Climate Change, Trends of Wet Spells and Flooding Implication in Lokoja, Kogi State, Nigeria

[1]Audu, E.B., [2]Francis, S.D.,[3]Abenu, A, [4]Agye, A.I., [5]Rizama, D.S. &[6]Mshelia, A.M.

[1]Governement Secondary School, Abuja@30, Pegi, Federal Capital Territory, Nigeria
[2]Dept. of Mathematical Sciences, OlusegunAgagu Uni. of Sci. & Tech., Okitipupa, Ondo State.
[3]Dept. of Civil & Environmental Engineering, Air Force Institute of Tech., Kaduna, Nigeria
[4]Department of Humanities & Social Sciences, The Federal Polytechnic, Nasarawa, Nigeria
[5]Governement Girls' Secondary School, Dukpa, Abuja, Federal Capital Territory, Nigeria
[6]Dept. of Environmental Management, Nigerian Army University, Biu, Borno State, Nigeria

Correspondence: audu_ebamaiyi@yahoo.com +234-8035856619

ABSTRACT

Climate change is impacting on all rainfall derived parameters. For this study on climate change, trends of wet spells and flooding implication in Lokoja, Kogi State, Nigeria**;** daily rainfall data for Lokoja, 1951-2020 were obtained from the Nigerian Meteorological Agency (NiMet), Abuja and analysed using R code, non-parametric test such as Mann-Kendall statistical test as well as Sen's slope technique. Results showed general downward trends in mean wet spells with 2-day and total wet spells having -0.014285714 each, while 3, 5, 7, 10 and 14-day mean wet spells having normal condition. Different magnitudes of trends were detected with the magnitude of >0 recording 8 (highest), =0 was 0 (lowest) and <0 was 3. The overall gradient estimator showed positive from January-August with June having the highest value of 3.0857 and January, the lowest (0.0143). September-November had negative value with September having the highest negative value of -7.7429 and November having lowest of -0.0571. This study concluded that, climate change was real and had impacted on the mean wet spells negatively. The following suggestions were made: the general public should be adequately informed on the concept of climate change, both adaptation and mitigation measures should be adopted to combat the impact of climate change, drainages should be cleared regularly to avert urban flooding; and forecast of wet spells should be incorporated into the Seasonal Climate Prediction (SCP) and daily weather forecast by NiMet.

Key words: Climate change, flooding, rainfall, trends, wet spells

Introduction

Climate change is a global concept which has attracted several scholarly works and being discussed regularly among intellectuals at local, national, regional and international levels. According to Abdulkadir (2021), globally; climate change and environmental degradation are probably the most complex and challenging twin environmental problems facing the world today. Similarly, Musa (2024) stated that, desertification contributes to climate change and is exacerbated by it in a feedback loop. The relevance of climate change on man's daily living is anchored on the fact that, it has great impact on the environment which is made up of both biotic and abiotic segments. According to Nsofor (2014) cited by Nsofor (2019), it is generally agreed that, the environment remains the ultimate resource, resource of last hope for man's survival. Man who is at the centre of climate change discourse interacts and survives on these biotic and abiotic segments. Hence, any modification on the environment caused by climate change both directly and indirectly affects man and his livelihood. In support of the fore-going, the conference proceedings of the Association of Nigerian Geographers (ANG, 2009)published by the Department of Geography, University of Nigeria, Nsukka was captioned "climate change and the Nigerian Environment." This has shown that, climate change has great modification indices on the totality of the environment. Closely linked to this is the fact that, the forty seven (47) chapters of the said proceedings were either directly or indirectly connected to climate change. Madu (2010) opined that, globally; changes in atmospheric concentrations of greenhouse gases (GHGs), solar radiation and land surface have altered the energy balance of the climate system. Likewise, Onokala (2010) in an address of welcome presented at the National Conference of ANG on climate change and the Nigerian Environment on 29th June, 2009 at the Princess Alexandra Auditorium, University of Nigeria, Nsukka; stated that, climate change and its associated consequences threaten Nigerian's desire of achieving socio-economic development. Climate change poses a very strong challenge to the global community especially sustainable development goals (MDGs). Man's environment is made up of several-interacting systems of which an alteration in a system, affects others; hence putting our socio-economic activities and survival under siege.

