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MONITORING CLIMATE EXTREME EVENTS TREND IN NIGERIA USING CLIMPACT2 SOFTWARE

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ABSTRACT

Monitoring Nigeria climate extremes is essential for building resilience, reducing vulnerabilities, and ensuring sustainable development in the face of Nigeria's changing climate. ClimPACT2 software is used in this research to quantify climate extreme indices rate of change in the three Nigeria's climate zones. The weather inputs were daily precipitation, minimum and maximum air temperatures secondary data obtained from ERA5 from 1979 to 2021. The peaks of the maximum day and night temperatures were observed to be on significant increase in all the regions. Warm Spell Duration Index (WSDI) is significantly increasing per year in the Savannah by about 1.19 and 1.14 in Savanna, 1.10 in monsoon and 0.50 in Sahel regions. CDD is significantly increasing per year by about 0.33 in Akure, 0.44 in Lokoja, 0.12 in Port Harcourt and insignificantly by about 0.46 in Katsina while CWD is observed to be decreasing in all the regions. The number of wet and very wet days were observed to be decreasing over the years indicating drying days. SPEI drought index on time scales of 3, 6, 12 and 24 revealed significant increase in short time scale drought magnitudes of about 0.001 in Sahel while no significant change was observed in monsoon region. The analysis has shown significant warming trends in the Nigerian climate zones with significant implication on our climate, agriculture and overall environment leading to ecosystem disruptions. It is crucial for policymakers and stakeholders to take note of these trends and consider implementing measures to mitigate its impacts.

Keywords: Climate change, Extreme indices, Drought, Flood, Nigeria

INTRODUCTION

Nigeria is a country located in the tropical climate zone of the world and has had its own share of the climate change consequences over the years. As a result of global warming, precipitation fluctuation, flooding and drought have been experienced and becoming more frequent and severe in the different climate regions of the country. The Intergovernmental Panel on Climate Change (IPCC, 2023) reported that extreme weather and climate events, droughts and floods inclusive, have significant impacts on the economy, agriculture, natural resources, livelihoods and human health in Africa. The most devastating flood incidents in the history of Nigeria were recorded recently in 2022 across the country, far more devastating than that of 2012, while extreme drought conditions and heatwaves are been witnessed in some northern parts of the country where crop production and animal rearing are the major agricultural activities (www.studycountry.com). One of the reasons for initiating this research is therefore, to join other researchers in providing early warning signals on extent of climate change impacts on agricultural activities for decision making on food security.

Part of the development in drought analysis and monitoring involves the quantification of its characteristics such as severity (magnitude), intensity, duration and frequency (Abara et al., 2020 & Birega et al., 2017). Among the drought indices are the Palmer Drought Severity Index (PDSI) and the self-calibrated version (sc-PDSI) which is based on a soil balance equation, Standardized Precipitation Index (SPI) which is based on a precipitation probabilistic approach, and the Standardized Precipitation Evapotranspiration Index (SPEI) based on water balance. The PDSI/sc-PDSI lack multiscalar character essential for both assessing and differentiating drought types and different hydrological systems (Vicente-Serrano et al., 2010). The SPI weakness is the fact that it takes into account only precipitation, it does not consider other drought variables such as increasing temperature, evapotranspiration, wind speed and soil water holding capacity. It is in view of the above limitations that SPEI is considered as the best drought index for this research. The Standardized Precipitation Evapotranspiration Index (SPEI) is a multiscalar drought index which is sensitive to global warming (temperature increase) and is based on temperature, precipitation and Potential Evapotranspiration, PET (Vicente-Serrano et al., 2015). It is very effective and useful for detecting, monitoring and exploring the effects of global warming on drought conditions. The basic activity for drought mitigation is drought monitoring which is defined as data collection, analysis and reporting information of the results to decision makers for early warnings and risk reduction. It is therefore imperative to detect temporal changes in drought trend across the three climatic zones in Nigeria.

Many researchers have studied and analyzed climate extremes in Nigeria including Isa et al., (2023); Ogunrinde et al., (2022); Oguntunde et al., (2017 & 2018); Adeyeri et al., (2019); Gbode et al., (2019); Abatan et al., (2018). While some of these researchers concentrated only on specific index trend like temperature or precipitation, those who analyzed both indices and more among them did so in specific locations using the software available to them as the time. In this research, we have quantified the rate of change of the relevant climate extreme indices in the three climate zones of Nigeria to guide the end users of research results in making future decisions and policies and providing early warning signs of potential threats to enable timely responses to minimize damage and loss in Nigeria's diverse climate regions. This analysis would further enhance and advance the work of the previous researchers by examining trends of relevant climate indices at different time scales considered under three categories - threshold indices, duration indices, and minimum/maximum indices in Nigeria using ClimPACT2 software.

MATERIALS AND METHODS

Location

Nigeria is a tropical climate West African country located between longitude 3ºE and 15ºE of the Greenwich meridian, and latitude 4ºN to 14ºN of the equator. Due to the location of the country near the equator, the temperature is high throughout the year, though with regional variations. The World Bank group puts the country annual mean temperature at 26.9ºC with average monthly temperature range between 24ºC in December and January, and 30ºC in April. The country experienced precipitation throughout the year with an average annual value of 1,165mm (climateknowledgeportal.worldbank.org). The region is characterized by two seasons (dry and wet), April to October covers the wet season while the dry season occurs between November and March.

Based on temperature and precipitation, the Koppens' three broad climate zones in Nigeria are:

* *Tropical Monsoon Climate*; in the south southern part of the country such as River, Delta and Bayelsa States. The monthly mean temperature ranges between 23ºC during the night to 31ºC at daytime during the dry season while mean annual precipitation is about 2000mm.

* *Tropical Savannah (wet and dry) Climate*; covering some parts of central and southwestern regions like Kogi, Kwara, Benue, Abuja, Ondo, Oyo, Ekiti, Osun and so on. Monthly average temperature is between 22ºC at nighttime to 33ºC at daytime while average annual rainfall is about 1200mm.

* *Sahelian Hot and Semi-Arid Climate*; covering northern parts of the country like Sokoto, Zamfara, Katsina, Kano, Jigawa, Yobe and Borno States. The average daytime temperature is as high as 35ºC and nighttime about 21ºC, while mean annual rainfall is below 700mm. The areas in this climate zones are more vulnerable to drought and heatwaves than those in other climate regions.

The chosen locations for this research are Akure in Ondo State and Lokoja in Kogi State representing humid and dry tropical savannah climate region respectively, Port Harcourt in River State representing the tropical monsoon and the Sahelian hot and semi-arid region is represented by Katsina.

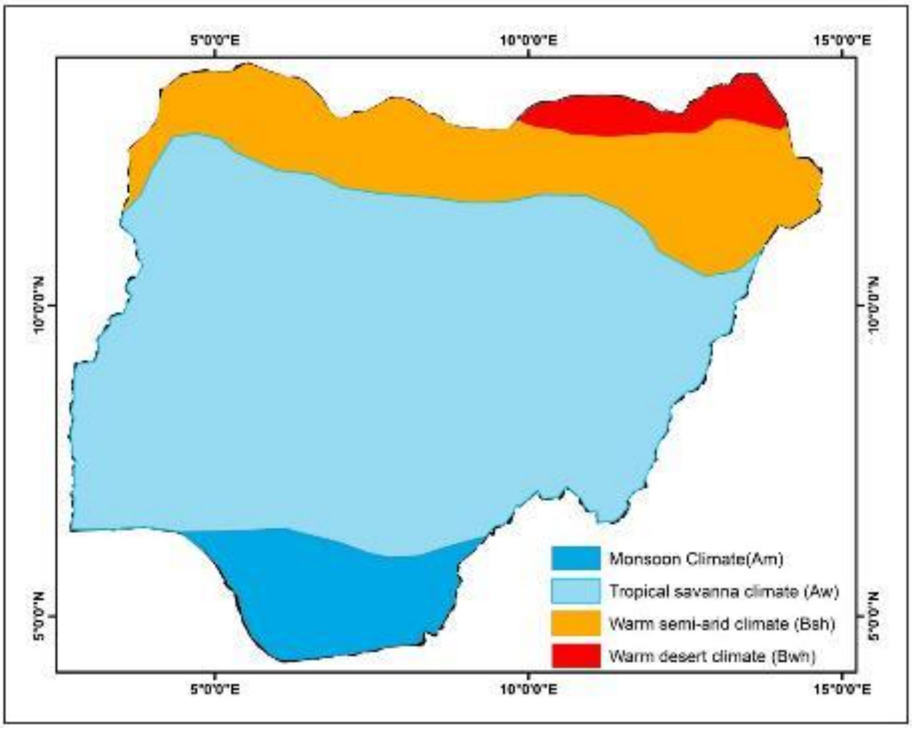

Figure 1: Nigeria Map of Koppens Climate Classification. Source: Nigieria map.png

Data

The data used include locations' Latitudes and Longitudes, in addition to secondary weather data on daily precipitation, near-surface minimum and maximum air temperature for 15,706 days (1979 - 2021) for each of the four chosen locations gotten from ERA5 Copernicus Sentinel Data Hub. The data were prepared in an ASCII text file format as input into the Climpact2 software. Climpact2 version 3.1.5 is used to analyze the data for climate extremes characterization in the climate zones of Nigeria. The outputs include the Expert Team on Climate Change Detection and Indices (ETCCDI) recommended indices relevant to Nigeria climate.

We used SPEI drought index to determine the drought characteristics such as duration, severity/magnitude and frequency. The negative and positive values of SPEI are considered as the drought and non-drought events respectively (Abara et al., 2020). A significant level of 0.05 (95% confidence level) is used to identify whether the trends are significant or insignificant from the result of the p-values accompanying each trend (Gocic et al., 2013). The Sen's slope gives the direction and magnitude of change per year of each of the indices. A negative Sen's slope value indicates increasing drought events while a positive Sen's slope indicates decreasing drought events (Giuseppe et al., 2019). A drought event is a period with negative SPEI values, that is, when the values of SPEI fall below zero. The duration *(D)* of drought is the length of period in which the SPEI value is continuously negative and ends when the SPEI value turns out to be positive. The drought severity *(S)* is the total SPEI values within the drought duration expressed as:

$$S = -\sum_{i=1}^{D} SPEIi \quad (1)$$

The intensity (I) of the drought is the ratio of its severity (S) to the duration (D)

$$I = \frac{S}{D} \quad (2)$$

Table 1: Categorization of the SPEI

CATEGORY	SPEI VALUE
Extremely wet	> 2.0
Severely wet	1.5 to 1.99
Moderately wet	1.0 to 1.49
Mildly wet	0 to 0.99
Mild drought	-0.99 to 0
Moderate drought	-1.49 to -1
Severe drought	-1.99 to -1.50
Extreme drought	< -2.0

Data Quality Control (QC)

The ClimPACT2 QC output indicates red circles for a missing or wrong data and allows users to easily identify them (https://github.com/ARCCSS-extremes/climpact2/). Some of such identifiable problems include outliers, missing data, jumps, unrealistic values, flatlines and duplicates. The outliers are identified based on the interquartile ranges (IQR) defined as the difference between the 75th (p75) percentile and the 25th (p25) percentile. For temperature, the outliers are values falling outside a range defined by:

p25 – 3*IQR (lower bound) and p75 + 3 *IQR (upper bound). For precipitation, 5*IQR are used.

