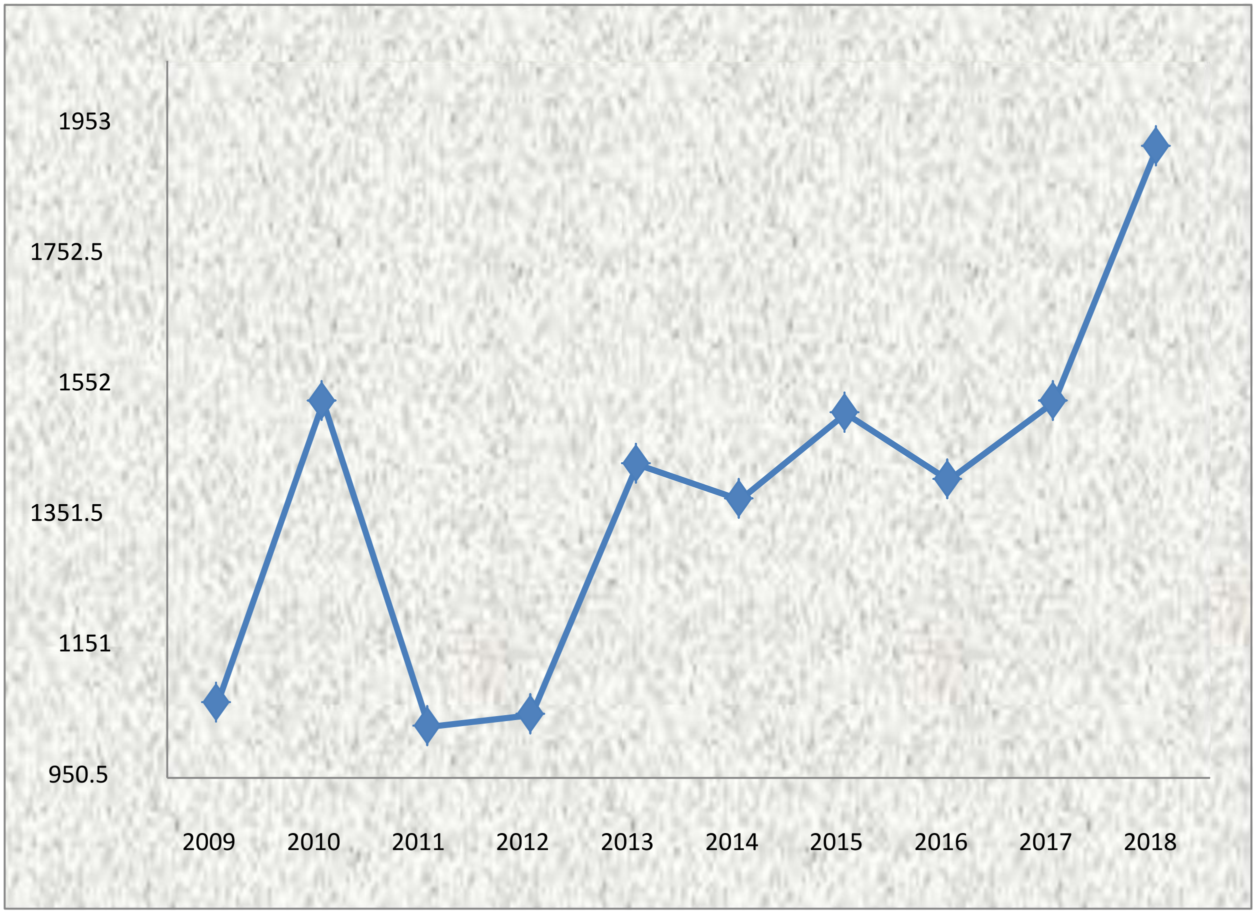


Figure 7 Average Yearly Temperature in ^{0}C of 30 years (1989-2018)