One major area affected by climate change in Nigeria is rainfall. Rainfall in Nigeria is seasonal (Bello, 2008, Audu*et al*., 2022a) and it is relied upon for most uses such as agriculture (El-Tantawi, 2013; Ibrahim *etal*., 2023),provision of domesticand industrial water (Adeleke*et al*., 2022), the ecosystem, water balance, hydrological circle (Abubakar, 2015) andvegetation growth (Danjuma*et al*., 2020).On 24th June, 2024; following a torrential rainfall in the Federal Capital Territory, Abuja, Nigeria; it was reported widely by both mass and social media that, the TradeMore Estate, Lugbe, FCT, Abuja, Nigeria was massively flooded resulting in the submergence of houses mostly along the encroached water path, lost of valuable household items, while two (2) lives were lost.

Rainfall occurs in a single day and inter-spaced with dry days or in a consecutive number of days called spells. Forinstance, the Nigerian Meteorological Agency (NiMet) predicted 3-day thunderstorms (TSs) which are wet TSs across some parts of Nigeria from Sunday, 23rd June-Tuesday, 25th June, 2024. The number of days in a wet spell may vary in both time and space over a location or across locations which is in line with rainfall attributes. Mashi (2018) opined that, annual rainfall ranged from 500 mm over the extreme north to 3500 mm in the southern part of Nigeria. The occurrence of rain spells is both a blessing and a curse especially when it is heavy. However, the negativity which usually accompanies rain spell seems to over shadow its blessings. During rain spells, sunlight is impeded thereby reducing its intensity and temperature. This results into cold and its associated health issues. Also, this period is known for stunted growth by crops such as swamp rice, cassava, groundnut, beans, tomato and grains. Of serious concern during wet spell is the occurrence of massive erosion, landslide, water pollution and flooding. According to Ismaila&Nura (2023), the World Meteorological Organisation stated that; there has been exponential increase in the damage caused by floods during the past decades attributable to the consequence of the effects of climate change. It is on that basis that this research intends to discuss climate change, trends of wet spells and flooding implication in Lokoja, Kogi State, Nigeria.

Research Questions

1. What is the trend of wet spells in Lokoja?
2. What is the implication of wet spells on flooding in the study area?

Objectives of the Study

1. To ascertain the trend of wet spells in the study area
2. To examine the magnitude of wet spells in the study area;
3. To explain the implication of the current wet spells trend on flooding in the study area

Conceptual Framework

The conceptual framework discussed in this study includes climate change, rainfall, trends, wet spells and flooding.

According to Olofin (2023), the debates on climate change have produced a complex array of theories or schools of thought. All the theories agree that there are some changes in the global climatic conditions, but disagree on whether or not it amounts to climate change. According to Agaja (2022), climate change is unavoidable and associated weather extremes such as high temperatures and heat waves, increased frequency of drought and high intensity rainfall causing floods. According to the Intergovernmental panel on climate change (IPCC, 2007) cited by Abdulkadir (2021); climate change implies the changes over time in the averages and variability of surface temperature, precipitation and wind as well as associated changes in earth's atmosphere, oceans and natural water supplies, snow and ice, land surface ecosystems and living organisms. Climate change therefore refers to all changes in mean climate parameters that last for a long time. The causes of climate change can be broadly classified into two (2), namely; natural and man-made (Odjugo, 2010). Consequences of climate change include rising temperature (Mastrandrea& Schneider, 2009 cited by Jimoh, 2012), erosion and flooding(Nabegu, 2012), landslides, desertification (Nsofor, 2019; Adeleke*etal*., 2022), shifts in rainfall patterns (Audu*et al*., 2014; Adeleke*et al*., 2022), flooding (Nabegu, 2012) and shrinking of water bodies (Nsofor, 2019), drought (Binbol, 2024) and water pollution. There are both traditional and modern methods of climate change adaptation.

On the concept of trend, no climate variable remains constant in mean value as they are all dynamic. The calculated changes either increase or decrease below or above the long term mean of rainfall is said to be its trend. This long term mean is usually calculated from 30 years of recent/current, relevant and continuous climate data.

