

Trend analysis of maximum consecutive dry and wet days in Northwestern Nigeria

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Abstract

Dry and wet spells are frequent extreme weather events that have a major global impact on ecosystems, water resources, and agriculture in most regions across the globe, with the arid and semi-arid areas being the hardest hit. This study examines the frequency and trend of maximum consecutive dry and wet spells in Northwestern Nigeria using long-term daily rainfall data from 1980 to 2021. The temporal trend of dry and wet spells was analysed using the Mann-Kendall test. Standardised Precipitation Index (SPI) and Standardised Precipitation Evapotranspiration Index (SPEI) were deployed for quantification of severity, intensity, and duration of drought. Pearson's correlation was used for the relationship between drought and indices, and dry and wet spells, while estimating the annual yield of the crop and dry and wet spells were correlated. Both dry and wet spells exhibited positive and negative trends. The analysis reveals a significant trend in dry and wet spell patterns, indicating increasing dryness in some areas and wetness, specifically in Kano, Sokoto, and Kebbi. Standardised Precipitation Index (SPI) and dry spells are significantly correlated. The findings of this study can inform decision-making in water resource planning, agriculture, and disaster risk reduction by supporting effective management of flood and drought events.

KeyWords: Dry spells, Wet spells, Trend analysis, climate variability, water resources

Introduction

Global changes in drought and wetness, as well as their future trends, have recently become a major focus of research in arid and semi-arid regions (Y. Li et al., 2024). This variability has led to numerous incidents of droughts and flood disasters at a global scale. Recurring droughts and floods have significantly impacted water resources in many regions worldwide, with arid and semi-arid regions being the most affected. (Bhaga et al., 2020; Mohammed et al., 2025). Climate change has increased the frequency and magnitude of hydro-meteorological hazards such as drought and flood. The characteristics of wet/dry spells have been analyzed at a global scale, focusing on spatial and temporal patterns. (Z. Li et al., 2017). Several studies conducted at the global level (Caloiero et al., 2015; Z. Li et al., 2017; Singh & Ranade, 2010), regional (Achite et al., 2021; Adane et al., 2020; Basse et al., 2024; Nouaceur et al., 2025), and sub-regional scales (Basse et al., 2024) have demonstrated increasing changes in precipitation over various timescales. In the context of climate change, research on precipitation at the regional and local scales is crucial for evaluating the hydrological effects, such as drought and flooding. (Caloiero et al., 2015).

A detailed understanding of the rainfall regime in a particular location is an important prerequisite for agricultural planning and management (Ravindran, 2021). Information about the risk of dry and wet spells is critical for agricultural purposes. According to characteristics of wet spells and intervening dry spells are extremely useful for the water-related sector, particularly in global climate change and climate-change scenario projections. The probability of wet and dry spell occurrence in tropical regions, particularly in West Africa, has been studied extensively due to their effects on rainfed agriculture (Kranjac-Berisavljevic & Abdul-Ghaniyu, 2014). One form of drought is the interruption of the rainy season by a dry spell. In humid countries, the success or failure of the crops, particularly under rainy conditions, is highly related to the distribution of dry and wet spells (Mathugama & Peiris, 2011). Changes in precipitation frequency and intensity distribution can have an impact on dry and wet spells and, therefore, will affect various climate-

sensitive sectors, primarily agriculture (Bouagila & Sushama, 2013). In Africa, agriculture is predominantly rain-fed; therefore, analysing the characteristics of wet/dry spells trend can provide valuable information for agricultural and water resource management (Matazu et al., 2020). Projected drought events over West Africa using the Regional Climate Model (RCM 2020) showed that areas north of 12°N will become hotspots for events with mild to moderate dry conditions, while the southern part will witness pronounced severe and extreme dry events (Ajayi & Ilori, 2020). The situation is well pronounced in recent years in northwestern Nigeria, where frequent droughts and floods experience were attributed to climate change.

According to Bouagila & Sushama, (2013) Changes in precipitation frequency and intensity distribution over Africa will have a direct impact on dry and wet spells, and the agricultural sector is the most sensitive to weather and climate. In addition, the sequence of dry and wet periods, along with the onset and withdrawal of the rainy season, is necessary for successful agricultural crop planning and soil and water conservation measures. (Manikandan et al., 2017). A dry spell is defined as the number of consecutive days with a daily precipitation amount below a certain threshold, such as 0.1, 1, 5, or 10 mm, preceded and followed by at least one day with rainfall exceeding the threshold. (Caloiero et al., 2015). According Basse et al., (2024) Dry and wet spells are useful indicators for the quantitative description of drought, flood, and flash flood occurrence. Li et al., (2017) observed that increases in the duration of wet spells were associated with corresponding increases in precipitation amounts.