Figure 8 shows annual rainfall from 1989-1998 of Jos-Metropolis, 1429mm of rainfall was recorded in 1998 but decrease in 1990 to 1155mm of rainfall, slight increase in 1991 with 1630mm then a fall in 1992, increase in 1993, less from 1994- 1995 and an increase in 1996 while 1997 appreciated to 1998. This shows that there are fluctuations in rainfall within 19891998 in Jos-metropolis. For 1999-2008, (see fig 9) shown high rainfall in 1999 with 1552.2mm then decrease in 2000 with continuous high and low rainfall recorded in between 2001 -2005. High rainfall was seen in 2006 (1422.8)mm then decrease from 2007 but in 2008 there was increase to 1354.3mm. 2009 as seen in 9 shows low rainfall (1065.3mm), high rainfall in 2010 with a record of 1552mm, in 2011 rainfall dropped to 1028.2mm and from 2012-2017 rainfall kept increasing and decreasing in the following 1046.8mm, 1431.8mm,1379.2mm, 1511.4mm, 1408mm,1528.3mm and 1918.8mm while 2018, there was a high increase of rainfall 1918.8mm. This shows an dramatic climate changes of records of rainfall experience within the periods of 2009 -2018. Interval of five (5) years was observed for 30years for the periods of 1998-2018, This revealed that from 1993 to 2013 on an average level shows depreciation in rainfall while 2018 revealed a high rainfall. A study by Ekpe, Afangideh and Offiong, (2013) evaluate annual rainfall amount for the period 1982 to 2011 (30 years) demonstrates the existence of marked variations and trends in the rainfall characteristics of the area. The result reflects a continuous inconsistency in the pattern of rainfall with an increasing trend, which clearly indicates that the climatic change.


1953
1752.5
1552
1351.5
1151
950.5
2009
2010
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2017
2018