The quality control result shows that the data used were of high quality, samples shown in figures 2 & 3 below. There were only few outliers and no identified duplicate of data (dates when temperature values were repeated more than four times). No observed situation where maximum temperature TX was ever less than minimum tempearture TN, no flatlines and large jumps in temperatures (dates when change in TX or TN > 20^{o}C). But on many occasions too large precipitation values were observed (where PRCP > 200mm or absT > 50^{o}C).

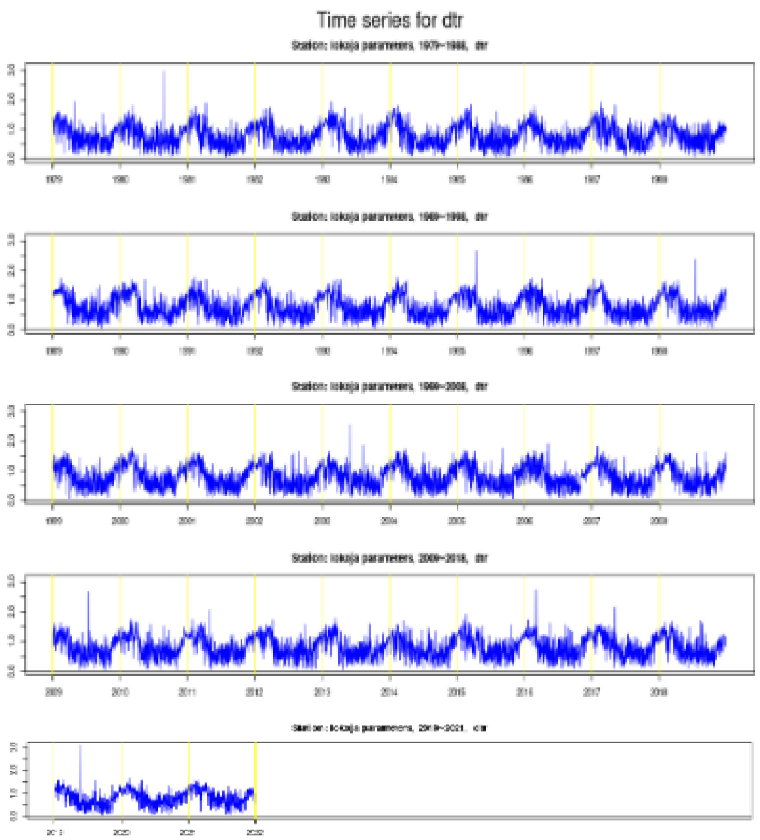

Figure 2: Time Series of Diurnal Temperature Range

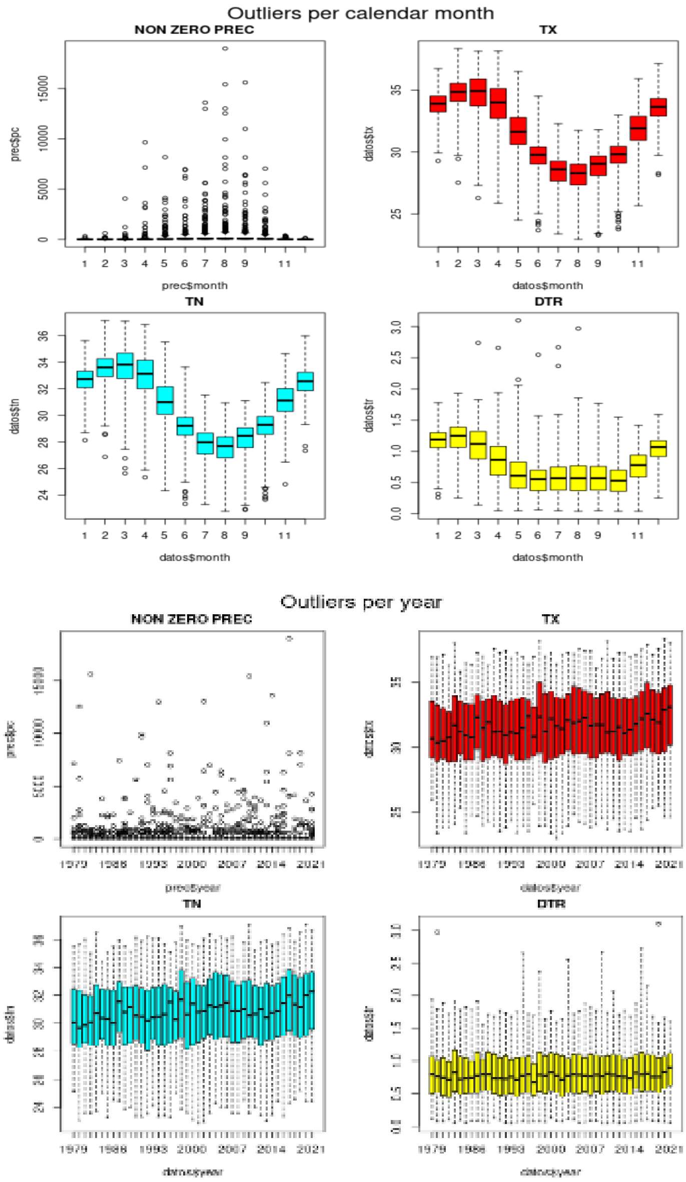

Figure 3: The Identified Outliers Diagrams

RESULTS AND DISCUSSION

Temporal Distribution of Climate Indices in Nigeria

Temperature

Figure 4 below shows significantly increasing annual average daily mean temperature in all the climate zones in Nigeria, Katsina and Lokoja been the hottest (with tmm sometimes getting as high as 32.8ºC and 32.4ºC per year respectively). The significant increase per year (as revealed by the Sen's slope) in the mean temperature is found to be about 0.024 and 0.022 degrees in the tropical savannah regions (Akure and Lokoja respectively), 0.012 and 0.018 in tropical monsoon (Port Harcourt) and sahelian region (Katsina) respectively. The observed increasing trend of the mean temperature is an indicator of significant climate change, with significant implications for the environment, ecosystems, and human societies. This result suggests that Nigeria is experiencing the effects of global warming, which can lead to more extreme weather patterns. The mean of the daily night and day temperatures (tnm & txm) have also been observed to be significantly increasing to show that the nights as well as the days are becoming significantly warmer yearly due to increasing air temperature (figures 5 & 6). The annual mean daily minimum temperature (Tnm) is observed to be significantly increasing ($p < 0.05$) per year by about 0.024 degrees in Akure, 0.021 degrees in Lokoja, 0.012 degrees and 0.018 degrees in Port Harcourt and Lokoja respectively, while the annual mean daily maximum temperature (Txm) is also significantly increasing per year by about 0.025 degrees and 0.022 degrees in the tropical Savannah region of Akure and Lokoja respectively, and 0.013 degrees in the tropical monsoon (Port Harcourt), 0.019 degrees in Katsina, Sahelian climate region. The rising temperatures can affect crop yields, reduce agricultural productivity, and lead to shifts in suitable crops and planting seasons.