A wet spell implies number of consecutive days of rainfall other than just a day. National Weather Service (NWS, 2009) cited by Audu (2019) referred to water droplet from clouds that is greater than or equal to ($\geq$) $0.01\, inch\, (0.25\, mm)$ in a single spot within a day as rainfall. However, rainfall as used in this study is based on the definition by Audu*et al*., (2022b) which designated rainfall agro-meteorologically as a value which is greater than or equal to ($\geq$) 0.3 mm/day (24 hours).

A flood happens when water overflows or soaks land that is normally dry (National Geographic Society, 2021). Floods usually occur mostly when there are heavy downpours in an area and all the rain water does not percolate into the soil, but flows or remains on the surface of the land as floods (Dogondaji*et al*., 2017). Floods are usually said to have occurred when there is excess water on the land (commonly due to heavy/frequent rainfall)which is not usually under water and does not flow or percolate easily. Urban flood is caused by excessive rainfall, dam breakage, blocked drainages, poor urban planning and/or poor sanitation. Flash floods imply the flooding that begins within 6 hours and often within 3 hours of the heavy rainfall (NiMet, 2024).

Materials and Methods

The Study Area

The study area lies between longitudes 6°30'-7°0' East and latitudes 7°30'-8°0' North (Figure 1). The meteorological station where data were acquired for this study is located on longitude 6.7°E, latitude 7.8°N, an elevation of about 062 and World Meteorological Organisation (WMO) station number of 65243 (Francis, 2017). Lokojais made up of two (2) Hausa language words namely, tree and colour. "Loko" implies iroko and "Ja" refers to red. Putting the two (2) words together, they become red iroko (tree). Kogi is also a Hausa word which means river. The study area houses the confluence of Rivers Niger and Benue with a visibly extensive floodplain which becomes conspicuous around Ozi village in Kogi Local Government Area along Abuja-Lokoja Road. Lokoja experiences both wet and dry season with wet season lasting between April-October, while dry season spans between October-April (Audu, 2012); hence April and October are transitional months. Highest annual rainfall within the period under study occurred in 1999 (1767.1 mm), lowest of about 804.5 mm occurred in 1982 (Audu*et al*., 2014), while climatological mean rainfall of 1213.2 mm (Audu*et al*., 2018). Climatological mean temperature is about 28.03°C with March been the hottest.