Figure 10 Annual Yearly Rainfall from 2009-2018

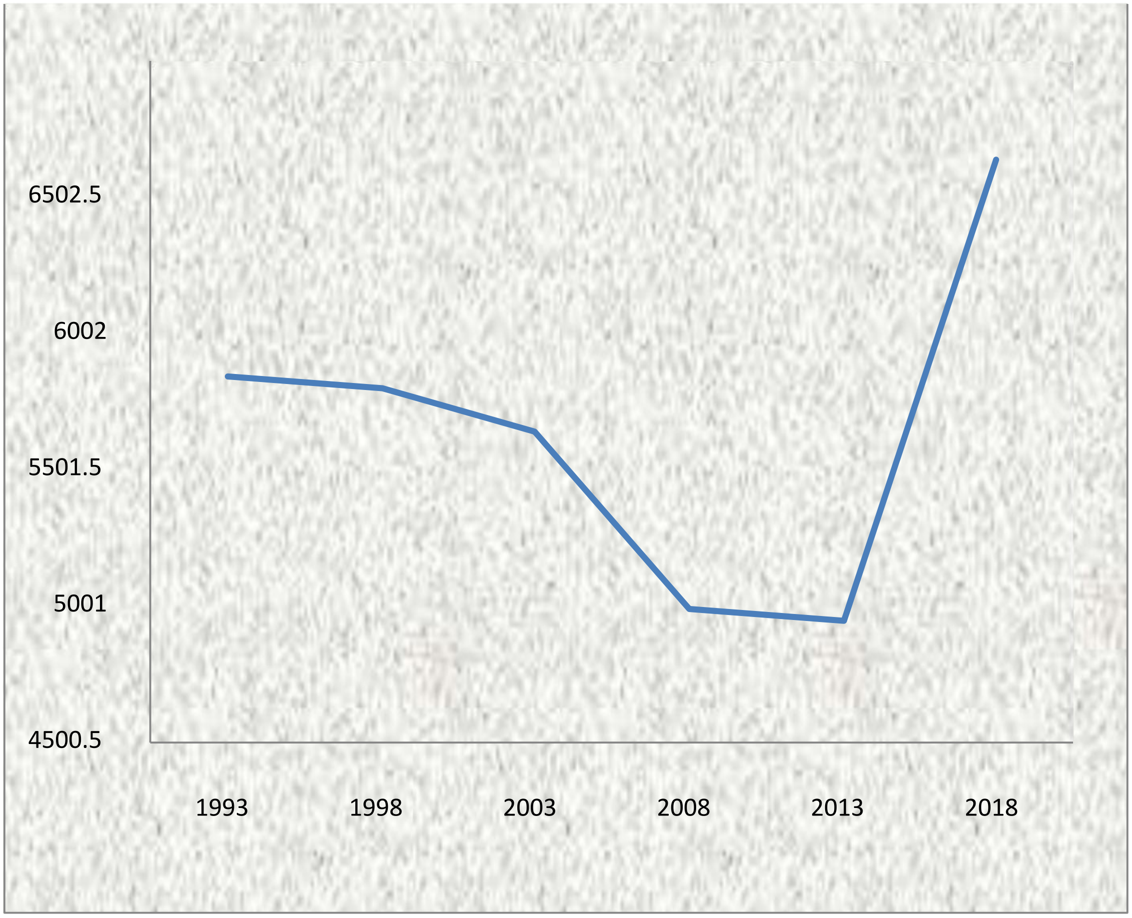

Figure 11 Interval of Five (5) Years Rainfall for 30 years

The total annual Rainfall recorded from 1998-2018 of Jos –Metropolis as seen figure 12 revealed rainfall variability with a zigzag changes of rainfall. Between 1989 to1998 shows highest rainfall recorded in 1993 and low rainfall was in 1997, between 1999 to 2008, the highest rainfall was recorded in 1999 while low rainfall