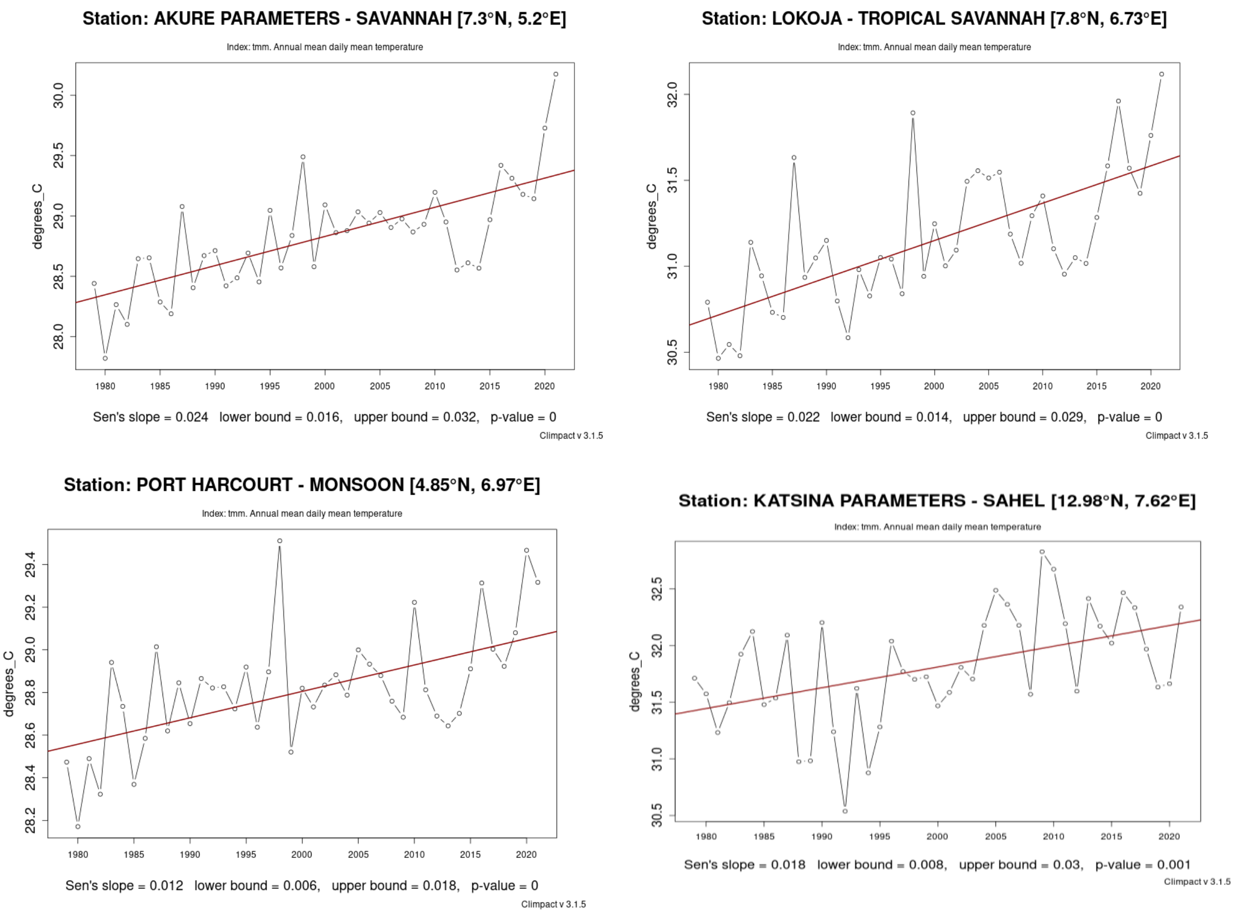

Figure 4: Annual Average Daily Mean Temperature, tmm

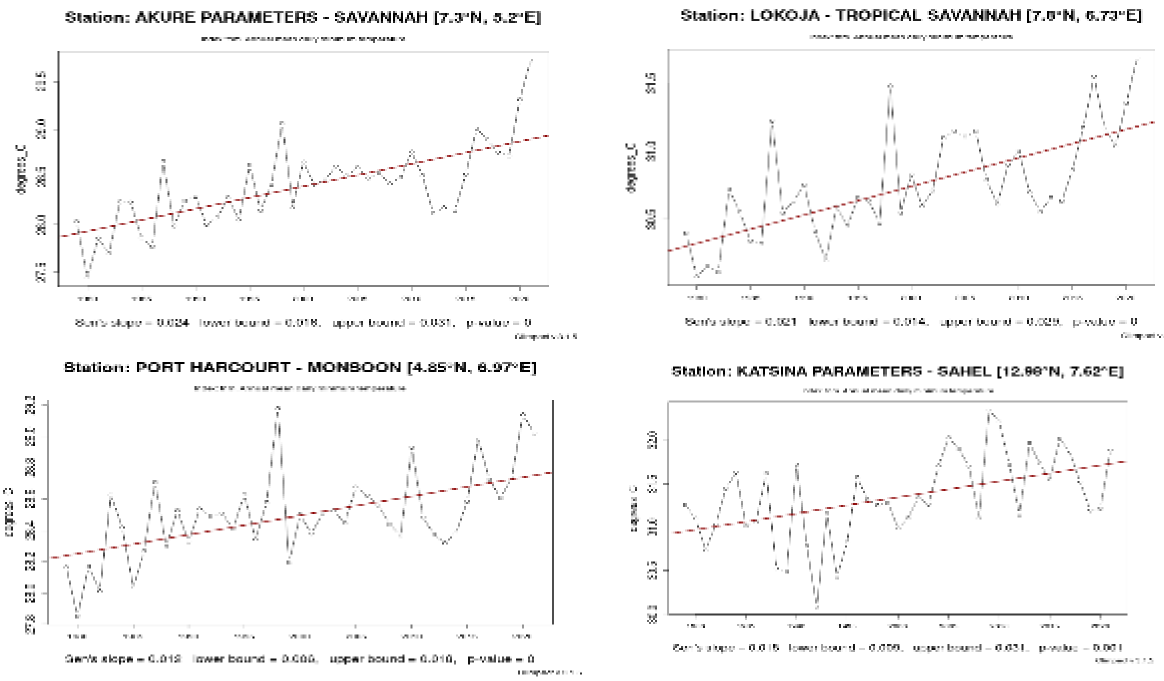

Figure 5: Annual Average Daily Minimum Temperature, tnm (Night Mean Tempearture)

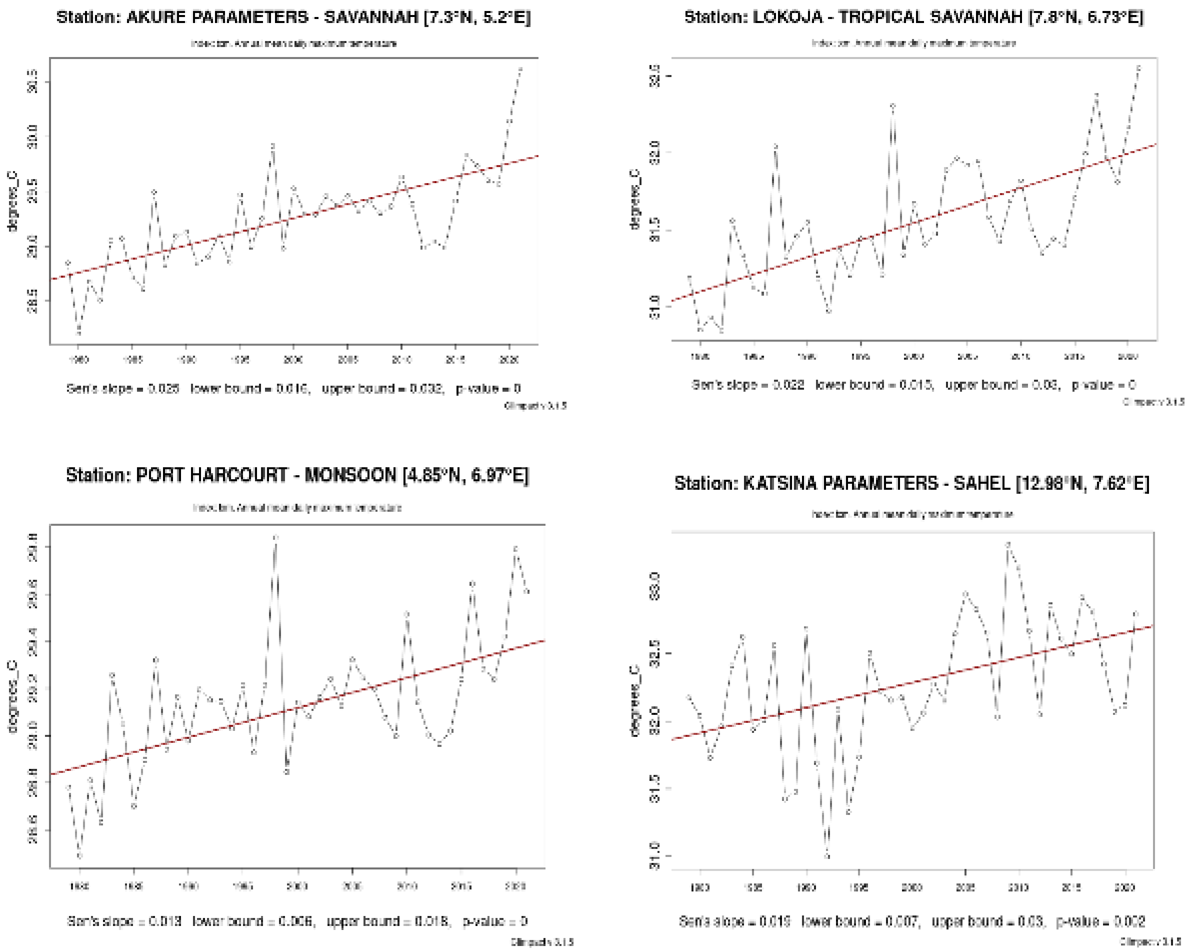

Figure 6: Annual Average Daily Maximum Temperature, txm (Day Mean Temperature)

It can be seen from figures 7 & 8 that there is steady significant increase in average peak temperatures of nights (Tnx) and days (Txx). Katsina has experienced the highest annual warmest daily minimum and maximum temperatures amongst the regions, with a peak annual warmest minimum temperature of above 41ºC and peak annual warmest maximum temperature well above 42ºC at some points in time. The annual warmest daily minimum temperature is observed to be significantly increasing per year by about 0.033 degrees and 0.019 degrees in Akure and Lokoja (Tropical Savannah) respectively, while it is about 0.035 degrees and 0.025 degrees in the Tropical monsoon (Port Harcourt) and Sahel (Katsina) regions respectively. To further confirm the warming of the regions, the annual warmest daily maximum temperature (Txx) has also been observed to be significantly increasing by about 0.034 degrees in Akure, 0.019 degrees in Lokoja, 0.04 degrees in Port Harcourt and 0.02 degrees in Katsina in figure 8.

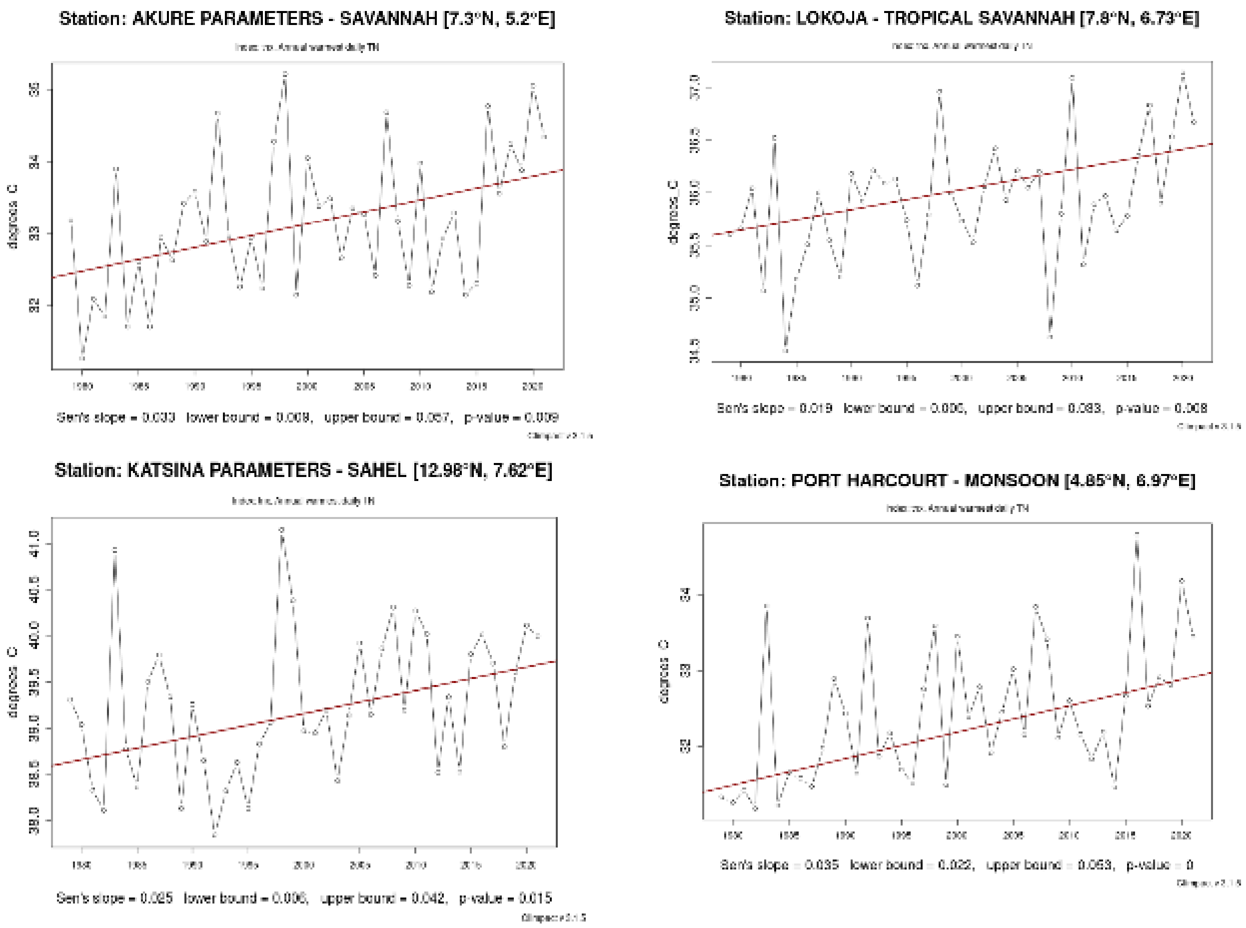

Figure 7: Annual Warmest Daily Minimum Temperature, tnx.