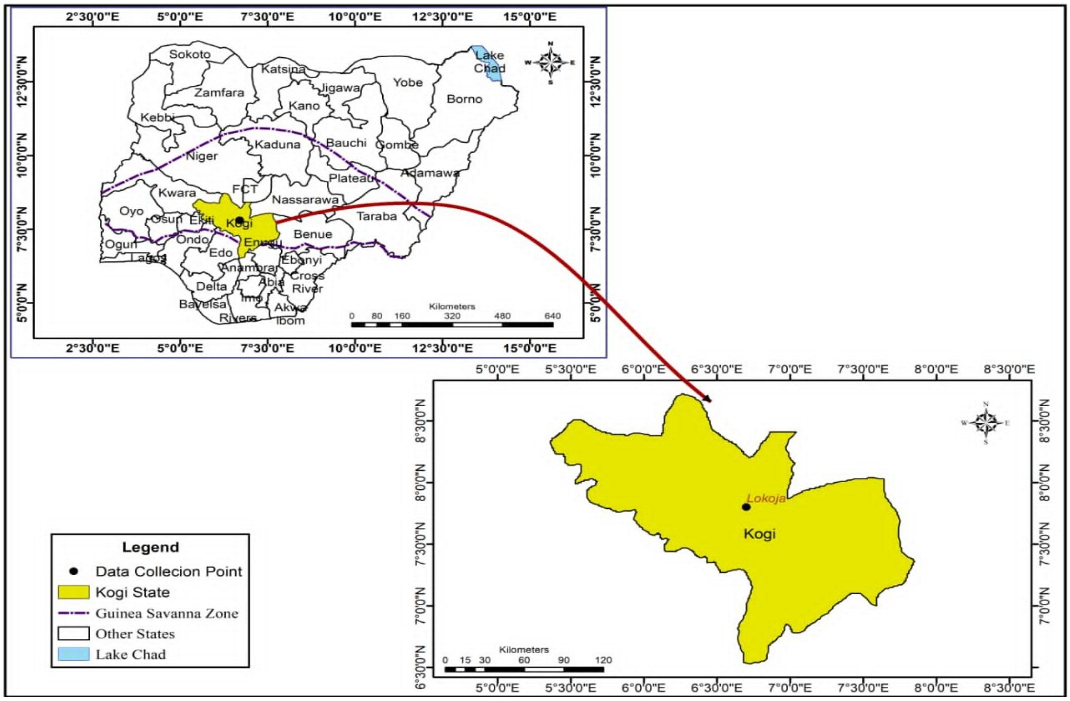

Figure 1: Map of the study area showing data collection point
Source: Department of Geography, Federal University Lafia, Nasarawa State, Nigeria, 2023

Method of Data Collection

Daily numerical rainfall data for Lokoja, Kogi State, Nigeria 1951-2020 were collected from the Nigerian Meteorological Agency, Abuja and analysed for this study.

Methods of Data Analyses

To determine the wet spells over the study area, R code was used to obtain the various wet spells counts such as 2, 3, 5, 7, 10 and 14-days spells. The wet spells counts were then analysed to derived the mean wet spell using Equation 1.

$$\bar{S}_w = \frac{1}{n}\sum_{j=1}^{n} S_i \qquad 1$$

Where: $n = number\ of\ months$; $j = 1,2,\ ...,n$;

$S = \ spells$; $S_w = wet\ spell$

Trend analysis was then used to determine increase or decrease in mean wet spells. The presence of trend is designated by either positive sign or negative sign, while zero implies no trend (Adamu& Umar, 2016). The method used to detect monthly mean rain spelltrendover the study area was the non–parametric tests as found in Adamu, 2014 and further cited by Audu, (2019). The non–parametric tests used were the Mann Kendall slope methods (Karabulut*et al.*, 2008; Longobardi&Villari, 2009) both cited by Audu (2019). The Mann–Kendall statistic *S* of the series *x* is stated by Mann (1945); Kendall *et al.* (1975) both cited in Somsubhra& Dwayne (2016) as:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right) \quad 2$$

Where sgn is the signum function. The variation linked with *S* is computed from Mann (1945); Mdarres&Sarhadi (2009) both cited in Somsubhra& Dwayne (2016) as:

$$v(s) = \frac{n(n-1)(2n+5) - \sum_{k=1}^{m} t_k(t_k-1)(2t_{k+}5)}{18} \quad 3$$

Where *m* refers to the number of tied groups and t_k refers to the number of data points in group *k*. In case where the sample size n > 10, the test statistics *Z(S)* is computed from Mann (1945); Mdarres&Sarhadi (2009) both cited in Somsubhra& Dwayne (2016) as:

$$(S) = \begin{cases} \frac{S-1}{\sqrt{V(S)}, ifS>0} \\ 0,\ ifS = 0 4 \\ \frac{S+1}{\sqrt{V(S)}, ifS<0} \end{cases}$$

Positive value of *Z(s)* indicates rising trends, whereas negative *Z (s)* value reflects declining trends. Trends are regarded remarkable if the absolute values$|Z(s)|$ are higher than the standard normal deviate - $Z_{1-\alpha/2}$ for the desired value of alpha ($\propto$) taken as 0.05 in this study.

The Theil–Sen approach (TSA), a frequently adopted procedure to compute the notable linear trends in time series was utilised in this study. Generally, the gradient *Q* between any two values of a time series *x* was determined from Somsubhra& Dwayne (2016) as thus:

$$Q=\frac{x_k-x_j}{k-j}, k\neq j \quad 5$$

For a time series *x* having n examinations, there are a possible *N = n (n - 1)/2* values of *Q* which can be computed based on Sen's technique. The general estimator of gradient is the median of these *N* values of *Q*. The overall gradient estimator (*Q**) is then computed after Somsubhra& Dwayne (2016):

$$Q^x = \begin{cases} Q(N+1)/2 , & N \quad odd \\ \frac{QN/2+Q(N+2)/2}{2} , & N \quad even \end{cases} \qquad 6$$