was in 2007 and between 2009 to 2018, the highest rainfall was recorded in 2018 while 2013 recorded low rainfall. Thus, 1993, 1999 and 2018 in 30years indicated high rainfall 1537.78mm, 1562.2mm and 1918.8mm respectively.

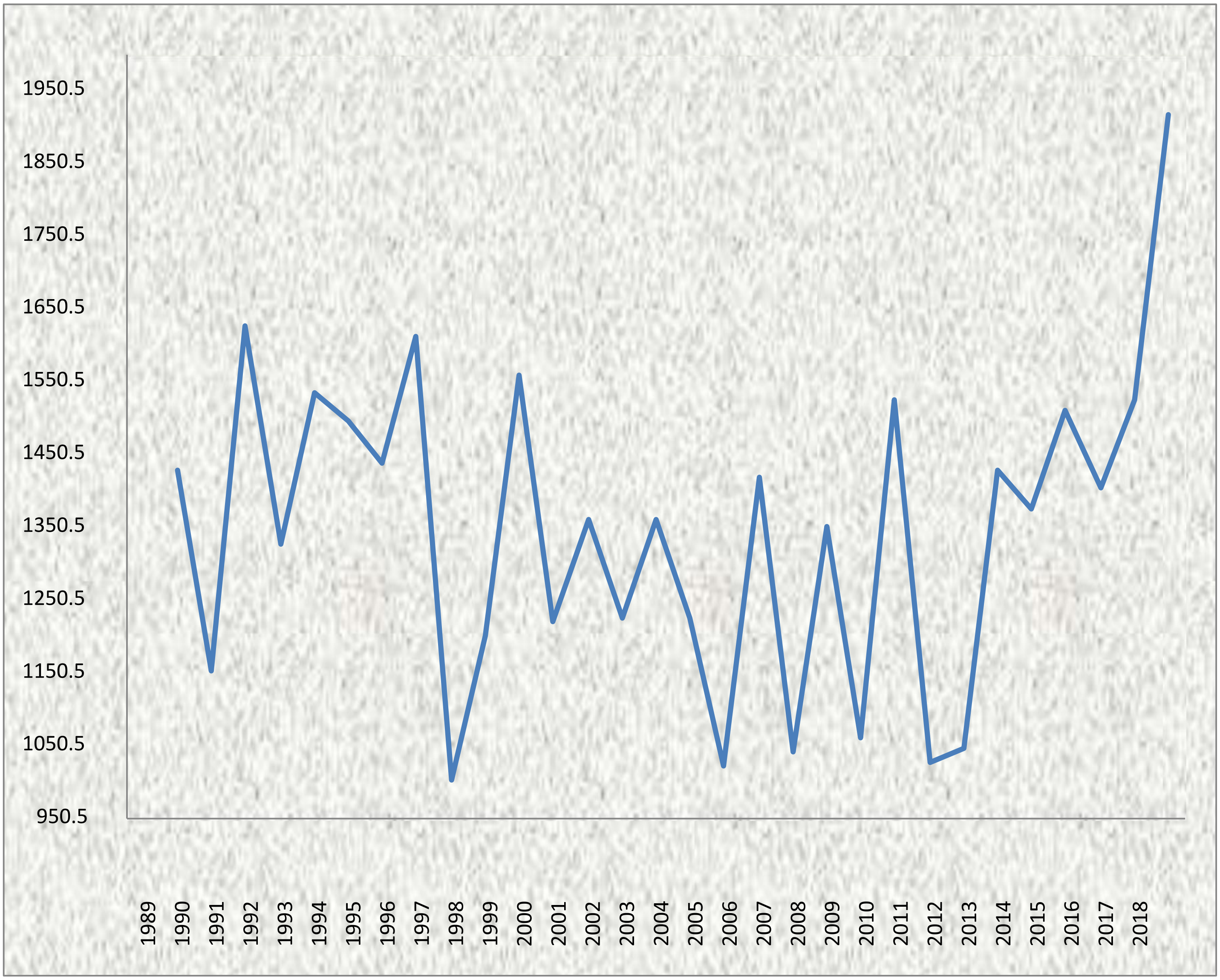
1950.5
1850.5
1750.5
1650.5
1550.5
1450.5
1350.5
1250.5
1150.5
1050.5
950.5
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Figure 12 Total Mean Annual Rainfall (1989 – 2018) for 30years of Jos-Metropolis