Previous research has shown that the persistence and duration of dry spells differ greatly between regions and are influenced by factors such as elevation, proximity to water bodies, and seasonal climatic variation. (El Hafyani, & El Himidi, 2024). Projected changes in dry and wet spell probabilities in West Africa during the July–August–September monsoon season analysis using a Markov chain approach revealed that increasing dry spells in the Sahel region contribute to the frequency of droughts. (Basse et al., 2024). The main focus of the current study was on the growing season months of June through September. Mann–Kendall (MK) trend test was used to identify an increasing monotonic trend at a significance level of 5% of Length of Wet Spells (LWS) in the mountainous landscape of the Upper Awash River Basin (Adane et al., 2020) contribution of wet and dry days to the total rainfall has been studied (Mandapaka, et al, 2016) using the following statistical indicators: the number of wet spells per year (NWs), mean wet spell length in days (WS mean), 95th Percentile wet spell length in days (WS₉₅), and wet spell lengths (WS_{d95%}). For dry spells, the indicators are: mean dry spell length, 95th Percentile dry spell length days (DS₉₅), maximum dry spell length (DS_{mx}), and Extreme dry spell percentage (PXDS). The results indicate statistically significant upward trends for a majority of wet spell indicators. Analysis of wet and dry spells by (Singh & Ranade, 2010) Across India, during 1951–2007 revealed that rainfall due to wet spells contributes 68% and dry spell 17% to the respective annual total. Changes in the characteristics of Dry and Wet periods in Europe (Hänsel, 2020) was detected using Decile Indicator and Modified Rainfall Anomaly Index (MRAI). The findings revealed spatial extent, duration, and frequency of dry and wet periods show a large multi-decadal variability resulting in comparatively small long-term trends over the entirety of Europe. Although the study uses monthly data instead of the daily rainfall records

Umar et al. (2019) employed a multi-scale dry spell detection method adopted from Salack et al (2011) in the Sudano Sahelian of Nigeria, four dry spell categories were identified: very short (DS1, 1–3 days), short (DS2, 4–7 days), medium (DS3, 8–14 days), and long (DS4, 15 days). Despite daily rainfall, the study lacks trend analysis and fails to consider the active growing season. In India, Standard Meteorological Weeks (SMW) were used to derive rainfall values from daily

rainfall data (Bora et al., 2021). The Markov chain probability model was used to analyze conditional and consecutive dry and wet spells. The finding revealed that within the first 12 weeks of the year, there was a 40.4 percent to 100 percent chance of two consecutive dry weeks, while the chances of a wet spell fell within weeks (21st to 41st). The result focused on weekly analysis rather than daily and neglected the maximum consecutive trend. Drought study in Saudi Arabia by (Al Asheikh & Tarawneh, 2013) ADSI depicts the severity of drought; the higher the ADSI, the more severe the drought on an annual basis, rather than daily analysis of rainfall. The increasing trend in the number of dry spells using Mann-Kendall was attributed to local effects on trend characteristics in Isfahan Province of Iran, not climate change (Nasri & Modarres, 2009). The finding is lacking information on the maximum consecutive dry and wet days. Dry spell indices: Standard total cumulative dry spell (STCD) and Average dry spell index (ADSI) were used to evaluate drought intensity in northern Nigeria (Ezra & Mayomi, 2020). The study revealed the longest multi-year drought and the longest single-year drought. Daily analysis of dry and wet days has been neglected.

Recent studies by (Caloiero et al., 2015) revealed a negative behavior in the duration of the dry spells at the annual scale. Most of the recent reports mainly focused on the temporal and spatial change. (Tyubee, & Iwan, 2023) shows that both dry and wet spells exhibited positive and negative trends. The use of Mann-Kendall test (Mathlouthi & Lebdi, 2021a) revealed three stations with a significant positive trend of the monthly extreme dry spell length. The study of patterns and probabilities of dry spells and rainfall for improved rain-fed farming in Northwestern Ethiopia reveals an increasing trend in dry spells. (Tegegn et al., 2024). A negative trend was revealed in a study conducted by (Nastos & Zerefos, 2009) on the spatial and temporal variability of consecutive dry and wet days in Greece. Currently, there has been minimal focus on the trends of maximum consecutive wet and dry days. Considerable attention has been devoted to the frequency of dry and wet spells, while relatively little emphasis has been placed on the trends in maximum consecutive dry and wet spells, which are important for understanding the temporal patterns of wet and dry conditions. In addition, many previous studies have relied on annual rainfall data rather than daily rainfall records, despite the latter being more relevant for the analysis of dry and wet spell characteristics. Limited attention given to the trends in maximum consecutive dry and wet spells based on daily rainfall records. Consequently, there is insufficient understanding of how the duration of prolonged dry and wet periods has changed over time, particularly during the growing season. This study addresses this gap by examining the trends in maximum consecutive wet and dry spells from 1980 to 2021 during the growing season.