Results and Discussion

The positive value in the trendsindicate an increasing mean wet spell, zero (0) indicates no trend that is, normal; while negative value implies a decline. The trend of 2-daymean wet spell was negative, -0.01429; 3-day mean wet spell was negative which in scientific form was -2.2E-16 (-$2.2*10^{-16}$) that is, 0.0000000000000002.2 and its approximately zero (0) hence the bar did not appear in Figure 2; 5-day mean wet spell was positive, $2.8*10^{-17}$that is, 0.00000000000000002.8; 7-daymean wet spell was positive, $1.0*10^{-17}$that is, 0.00000000000000001; 10 as well as 14-daysmean wet spells was normal (0) and the monthly total mean wet spell was negative -0.01429.

Due to the large outliers in the data, the bars in Figure 2 only showed negative. 5-day and 7-day wet spells were positive, but their values were too minute, hence resulted to approximately zero and the bars did not appear in Figure 2. Also, 10-day and 14-day wet spells were zero (0). The total mean wet spells showed a downward trend which is an indication of climate change over the study area. According to Olatunde& Love (2018), Lokoja has suffered the effects of climate change.

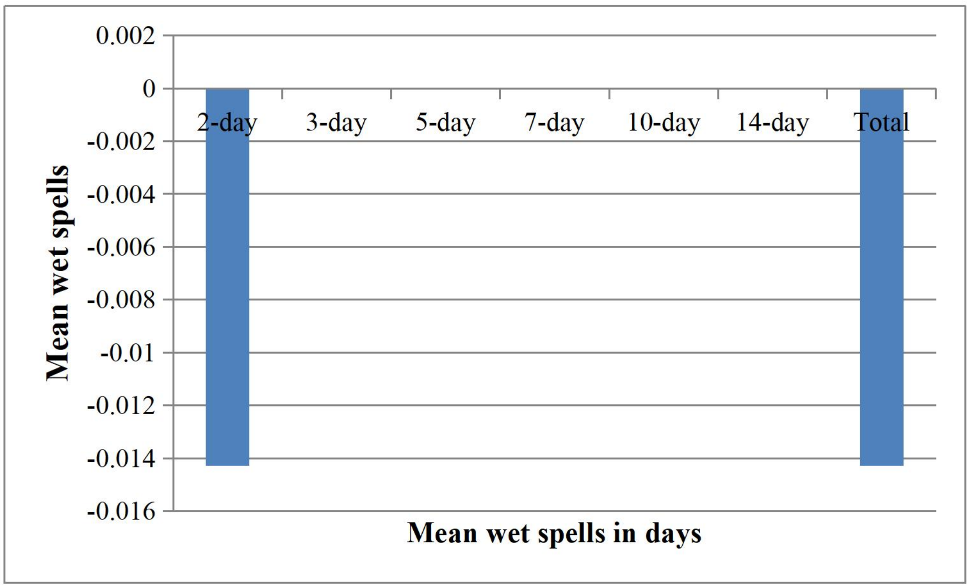

Figure 2: Mean wet spells trend over the study area

Source: Authors' computation, 2024

Figure 3 shows the magnitude of trend shown on the basis of magnitude greater than (>) 0, equal to (=) 0 and less than (<) 0. In the result, 2-daymean wet spell showed 8 is > 0, = 0 is 0 and < 0 is 3. Also, 3-daymean wet spell showed magnitude of > 0 as 6, = 0 is 2 and < 0 is 3. Magnitude of > 0 is 5, = 0 is 3 and < 0 is 3 for the 5-daymean wet spell. In 7-daymean wet spell, the magnitude showed > and = 0 as 4 each, while < 0 is 3. Under the 10-daymean wet spell, > 0 is 3, = 0 is 6 and < 0 is 2. For the magnitude of 14-daymean wet spell, > 0 is 2; = 0 is 7 and < 0 is 2.

Lastly, the monthly mean total magnitude indicated > 0 as 8 (highest), = 0 is 0 (lowest) and < 0 is 3.