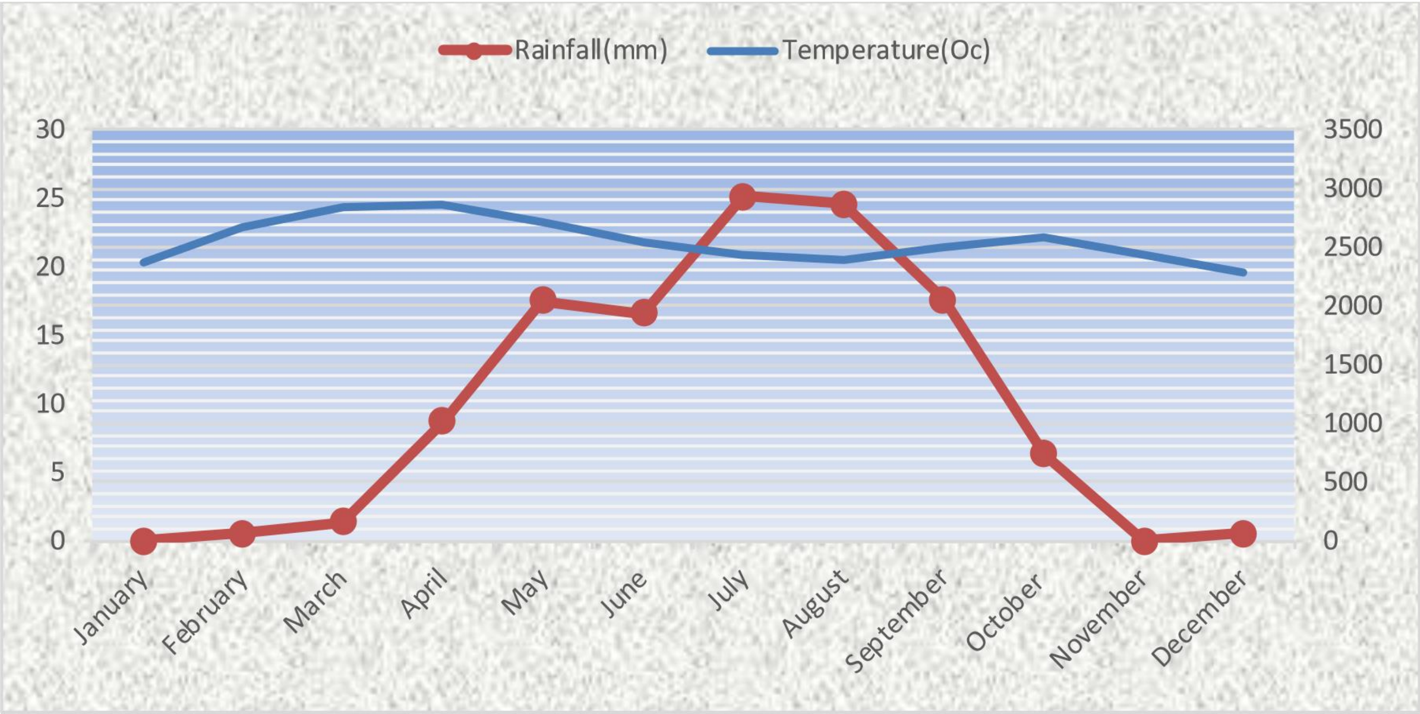

Fig 1 Total Mean Annual temperature and Mean Annual Rainfall of Jos- Metropolis

By virtual of figure 13 a presentation of average annual temperature and average annual rainfall in Jos-metropolis for 10 years (2008-2018) revealed high temperature at the period that there was low or no rainfall and in the same pattern, low temperature when the rainfall is at its season. This show changes occur in variation between temperature and rainfall as direct or indirectly temperature affects rainfall reversal may be the case in terms of climatic change. The influence of temperature on rainfall has been incorporated in an indirect, or sometimes a direct way in a number; such that in some cases high temperatures may result in exceedingly high rates of potential evaporation and low precipitation. This results in an area being dominated by an arid or semiarid landscape. In other cases, High temperatures lead to more evaporation and consequently increased condensation leading to high rainfall (Macatsha, 2006; Buishand and Brandsma, 1999; Longobardi and Villani 2010; Gebrehiwot and Veen 2013; Nkuna and Odiyo, 2016). However, relationship between temperature, rainfall and years (period of data collected) were tested through plotting of scatter graph which were shown below:

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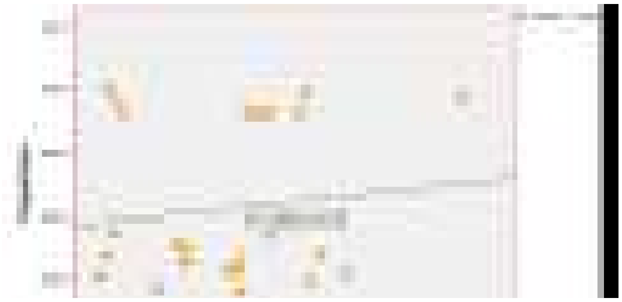

Figure 14 Scatter diagram of Temperature and Rainfall

Figure15 Period of Years and Temperature

Figure 16 Periods of Years and Rainfall

There was no linear relationship between average annual temperature and average annual rainfall as seen in fig 14 of the scatter plot where the calculated PCC revealed the correlation of temperature and rainfall r = 0.122, p > 0.005 which indicated no statistically significant linear relationship between temperature and rainfall. Followed the relationship between periods of years and temperature (fig 15) showed a linear relationship where r= 0.846, p< 0.005 an indication of statistically significant linear relationship while relationship between periods of years and annual rainfall (see fig16) shows r = 0.041, p> 0.831

CONCLUSION/RECOMMENDATIONS

The study on temperature and rainfall pattern in Jos-Metropolis over the periods of 30years (1989-2018) revealed the irregularities and fluctuations of temperatures as well as rainfall which indicates that climate is changing or variation within given time. There were instable significant changes in temperature between 1989-1998, 1999-2008, and 2009-2018 and by virtual of interval of five (5) temperatures increases between 1993-1998 with slight decrease from 1998 -2008 and a sharp increase between 2008-2013 while temperature was less from 2013-2018 and such fluctuation were indication of temperature variability. Yearly average temperature for 30 years (1989- 2018) was increasing and decreasing (zigzags) from (1989-2008), sharp increase in 2010 and slight stable high temperature from 2010-2018.

For rainfall, variation among years was noticeable in a zigzag pattern, high rainfall in 1993, 1999 and 2018 (1537.78mm, 1562.2mm and 1918.8mm) respectively while low rainfall was recorded 1997, 2007 and 2013. Observation of 10 years (2008-2018) revealed high temperature at the period that there was low or no rainfall and in the same pattern, low temperature when the rainfall is at its season as if direct or indirectly temperature affects rainfall reversal may be the case in terms of climatic change. Such happening affects agricultural activities that could be devastation on people livelihood. However, no linear relationship exits between temperature and rainfall, periods of years and rainfall only between temperature and periods of years. Climate change in this 21st Century have impacts to the livelihood of people in several aspect of their lives; agricultural production, adaptation to changing and economic activities that require intervention from government through the NIMET to inform citizenry on the expected climate changes on periodic seasons to be able to acclimatized with the changes and also areas affected by the temperature and rainfall variability should be interference by the government projects such as drought resistant varieties of crop, irrigation schemes, livelihood diversifications, clothing among others to reduce the magnitude of the effects of temperature and rainfall pattern in Jos-Metropolis of Plateau State, Nigeria.