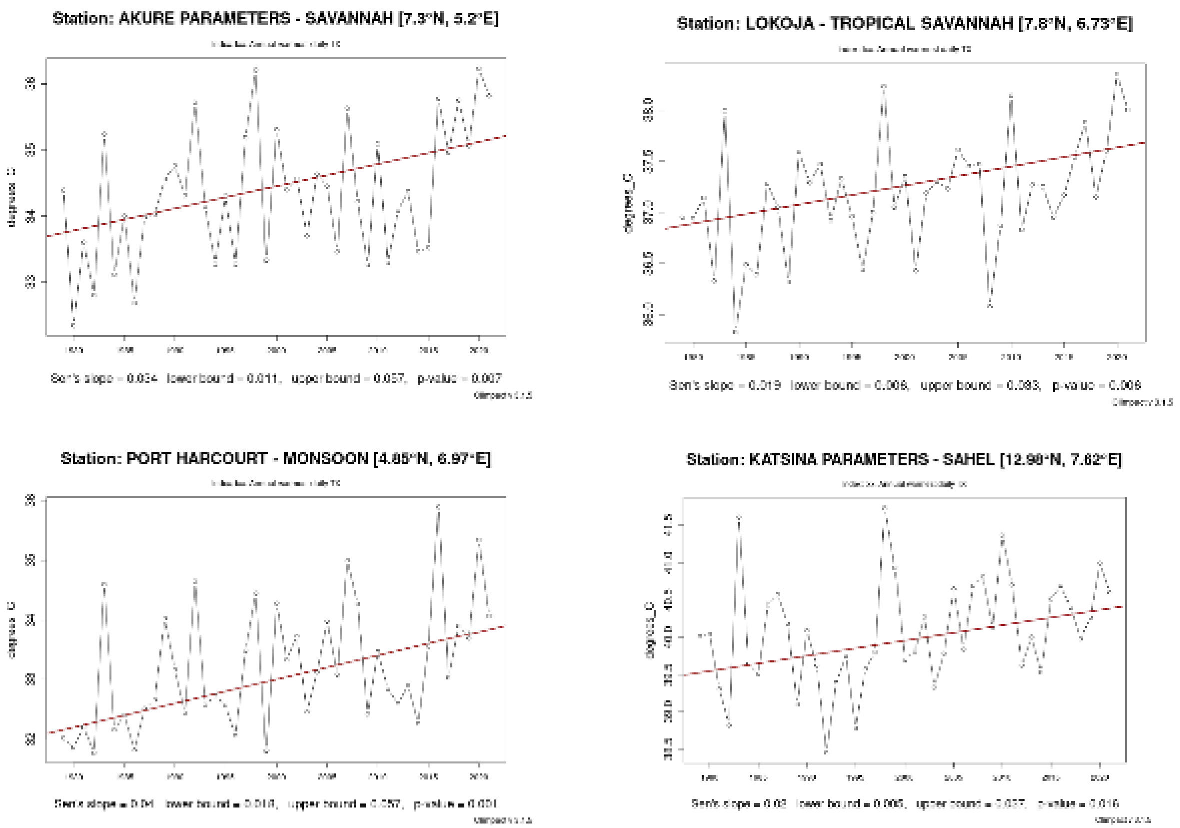

Figure 8: Annual Warmest Daily Maximum Temperature, txx.

The Warm Spell Duration Indicator is the annual number of days with at least one consecutive day when maximum temperature (Tx) is greater than 90th Percentile (WSDI). The WSDI1 result shown in figure 9 reveals significant increasing trend in all the regions by about 1.188 per year in Akure, 1.143 per year in Lokoja, 1.095 and 0.50 per year in Port Harcourt and Katsina respectively, in descending order. These values of WSDI are quite high suggesting that the regions are experiencing potentially unusual significant prolonged periods of warm temperatures which would have negative impacts on ecosystems, plants, animals and human populations. This is a clear indication of global warming in all the climatic regions of Nigeria.

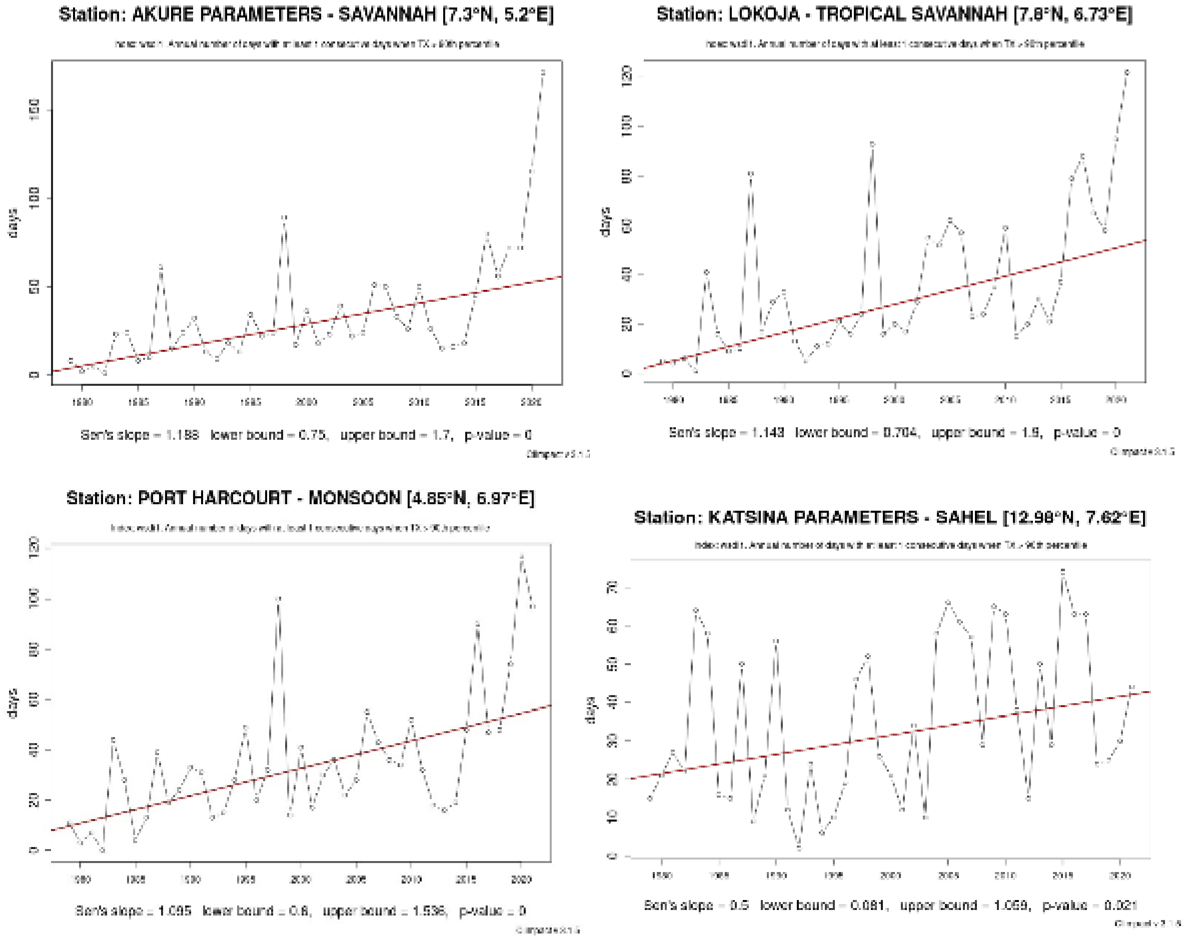

Figure 9: Annual Number of Days with at least 1 Consecutive Days when TX > 90th Percentile (WSDI1)

Precipitation

The annual sum of daily precipitation, PRCPTOT (fig. 10) is found to be increasing insignificantly per year in the tropical savannah regions by about 250mm in Akure and 156mm in Lokoja while it is insignificantly decreasing per year (revealed by the Sen's slope) by about 367mm in the tropical monsoon (Port Harcourt) and 55mm in the sahelian region (Katsina). The observed changes in precipitation patterns can disrupt local ecosystems and habitats, potentially threatening biodiversity in these regions. Species that rely on specific moisture conditions may face challenges in survival. The insignificant decreasing trend in the annual sum of daily precipitation totals in the Nigerian tropical monsoon and Sahel regions can have several implications for the environment, agriculture, water resources, and climate adaptation strategies. The decreasing trend in precipitation may affect agricultural productivity, particularly in rain-fed farming systems that are prominent in both the monsoon and Sahel regions. Reduced rainfall can lead to water stress in crops, decrease yields, and threaten food security. Farmers may need to adjust their planting schedules and crop varieties to adapt to changes in precipitation patterns (seasonal adaptation), which can affect traditional farming practices.

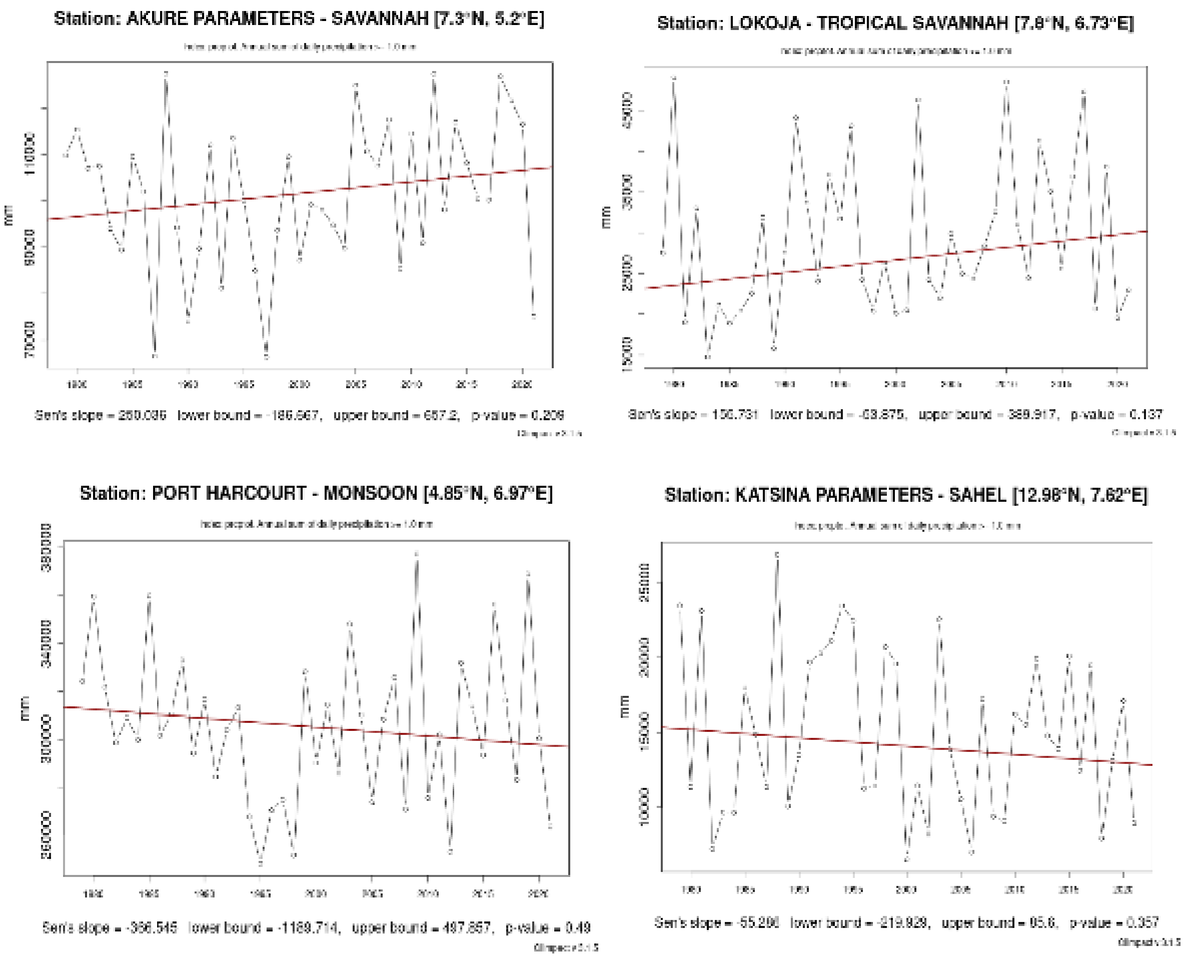

Figure 10: Annual Sum of Daily Precipitation Greater than or Equal to 1.0mm, PRCPTOT