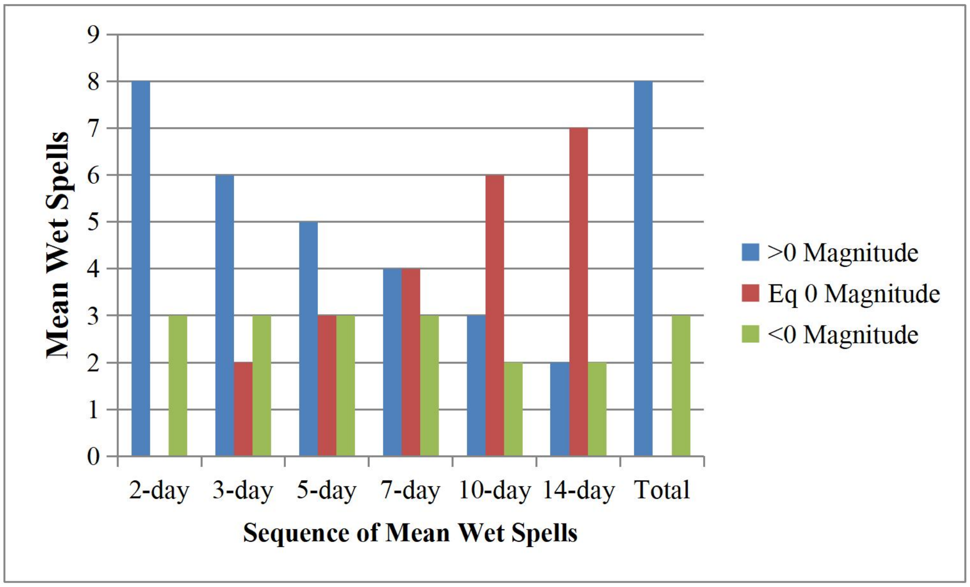

Figure 3: Magnitudes of Mean Wet Spells >,= and <0

Source: Authors' computation, 2024

Figure 5 showed the monthly mean wet spells overall gradient estimator (Q*) for 2-day, 3-day, and 5-day over the study area. Generally, the overall gradient estimator has neutral/normal (0), positive and negative values. The highest positive overall gradient estimator of 2-daymean wet spell occurred in June (0.4429), while the lowest occurred in January (0.0143). The highest negative overall gradient estimator occurred in September (-3.5857), the lowest was in November (-0.0571), December hadno value (empty).The 3-day mean wet spell overall gradient estimator in January and November was zero (0); highest positive was in June (1.3857); lowest positive was in February (0.0143); highest negative occurred in October (-1.4286); while lowest negative occurred in August (-0.2286). For the 5-day mean wet spell overall gradient estimator, January, February and November had zero value; July had the highest positive (0.4857); March had the least positive of 0.0143; September (-0.8429) had the highest negative; while August (-

0.0714) had the least negative.

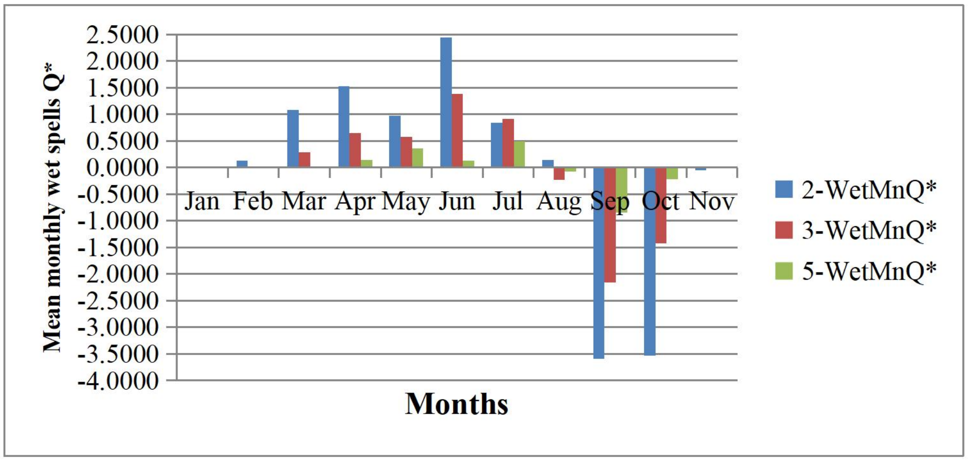

Figure 5: Mean monthly wet spellsoverall gradient estimator (Q*)of 2-day, 3-day& 5-day for Lokoja, Kogi State, Nigeria