REFERENCES

Ahrens DC., (2011) Essentials of meteorology: an invitation to the atmosphere. Cengage Learning

Audu, E.B., H.O. Audu, N.L. Binbol and J.N. Gana., (2013).Climate change and its implication on agriculture in Nigeria. Abuja J.Geogr. Dev., Vol. 3, No. 2

Ayansina A., and Ogunbo, S. (2009). GIS Approach in Assessing Seasonal Rainfall Variability in Guinea Savanna Part of Nigeria,7th FIG Regional Conference, Vietnam, 19-22 October 2009 16pp

Akinsanola A. A & Ogunjobi K. O, (2014). Analysis of Rainfall and Temperature Variability Over Nigeria Global Journal of HUMAN-SOCIAL SCIENCE: B Geography, GeoSciences, Environmental Disaster Management Vol. 14 Issue 3Type Double Blind

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Bryan JB, Konstantin YV, Russell RD., (2010) Changes in seasonal and diurnal cycles of ozone and temperature in the eastern US. Atmospheric Environment 44: 2543-2551.

Coumou, D. and S. Rahmstorf, (2012): A decade of weather extremes. Nat. Clim. Chang., **2**,

491–496, doi:10.1038/nclimate1452

Espinoza, J.C. et al., (2014): The extreme 2014 flood in south-western Amazon basin: The role of tropical-subtropical South Atlantic SST gradient. Environ. Res. Lett., **9**, 124007, doi:10.1088/1748-9326/9/12/124007.

Espinoza, J.C., J. Ronchail, J.A. Marengo, and H. Segura, (2018) Contrasting North–South changes in Amazon wet-day and dry-day frequency and related atmospheric features (1981–2017). Climate Dynamics, **52**, 5413–5430, doi:10.1007/s00382-018-4462-2.

Fan, Z., Brauning, A., Thomas, A., Li, J., and Cao, K. (2010). Spatial and temporal temperature trends on the Yunnan Plateau (Southwest China) during 1961–2004. Int J Climatol. doi:10.1002/joc.2214.

Fischer, E.M. and R. Knutti, (2014), Detection of spatially aggregated changes in temperature and precipitation extremes. Geophys. Res. Lett., **41**, 547–554, doi:10.1002/2013GL058499.

Fischer, E.M., U. Beyerle, and R. Knutti, (2013): Robust spatially aggregated projections of climate extremes. Nat. Clim. Chang., **3**, 1033–1038, doi:10.1038/nclimate2051.

Guhathakurta, P., D.S. Pai, and M.N. Rajeevan, (2017): Variability and trends of extreme rainfall and rainstorms. In: Observed Climate Variability and Change over the Indian Region

[Rajeevan, M. and S. Nayak (eds.)]. Springer, Singapore, pp. 37–49.

Hasanean, H.M. (2001). Fluctuations of surface Air Temperature in the East Mediterranean. Theoret Appl Climatol 68 (1–2):75–87.

Hoegh-Guldberg, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R.

Djalante, K.L. Ebi, F. Engelbrecht, J.Guiot, Y. Hijioka, S. Mehrotra, A. Payne, S.I.

Seneviratne, A. Thomas, R. Warren, and G. Zhou, (2018): Impacts of 1.5°C of Global

Warming on Natural and Human Systems. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R.

Matthews, Y. Chen, X. Zhou, M.I.Gomis, E. Lonnoy, T.Maycock, M.Tignor, and T. Waterfield (eds.)]. In press, pp. 17

Idowu, A. A., S.O. Ayoola, A.I. Opele and N.B.Ikenweiwe., (2011).Impact of climate change in Nigeria. Iranica J. Energy Environ.,2: 145-152.

IPCC (2007). Climate change and world food security: a new assessment, Global Environmental Change 9: 551–S67.

Jaswal AK, Rao PCS, Singh V (2015) Climatology and trends of summer high temperature days in India during 1969-2013. *Journal of Earth System Science 124: 1-15.*

Krishnan, R. et al., (2016), Deciphering the desiccation trend of the South Asian monsoon hydroclimate in a warming world. Clim. Dyn., **47**, 1007–1027, doi:10.1007/s00382-0152886-5

Meissner K, Weaver A, Matthews H, Cox P (2003) The role of land surface dynamics in glacial inception: a study with the UVic earth system model. Clim Dyn 21:515–537

Nkuna T.R and Odiyo, O.O,(2016) The relationship between temperature and rainfall in the Levubu sub-catchment, south Africa. International journal of Environment Science http://iaras.org/iaras/journals/ijes O'Gorman, P.A., (2015): Precipitation extremes under climate change. Curr. Clim. Chang. Reports, **1**, 49–59, doi:10.1007/s40641-015-0009-3.