Annual number of days when precipitation is greater than or equal to 10mm, r10mm (so also annual number of very heavy rain days; r20mm and r30mm) is significantly decreasing in all the regions (fig. 11) which signifies significant decrease in hydrological water availability in the regions except in Katsina where the decrease is observed to be insignificant (p >0.005), with the lowest values occurring in the most recent years (2020 – 2021) in the country climate regions. The number of heavy rain days (R10mm) is decreasing by about 0.76mm and 0.61 per year in the tropical savannah regions, Akure and Lokoja respectively, while tropical monsoon (Port Harcourt) and Sahelian regions are having decrease per year of about 0.47mm and 0.18mm respectively. The maximum 1 day precipitation total (rx1day) is equally decreasing insignificantly in Akure and Katsina by about 10mm per year and 7mm per year respectively, a significant increase of 129mm per year was observed in Port Harcourt (Tropical Monsoon) while Lokoja experienced an insignificant increase of about 43mm per year (fig. 12). These analysis reveals that the regions are relatively getting dryer yearly, so irrigation for agriculture and other steps should be taken to mitigate its effects.

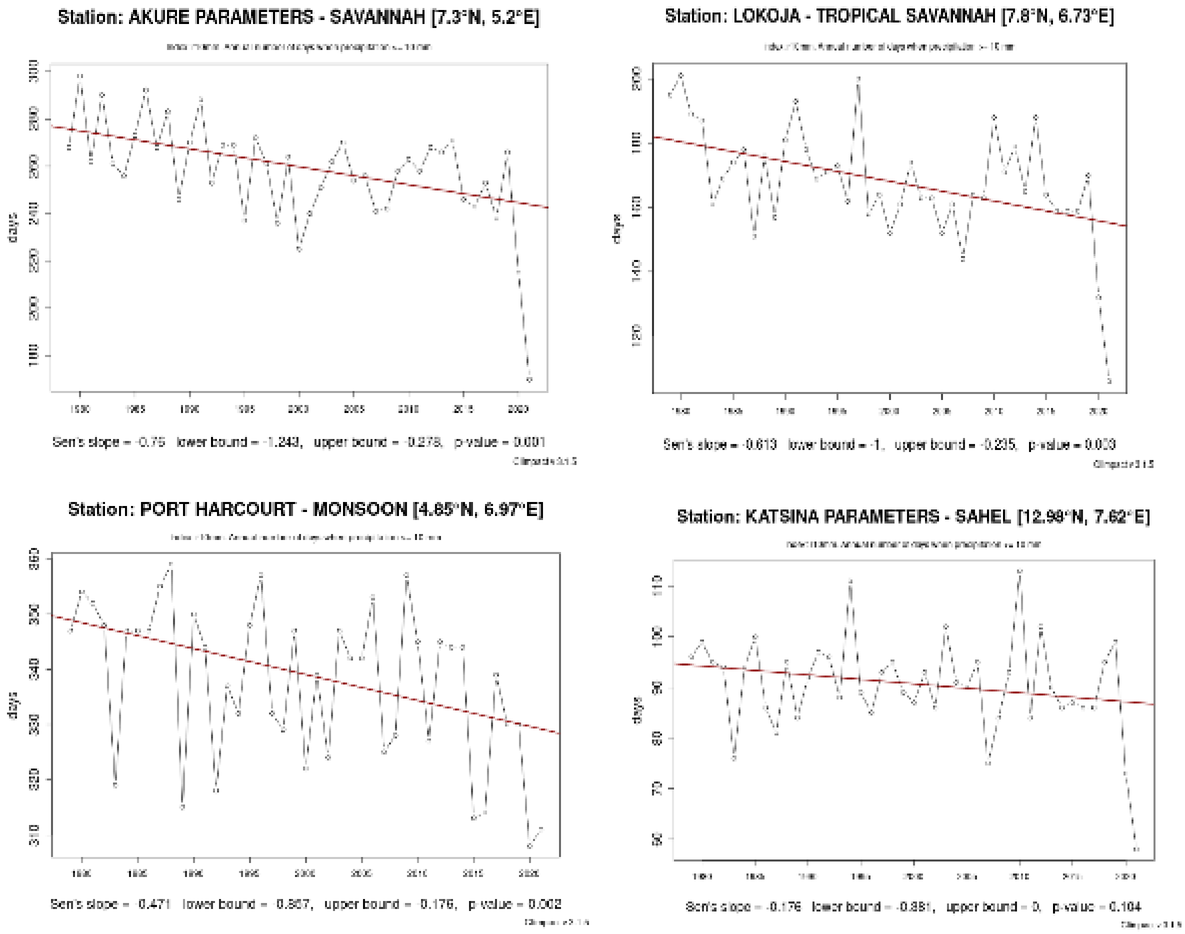

Figure 11: Annual Number of Days when Precipitation > 10mm, Number of Heavy Rain Days

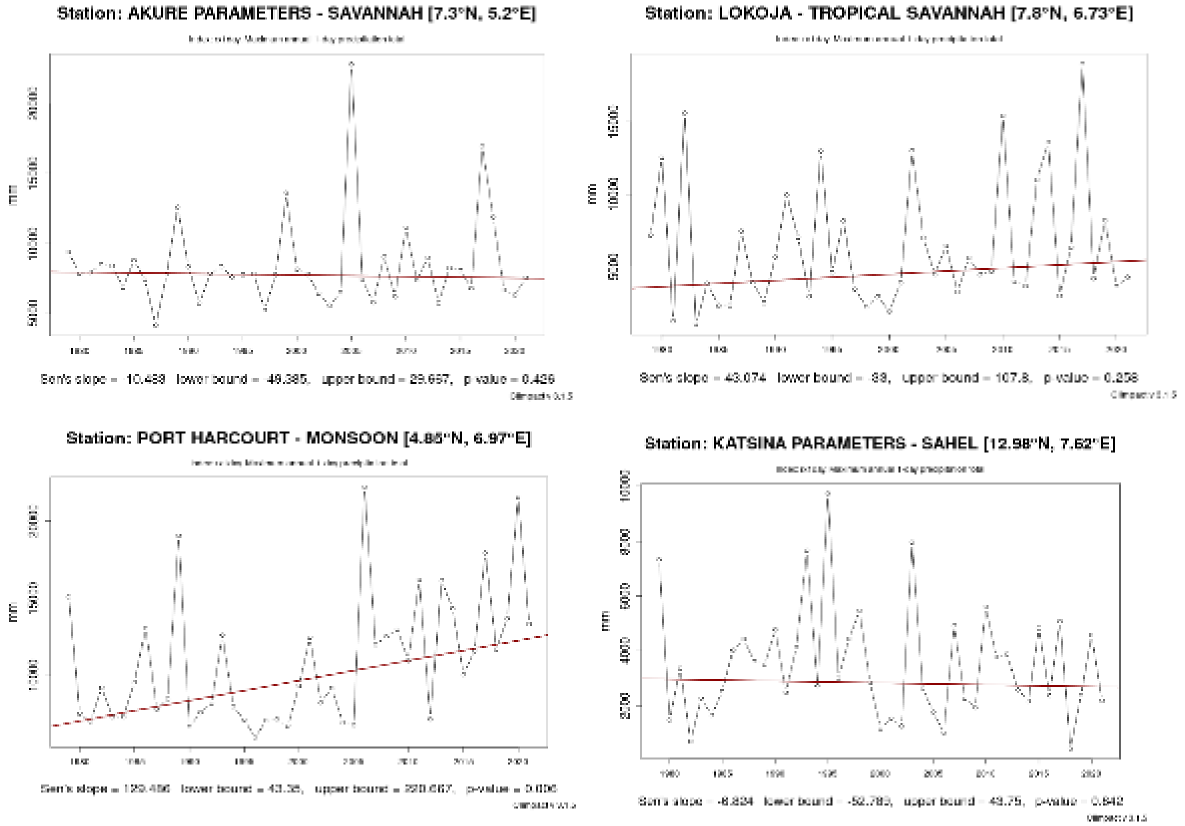

Figure 12: Maximum Annual 1 Day Precipitation Total, rx1day

Though temperature is seen to be on the increase in all the regions (warming), the daily precipitation index SDII (Simple Daily precipitation Intensity Index) in figure 13 is observed to be increasing in the tropical savannah and monsoon climate zones by about 1.45mm insignificantly in Akure, significantly by about 1.13 in Lokoja and insignificantly by about 0.121 in Port Harcourt. SDII in the sahelian hot and semi-arid climate region (Katsina) is decreasing insignificantly by about 0.119mm. This is an evidence that despite the observed decrease in Consecutive Wet Days (CWD), possibility of seasonal flood events in the regions of tropical savannah and monsoon cannot be ruled out. Katsina has the least SDII change rate while Akure has shown the highest change rate.