Source: Authors' computation, 2024

In Figure 6, 7-day mean wet spell overall gradient estimator (Q*) showed zero (0) in January, February, March and November; highest positive of 0.3857 in May; lowest positive in April (0.0143); highest negative (-0.5000) in September and lowest negative (-0.0286) in October. The 10-day mean wet spell overall gradient estimator of zero (0) occurred in January, February, March, April, October and November; highest positive in May (0.3429); lowest positive of 0.0429 in July; highest negative of -03571 in September and lowest negative of -0.3429 in June. 14-day mean wet spell overall gradient estimator had zero value in the months of January, February, March, April, October and November. Two (2) positive and 2 negative overall gradient estimatorsoccurred. The highest positive occurred in August (0.3000), lowest positive occurred in May (0.2857), highest negative occurred in September (-0.3000) and least negative occurred in June (-0.2857).

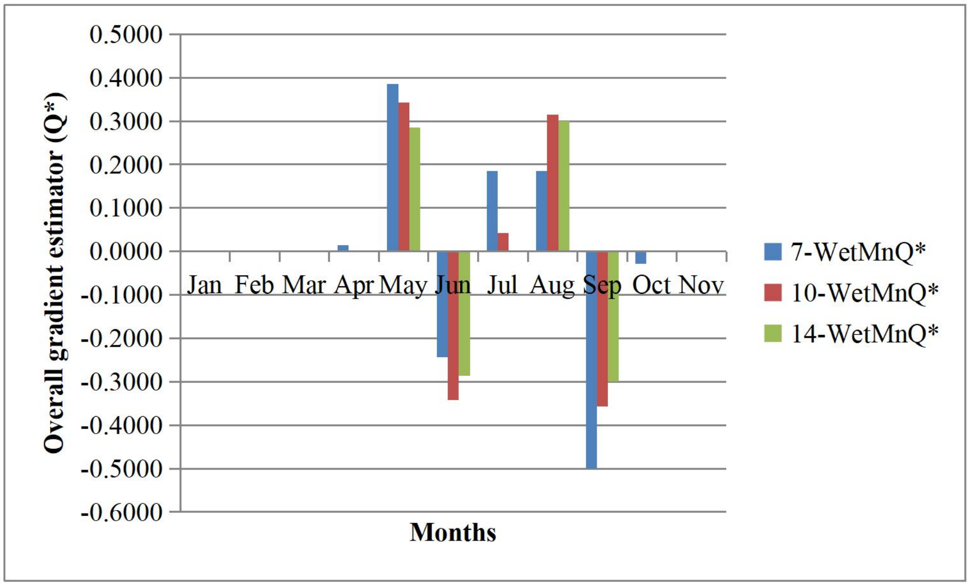

Figure 6: Mean monthly wet spells Q*of 7, 10 & 14-daysfor the study area

Source: Authors' computation, 2024

In Figure 7, December was excluded because it had no value due to the subtraction of one month value from the preceding one. The total monthly mean wet spells overall gradient estimator (Q*) showed both positive (08) and negative (03). Highest positive Q*occurrence was in June (3.0857), lowest positive was in January (0.0143), highest negative occurred in September (-7.7429); while least negative occurred in November (-0.0571).