Odjugo, P.A.O. (2010). General overview of climate change impacts in Nigeria. *Journal of Human Ecology. 29(1): 47-55.*

Oguntunde,P.G.,Abiodun, B.J.,Gunnar L,.(2012).Spatial and temporal temperature trends in Nigeria, 1901–2000. Meteorology and Atmospheric Physics118:95–105

Ologunorisa, E.T. (2004). Rainfall Flood Predictionin the Niger Delta, Nigeria (Abstract), International Conference in Hydrology: Science and Practice for the 21st Century, London, U.K.

Pall, P. et al., (2011), Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. Nature, **470**, 382–385, doi:10.1038/nature09762

Pfahl, S., P.A. O'Gorman, and E.M. Fischer, (2017) Understanding the regional pattern of projected future changes in extreme precipitation. Nat. Clim. Chang., **7**, 423–427, doi:10.1038/nclimate3287.

Prein, A.F. et al., (2017): The future intensification of hourly precipitation extremes. Nat. Clim. Chang., **7**, 48–52, doi:10.1038/

Roy S, Shouraseni, Yuan F., (2009) Trends in extreme temperatures inrelation to urbanization in the Twin Cities Metropolitan Area, Minnesota.*Journal of Applied Meteorology and Climatology 48: 669-679.*

Schleussner, C.-F., P. Pfleiderer, and E.M. Fischer, (2017), In the observational record half a degree matters. Nat. Clim. Chang., **7**, 460–462, doi:10.1038/ nclimate3320

Seneviratne, S.I., N. Nicholls, D. Easterling, C.M. Goodess, S. Kanae, J. Kossin, Y. Luo, J.

Marengo, K. McInnes, M. Rahimi, M. Reichstein, A. Sorteberg, C. Vera, and X. Zhang,

2012: Changes in Climate Extremes and Their Impacts on the Natural Physical Environment. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.

Sippel, S. and F.E.L. Otto, (2014): Beyond climatological extremes – Assessing how the odds of hydrometeorological extreme events in South-East Europe change in a warming climate.

Clim. Change, **125**, 381–398, doi:10.1007/s10584-014-1153-9.

Snyder, P.K., Delire, C. and Foley, J.A. (2004). Evaluating the influence of different vegetation biomes on the global climate. ClimDyn 23:279–302

ISSN: 3065-047X

Journal of Climate Science and Meteorology

Research Article

Taylor, C.M. et al., (2017): Frequency of extreme Sahelian storms tripled since 1982 in satellite observations. Nature, **544**, 475–478, doi:10.1038/nature22069

Thompson, V. et al., (2017): High risk of unprecedented UK rainfall in the current climate. Nat. Commun., **8**, 107, doi:10.1038/s41467-017-00275-3.

Trenberth, K.E., (2012), Framing the way to relate climate extremes to climate change. Clim. Change, **115**, 283–290, doi:10.1007/s105

Trenberth, K.E., J.T. Fasullo, and T.G. Shepherd, (2015), Attribution of climate extreme events. Nat. Clim. Chang., **5**, 725–730, doi:10

Thomas PC, Stott PA, Stephanie H., (2012) Explaining extreme events of 2011 from a climate perspective. Bulletin of the American Meteorological Society 93: 1041-1067.

Timothy MK., (2010) Climate change: shifting glaciers, deserts, and climate belts. Infobase Publishing.

Udayashankara, T.H., B.M.S. Murthy and M. Madhukar, (2016).Impact of climate change on rainfall pattern and reservoir level. J. Water Resour. Eng. Manage. 3: 10-14 Walter JS (1989). *Principles of Meteorological Analysis* Courier Corporation.

Wang K, Ye H, Chen F, Xiong Y, Wang C (2012) Urbanization e ؤecton the diurnal temperature range: di ؤerent roles under solar dimming and brightening. *Journal of Climate 25: 1022 1027*

Westra, S., L.V. Alexander, and F.W. Zwiers, (2013): Global increasing trends in annual maximum daily precipitation. J. Clim., **26**, 3904–3918, doi:10.1175/ JCLI-D-12-00502.1

Wuyep S. Zitta and Daloeng H. Madaki., (2020). Climate change, rainfall trends and variability in Jos Plateau. J. Applied Sci., 20: 76-82.