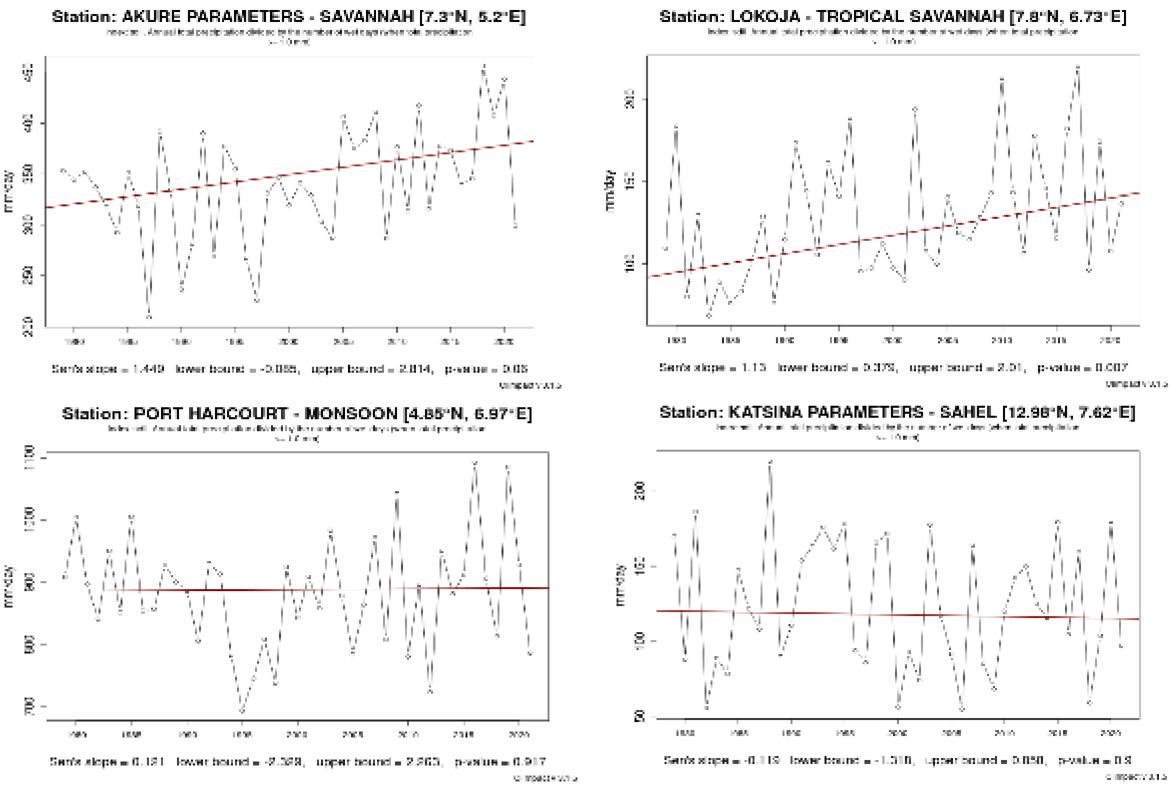

Figure 13: Simple Daily-Precipitation Intensity Index (SDII), Daily Precipitation Intensity

While the current observed trend in precipitation may be insignificant, it underscores the need for vigilance and proactive management strategies to cope with potential future changes in precipitation patterns. Continued research and monitoring are crucial to understand the implications fully and to guide policy-making in the face of evolving climatic conditions.

Dry and Wet Spells (CDD & CWD) Trend

Figure 14 shows plots of the number of consecutive dry and wet days (CDD & CWD) taken at precipitation below and greater than or equal to 1.0mm per day respectively. It can be seen from the figures that the maximum annual number of consecutive dry days with precipitation less than 1.0mm (PRCP < 1.0mm) has generally been on increase in all the climate regions of Nigeria, and significantly so (P-value < 0.05) except in Katsina where the increase is observed to be insignificant (P-value > 0.05). The maximum number of consecutive wet days with PRCP $\geq$ 1.0mm (CWD) is decreasing insignificantly, only Lokoja has shown significant decrease as shown in figure 15.

The maximum annual number of consecutive dry days is significantly increasing by about 0.33 and 0.44 per annum in the tropical savannah of Akure and Lokoja respectively, 0.12 and 0.46 per annum in tropical monsoon (Port Harcourt) and insignificantly in Sahelian region respectively (fig. 14). The maximum number of CWD has been decreasing by about 0.11 and 0.11 per annum in tropical savannah of Akure (insignificantly) and Lokoja (significantly) respectively while it is insignificantly decreasing by about 0.15 per annum in Port Harcourt (Tropical Monsoon) and 0.83 per annum in Katsina (Sahel). The region with the highest number of consecutive dry days is Sahelian & Semi-arid region of Katsina (about 240 days in a year) while the least CDD was about 2 days in a year in tropical monsoon of Port Harcourt. The highest maximum annual number of consecutive wet days, 280 days in a year, was observed in Port Harcourt (tropical monsoon) while the least, about 12 days in a year, occurred in Katsina (sahelian climate), Lokoja (tropical savannah) and Port Harcourt (Tropical monsoon).

The trends of decreasing consecutive wet days and increasing dry days can have profound implications for Nigeria across multiple dimensions such as agriculture, water resources management, ecosystems and socioeconomic issues, prompting urgent need for adaptive measures, sustainable practices, and comprehensive planning to mitigate adverse effects and enhance resilience against climate variability and change.

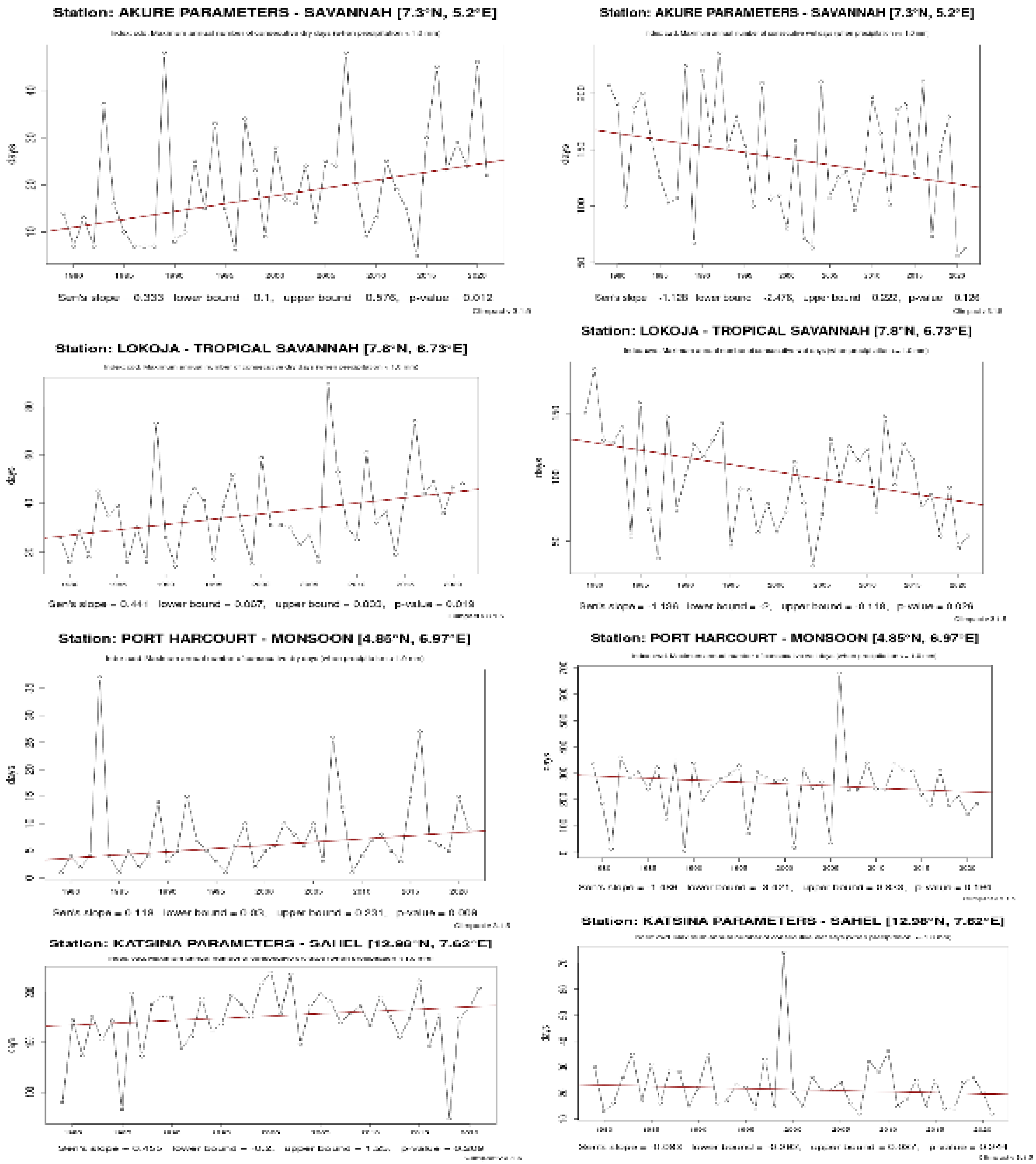

Figure 14: Dry and Wet Spells

Standardized Precipitation Evapotranspiration Index (SPEI)

The Standardized Precipitation Evapotranspiration Index (SPEI) is one of the output indices of ClimPACT2 and it uses both precipitation and evapotranspiration to quantify drought characteristics. The results of the short, medium and long time SPEI drought indices for the four chosen locations are plotted in figures 15 to 18. The short and medium time scales (3- and 6-month) show more variations in magnitude than the longer time scales of 12- and 24-month. Generally, at 3- and 6-Month time scales all the stations have consistently shown intermittent meteorological/agricultural droughts over the years, Lokoja (Tropical Savannah) and Port Harcourt (Tropical Monsoon) showing some significant levels of extreme droughts in recent years between 2020 and 2021, which turns evidently obvious from the longer time scales of 12- to 24- months (hydrological drought). No significant change in meteorological drought magnitude was observed (Sen's slope=0, P-value above 0.05) in the other climate zones except Sahelian hot climate region of Katsina with significant decrease in precipitation and increase in drought of about 0.001 per year for the 3-month SPEI drought. This raises concerns about the potential implications for the affected area (Sahelian region) and the need for proactive measures to address drought and its associated challenges such as heatwaves.