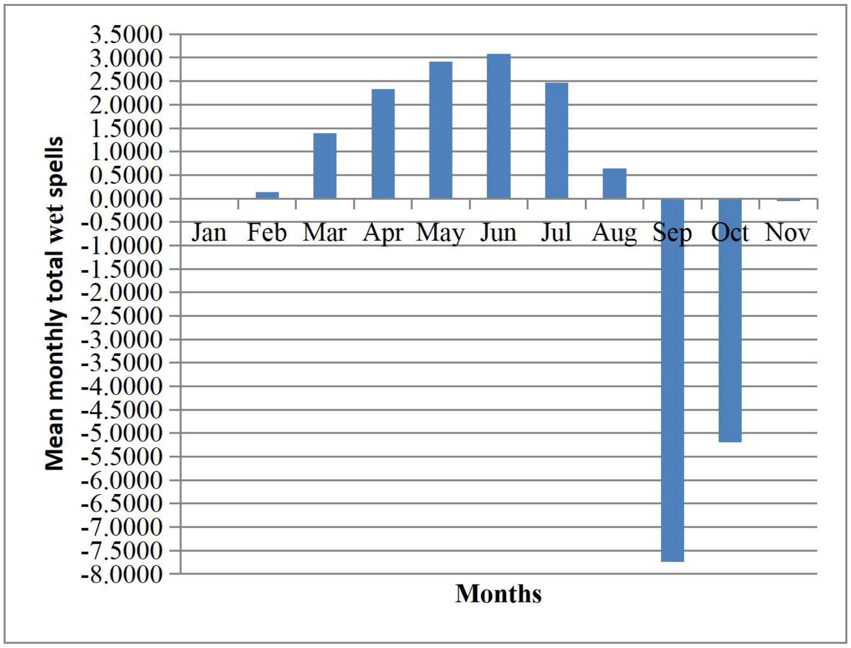

Figure 7: Mean monthly total wet spells overall gradient estimator (Q*) for the study area

Source: Authors' computation, 2024

Discussion of Result

In this study, 2-daymean wet spell was the dominant which was mostly frequent and was capable of causing urban flooding aside flash floods especially in areas that are unplanned and having poor and/or blocked drainages. However, the resultshowed that, 2 and 3-days mean wet spells were on the decline likewise the total monthly mean wet spell. The positive, normal and negative wet spells were the manifestations of variability associated with rainfall. There were inter and intra variability associated with wet spells across the months. The trend, magnitude and overall slope estimator varied across the months. Likewise, values for the trend, magnitude and overall gradient estimator varied within and across the months. In a study conducted by Tubosun (2022) on temporary assessment of rainfall variability in Lower Niger Basin Development Authority Catchment Area, significant variations were found mostly in 1994 and 2001.

In addition, the zero (0) value in the monthly total was found in November-March which were dry season months. Hence, this study had confirmed two (2) seasons over the study area- wet and dry. In a study on past and future climate change in Central Nigeria, Usman*et al*. (2024) discovered alternate dry and wet periods between 1922 and 2021. Again, the monthly total indicated that, the bulk mean wet spells occurred from June to September with September (13) having the highest value. This corresponded with the previous studies which depicted September as having the highest mean rainfall. The total monthly mean wet spells had a pick which confirmed that the study area observed single maximum rainfall (Audu*et al*., 2022a). The overall gradient estimator (Q*) indicated negative over September, October and November with September having the highest negative this was a clear indication of climate change which was impacting negatively on September and October rainfall.The study by Umar (2012) revealed highly significant downward trend in annual rainfall in Benin, Ibadan, Kano, Ondo, Warri and Yelwa. Months with rising mean wet spells should expect more soil moisture and consequently, flooding. On the other hand, months with declining trend should expect reduction in flooding and water bodies especially streams and ponds. With the decline in mean wet spells over the study area, it is expected that urban flooding would also reduce.

Conclusion and recommendations

This study focused on climate change, trends of wet spells and flooding implication in Lokoja, KogiState, Nigeria. Daily rainfall data for Lokoja, 1951-2020 were obtained from the Nigerian Meteorological Agency (NiMet), Abuja and analysed using R code, non-parametric test such as Mann-Kendall statistical test as well as Sen's slope technique. Results showed general downward trends in mean wet spells with 2-day and total wet spells having -0.014285714 each, while 3, 5, 7, 10 and 14-days mean wet spells having normal condition. Different magnitudes of trends were detected with the magnitude of >0 recording 8 (highest), =0 was 0 (lowest) and <0 was 3. The overall gradient estimator showed positive from January-August with June having the highest value of 3.0857 and January, the lowest (0.0143). September-November had negative value with September having the highest negative value of -7.7429 and November having lowest of -0.0571. This study concluded that climate change was real and had impacted on the mean wet spells negatively. It was on that note that the following suggestions were made: the general public should be adequately informed on the concept of climate change, both adaptation and mitigation measures should be adopted to compact the impact of climate change, drainages should be cleared regularly to avert urban flooding and forecast of wet spells should be incorporated into the Seasonal Climate Prediction (SCP) and daily weather forecast by NiMet.

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