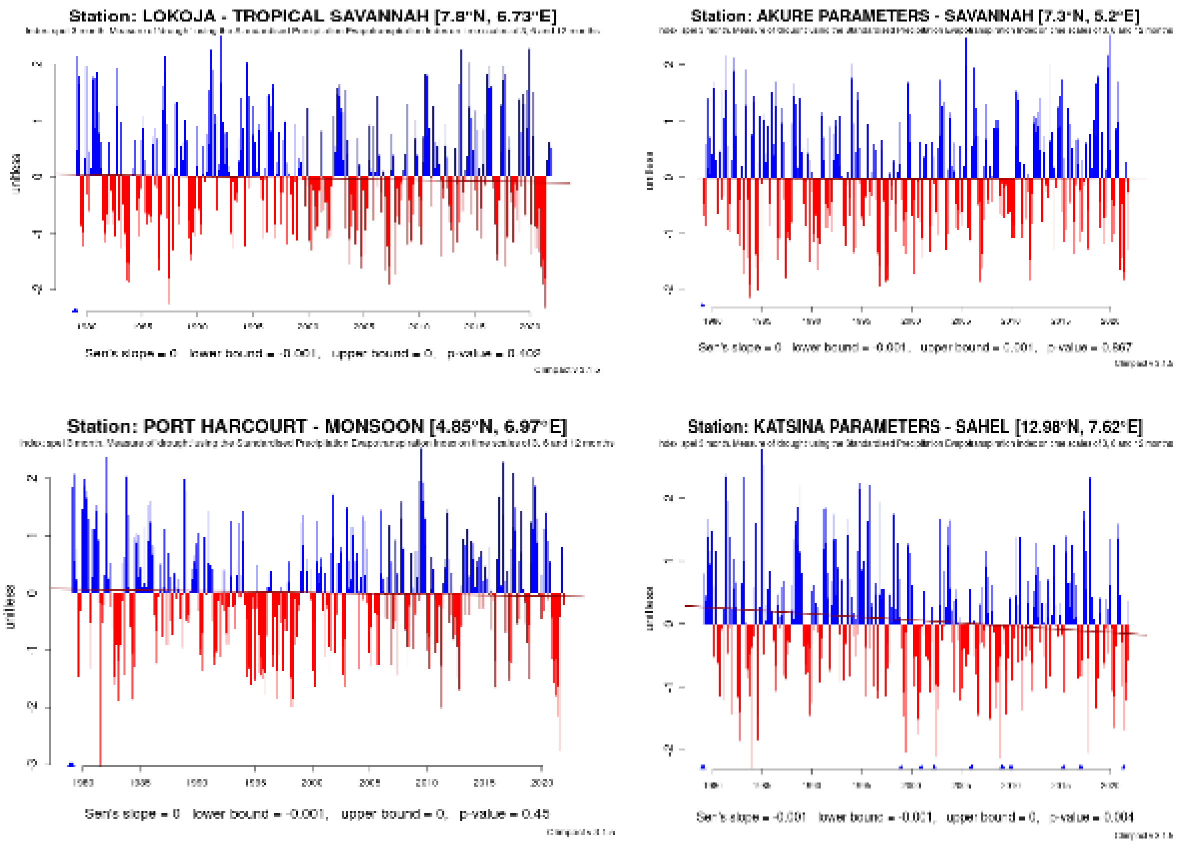

Figure 15: Measure of Meteorological Drought Using the SPEI-3 Time Scale

Tropical Savannah (Lokoja and Akure) showed decrease in agricultural drought (6-month time scale) in the region, no change in the Tropical Monsoon but significant increase in Sahel region. The results revealed decrease of drought of about 0.001 in tropical savannah climate, significant in Lokoja but insignificant in Akure. All the time scale droughts have been observed to significantly increase by about 0.001 per annum in the Sahelian climate region (Katsina) in Nigeria. Hydrological drought (SPEI-12 and 24) decreased significantly by about 0.002 per annum in tropical savannah climate regions (Lokoja and Akure), significantly increased by about 0.001 per annum in Sahel region (Katsina), and no significant change in magnitude in tropical monsoon (Port Harcourt) as shown in figures 17 and 18. The significant increase in droughts of different time scales, especially in the Sahel, can be linked to climate change and other environmental factors, and can have severe impact on agriculture leading to crop failures and food insecurity for local communities. The medium and long term prolonged dry spells can exacerbate the effects of short-term droughts, causing water scarcity and further straining agricultural production. They can have lasting effects on the local ecosystem, leading to desertification, loss of vegetation, and displacement of populations. These highlights the vulnerability of the regions, especially Sahel, to climate variability and the need for adaptation strategies to mitigate the impacts of these extreme weather events. Efforts to improve water management, promote sustainable agriculture practices, and enhance resilience to droughts will be crucial in addressing the challenges posed by this changing climate in the regions of Nigeria.

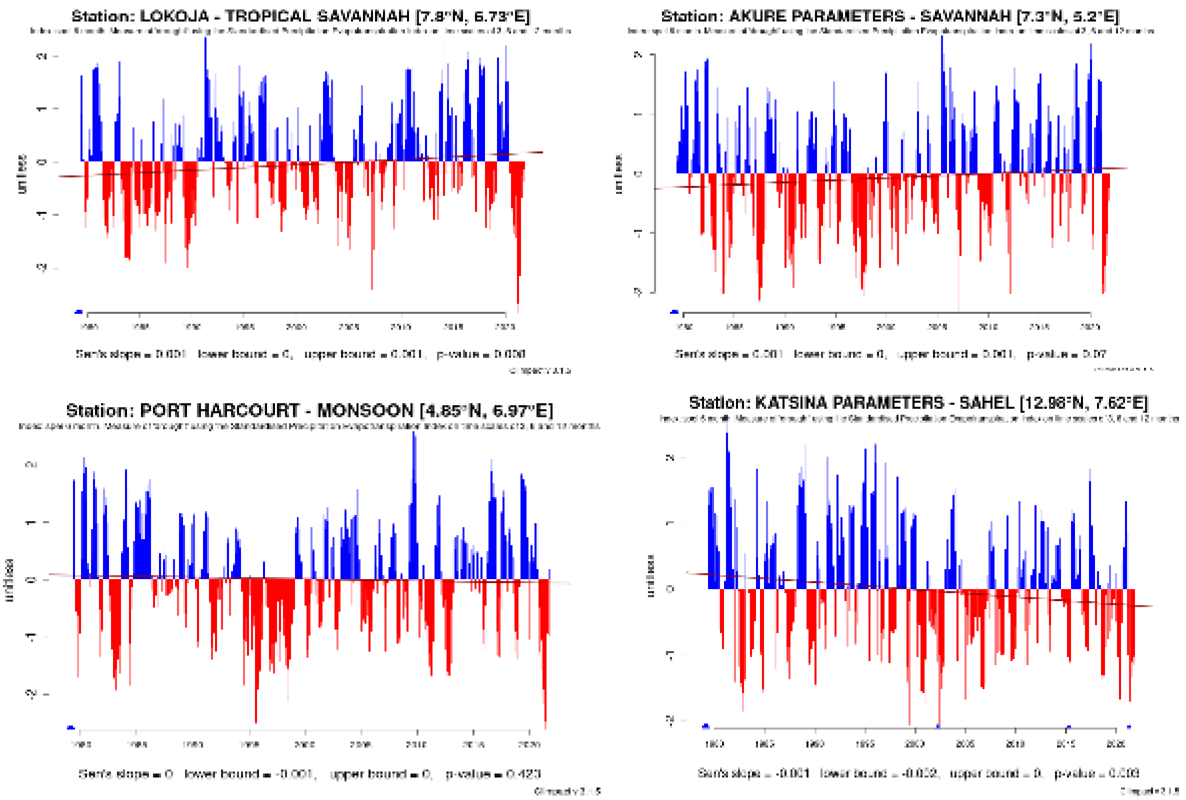

Figure 16: Measure of Agricultural Drought Using the SPEI-6 Time Scale

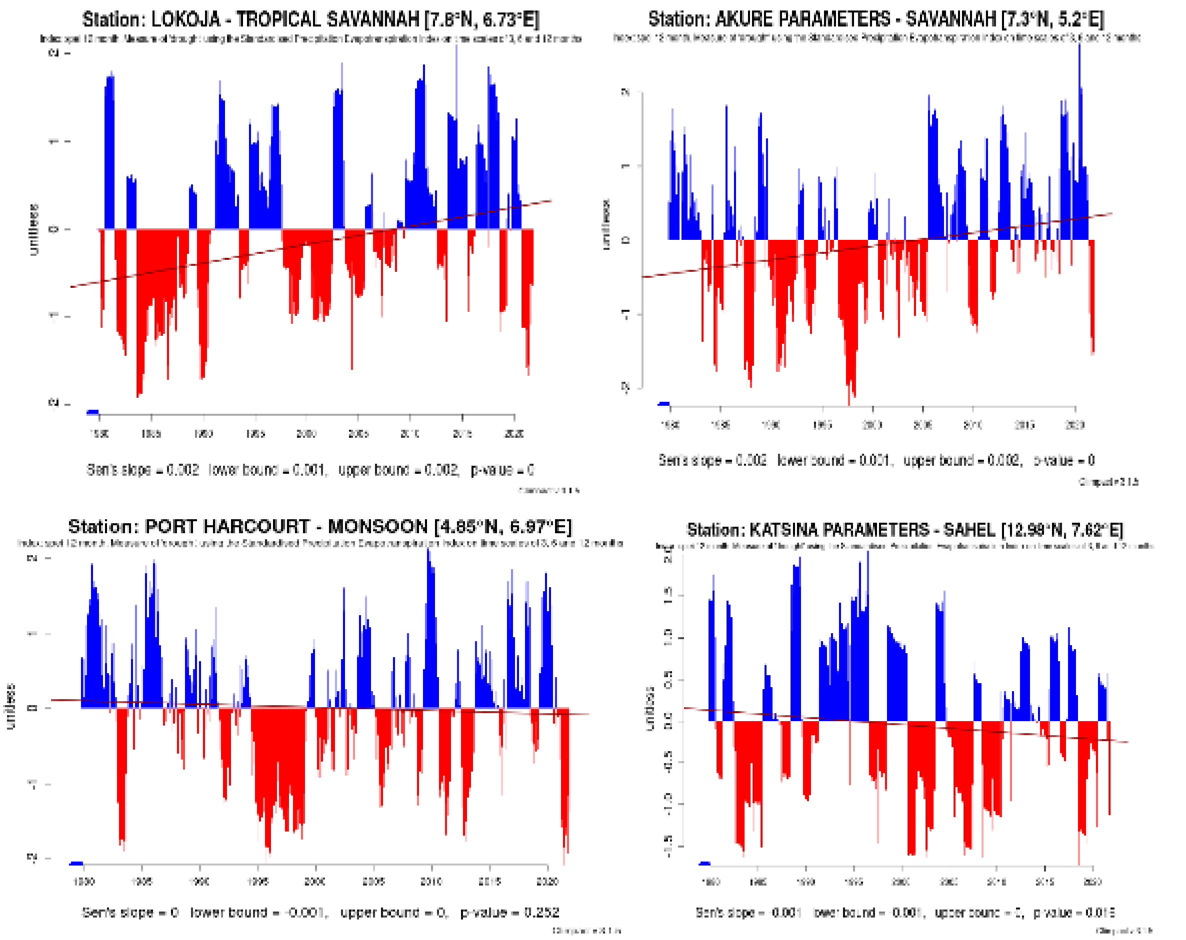

Figure 17: Measure of Hydrological Drought Using the SPEI-12 Time Scale

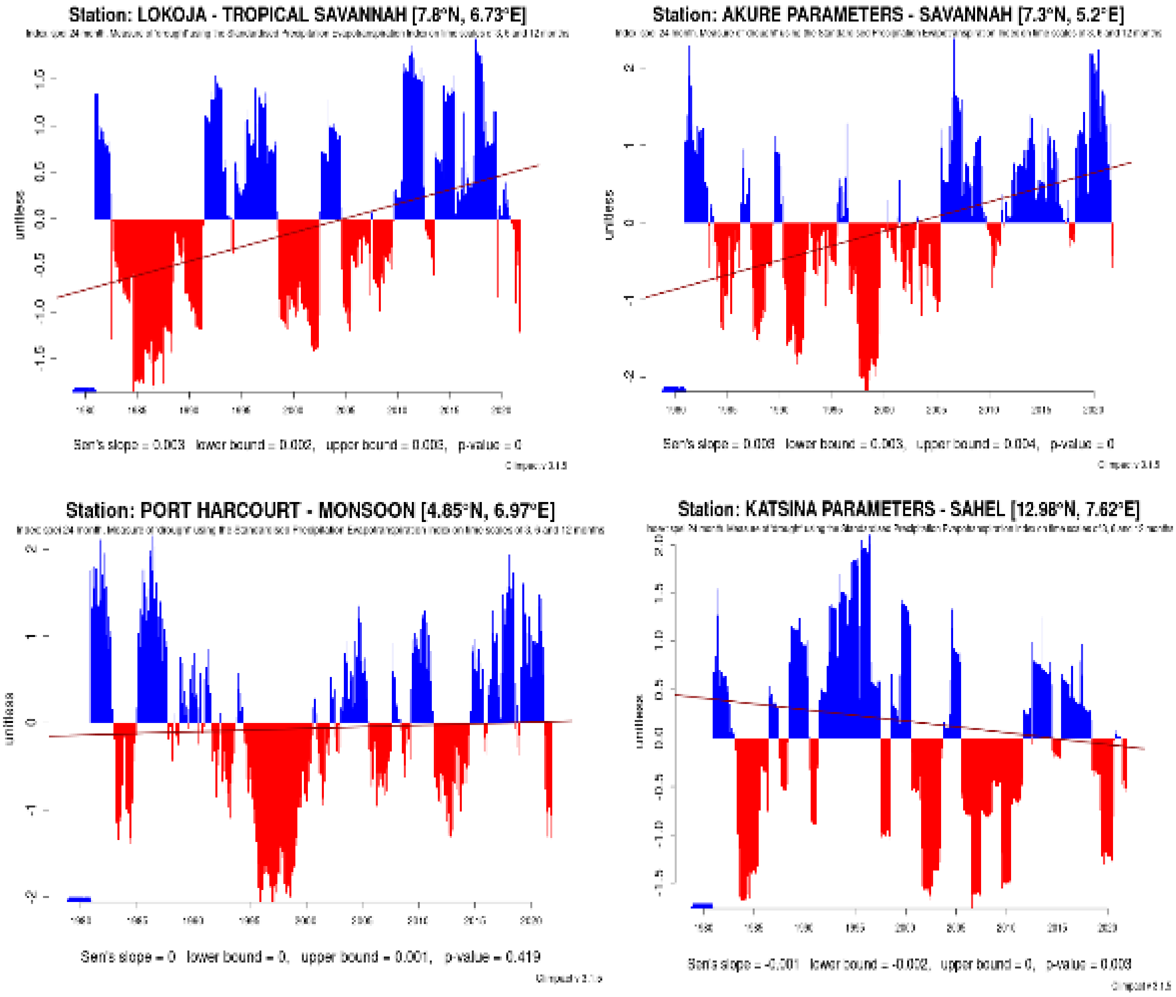

Figure 18: Measure of Hydrological Drought Using the SPEI-24 Time Scale

Drought Characteristics across the Climate Regions

Based on the time scale specifications, the basic drought characteristics (frequency, duration, magnitude/severity and intensity) calculated for each location from 1979 to 2021 are presented in table 2. The meteorological and agricultural drought frequency is generally above average (> 50%) in tropical savannah climate regions (Akure and Lokoja) but below average in tropical monsoon region (Port Harcourt). Except SPEI-12, other SPEI time scales surprisingly revealed below average drought frequency in Katsina, sahelian region. The highest drought magnitude/severity in a single drought period was 110.91 in Lokoja, tropical savannah. Short and medium time scales revealed alternate wet and dry conditions in the climate zones of Nigeria but with extremely severe droughts (below -2.0) observed to have occurred most recently between 2020 and 2021 in Lokoja at higher frequencies. Hydrological droughts from SPEI-24 showed severe droughts (-1.5 to -1.9) and extremely severe droughts (< -2.0) in the 80s and 90s with very few extending to early 20s. Port Harcourt experienced its most severe (-2.0 and below) and longest hydrological droughts between 1995 and 2000. Katsina has the highest hydrological drought frequency among the stations considered. Moderate drought is the most common drought category in Nigeria, tropical climate region. The longest hydrological drought durations were observed in Lokoja August 1982–September 1992 (108 months), Port Harcourt July 1994 - August 2001(74 months) and most recently in tropical sahelian and semi-arid climate region, Katsina in August 2005 to August 2011 (73 months).

On an average for SPEI-3 time scale, the tropical savannah regions showed the highest drought frequency, with mild drought in all the regions except Lokoja where moderate drought (-1.41) occurred frequently. The category of hydrological drought was generally a moderate type for the climate regions, mild in Port Harcourt for SPEI-12 and Katsina for SPEI-24 time scales. Drought high duration, severity, intensity and frequency are frequently found in the Sahel and Semi-arid zone of Nigeria. The results show that the drought events have a significant impact on water resources, agriculture, and livelihoods in the regions, hence the need for improved drought monitoring and early warning systems to help mitigate the impacts of drought on local communities.

Table 2: Climate Stations Drought Characteristics

			CLIMATE STATIONS			
			HUMID SAVANNA	**SAVANNA**	**MONSOON**	**SAHEL & ARID**
			AKURE 7.3ºN, 5.2ºE	LOKOJA 7.8ºN, 6.7ºE	PORT HARCOURT 4.85ºN, 6.97ºE	KATSINA 12.98ºN, 7.62ºE
SPEI	3	NUMBER OF DROUGHT MONTHS	265	264	255	249
		FREQUENCY (%)	51.4	51.2	49.4	48.3
		LONGEST DURATION (IN MONTHS)	14	13	12	10
			NOV 2018-DEC2019	JULY 2020-JULY 2021	JUNE 1991-APRIL1992 MARCH 1994-FEB 1995	JUNE 1983-MARCH 1984 FEB 2005-NOV 2005
		SEVERITY	-6.7	-18.36	-7.48	-8.38
					-8.93	-5.53
		INTENSITY	-0.48	-1.41	-0.62	-0.84
					-0.74	-0.55
		CATEGORY	mild	Moderate	Mild	mild
	6	NUMBER OF DROUGHT MONTHS	266	271	254	257
		FREQUENCY (%)	51.6	52.5	49.2	49.8
		LONGEST DURATION (IN MONTHS)	21	17	31	18
			JULY 1996-MARCH 1998	JULY 2020-NOV 2021	JULY 1996-JAN 1999	SEPT 2004-FEB 2006
		SEVERITY	-25.77	-20.55	-31.76	-10.3
		INTENSITY	-1.23	-1.21	-1.02	-0.57
		CATEGORY	moderate	Moderate	moderate	mild
	12	NUMBER OF DROUGHT MONTHS	258	267	248	260
		FREQUENCY (%)	50	51.7	48.1	50.4
		LONGEST DURATION (IN MONTHS)	33	59	59	37
			OCT 1989-JUNE 1992	SEPT 1997-JULY 2002	JULY 1994-MAY 1999	JULY 1982-JULY 1985
		SEVERITY	-33.93	-40.05	-77.08	-41.77
		INTENSITY	-1.03	-0.68	-1.31	-1.13
		CATEGORY	moderate	Mild	moderate	moderate
	24	NUMBER OF DROUGHT MONTHS	252	247	257	231
		FREQUENCY (%)	48.8	47.9	49.8	44.8
		LONGEST DURATION (IN MONTHS)	46	108	74	73
			AUG 1996-MAY 2000	AUG 1982-SEPT 1991	JULY 1994-AUG 2020	AUG 2005-AUG 2011
		SEVERITY	-58.16	-110.91	-98.68	-70.03
		INTENSITY	-1.26	-1.03	-1.33	-0.96
		CATEGORY	moderate	Moderate	Moderate	mild

CONCLUSION

In this research, we have used the recent version of ClimPACT2 software to analyze the trends of climate extreme events in the three major climate regions of Nigeria. The minimum and maximum temperatures as well as their peaks have been observed to be significantly increasing signifying steady warming of days and nights in all the Nigeria climate zones. The climate indices analyzed showed that tropical sahelian region (Katsina) is getting warmer and drier fastest compared to other regions as temperatures are increasing significantly with decreasing precipitation in the region. The number of days contributing to a warm period, where the period has to be at least 6 days long, (WSDI) was also observed to be increasing significantly in all the regions by about 118.8% per year in Akure, 114.3% per year in Lokoja, 109.5% and 50% per year in Port Harcourt and Katsina respectively.

The number of consecutive dry and wet days (CDD and CWD) results showed that the entire country is becoming drier than before as the CWD is decreasing while CDD is increasing significantly in all the climatic regions of Nigeria. The number of wet and very wet days (r10mm, r20mm, r30mm, rx1day and rx3day) were all observed to be decreasing over the years. Despite these observed increasing drought trends, the increase in the Simple Daily-precipitation Intensity Index (SDII) in the tropical savannah and monsoon

regions revealed that flash flood occurrence is also inevitable in those areas in the near future. The short, medium and long time (meteorological, agricultural and hydrological) droughts revealed by SPEI-3, 6, 12 and 24 are shown to be on increase, fastest in the Sahel & Semi-Arid climate zone (Katsina). This observed increasing trends in droughts in Nigerian climate regions underscore the urgency of addressing climate change and implementing sustainable measures to mitigate the impacts of water scarcity and environmental degradation on the country's economy and society.
From the observed increasing temperature trends and fluctuating precipitation in the climatic zones, more intense drought (in dry seasons) with increased heatwave situations are equally likely and may impact more negatively on agriculture, health and economy of Nigeria if steps are not urgently taken to mitigate it. Irrigation farming should be given more priorities in the country to ensure adequate food security as the country is faced with challenging climate change impacts. Such sustainable measures to mitigate the impacts may include: implementing rainwater harvesting systems in both urban and rural areas to capture and store water during the rainy season for use during dry seasons; promoting water conservation practices such as fixing leaky faucets, using water-efficient fixtures, and promoting awareness about the importance of managing water resources wisely; encouraging the use of drip irrigation systems in agriculture to reduce water wastage and increase crop yield; investing in water purification technologies to treat and recycle wastewater for agricultural and industrial purposes; implementing watershed management plans to protect and restore critical ecosystems, such as forests and wetlands, that play a crucial role in regulating water supply and quality; promoting afforestation and reforestation initiatives to increase forest cover and prevent soil erosion, which can lead to water scarcity and degradation of water quality; enforcing stricter regulations on pollution and waste management practices to prevent contamination of water sources and protect public health; promoting sustainable land use practices, such as organic farming and agroforestry, to preserve soil fertility and water resources; engaging local communities and stakeholders in participatory water management initiatives to ensure inclusive and sustainable water governance; and investing in renewable energy sources, such as solar-powered water pumps and hydropower systems, to reduce reliance on fossil fuels and minimize the environmental impact of water extraction and distribution.

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