Materials and Methods

Data and Description of Stations

Daily precipitation data from 6 stations were taken from the ground climate dataset provided by the Nigerian Meteorological Agency (NIMET). The study period was 1980–2021. The criteria used in choosing the stations are: a long period of available rainfall. Therefore, all the stations have a long history of data. During the data pre-processing stage, inconsistencies in hydro-meteorological data were checked and adjusted for quality control, and months with missing data were replaced by the average method of month before and after the missing values, it is commonly used in meteorological data analysis. Many researchers used this technique to calculate rainfall and temperature missing data. In the study area, time series data on crop yield information for rice, maize, and millet from 1980 to 2021 are not readily available. This led to the utilization of National Agricultural Extension and Research Liaison Service (NAERLS) data that was available from 2009 to 2021. The description of the study site was presented in Table 1.

Table 1. Description of the Atudy Area

	Statio n No.	Latitude (°N)	Longitud e (°E)	Altitud e (m)	Geographical Classification	Average Temperatur e (°C)	Averag e Rainfal l (mm)	Data Used
Gusau	1206.1 4	12.100	6.420	468	Sahel Savannah	34	904	1980 - 2021
Kadun a	1007.3 2	10.360	7.270	634	Sudan Savanah	32	1249	1980 - 2021
Kano	1208.0 3	12.030	8.120	475.8	Sudan Savanah	34	1004	1980 - 2021
Katsin a	1307.0 4	13.010	7.410	516.63	Sahel Savannah	34	620	1983 - 2021
Sokoto	1205.5 1	13.010	5.150	309	Sahel Savannah	35	646	1980 - 2021
Yelwa	1004.5 4	11.080	4.430	224	Sudan Savanah	34	1015	1980 - 2021

Definition of Indices

To determine the maximum number of consecutive wet and dry days, considering the spatial variability of climate differences in the study area, we adopt a threshold where a wet day has precipitation ≥ 1 mm and a dry day has precipitation < 1 mm. Due to the strong seasonality of the behaviours and influences of MCDD and MCWD. We calculated the maximum consecutive wet and dry periods during the growing season (June- September). The Longest Dry Spell Duratio (LDS) is the maximum number of consecutive dry days that take place once through the record of daily rainfall data using a threshold of values.

Previous studies on the analysis of dry spells have been carried out using daily rainfall data between the 1st of May and the 30th of September, considered as a growing season. (Frappart et al., 2009). For this study, an analysis of dry and wet spells was carried out using daily rainfall data from 1st June to 30th September, in accordance with Nimet Seasonal Climate in Nigeria. The frequency of the Maximum Consecutive Dry Days (MCDD) and Maximum Consecutive Wet Days (MCWD) was examined during the growing season, which is from 1st June to 30th September. Several studies (Atedhor, 2014; El-tantawi, 2013; Shiru et al., 2019; Shiru & Shahid, 2018) have acknowledged June-September as the growing season in the Sudano Sahelian area of Nigeria. One advantage of the wet and dry spell analysis is that it reflects the need to consider drought-sensitive crops such as maize and rice, as opposed to drought-hardy crops such as millet, which can withstand a long dry spell of even 15 days. (Sivakumar, 1991). Another important issue is that certain crops during growth stages are more sensitive to drought and have higher water requirements.

Study Area

The study area, from its southern parts, is situated along the dry sub-humid with an annual rainfall of over 1,000mm, while its northern part is semi-arid with an annual rainfall range of between 600 and 800mm. The extreme northern part is arid with an annual rainfall of between 400mm and 600mm; this confirms that the study area has a dry climate. (Umar & Adamu 2019). Mean annual rainfall is indicated in Figure 1. Rainfall in the area is only concentrated within the months of June to September, but sometimes up to October in the Southern parts, during which the humidity of

the air goes beyond 60%. Rainfall in the study area is characterised by the occurrence of a few extremely high and torrential episodes. Umar, A.T, & Ismaila, A. (2017) observed nethermost part of northwestern Nigeria's seasonal regime of rainfall is more important than the annual total and a major controlling factor of the calendar of agricultural activities (Li et al., 2021).

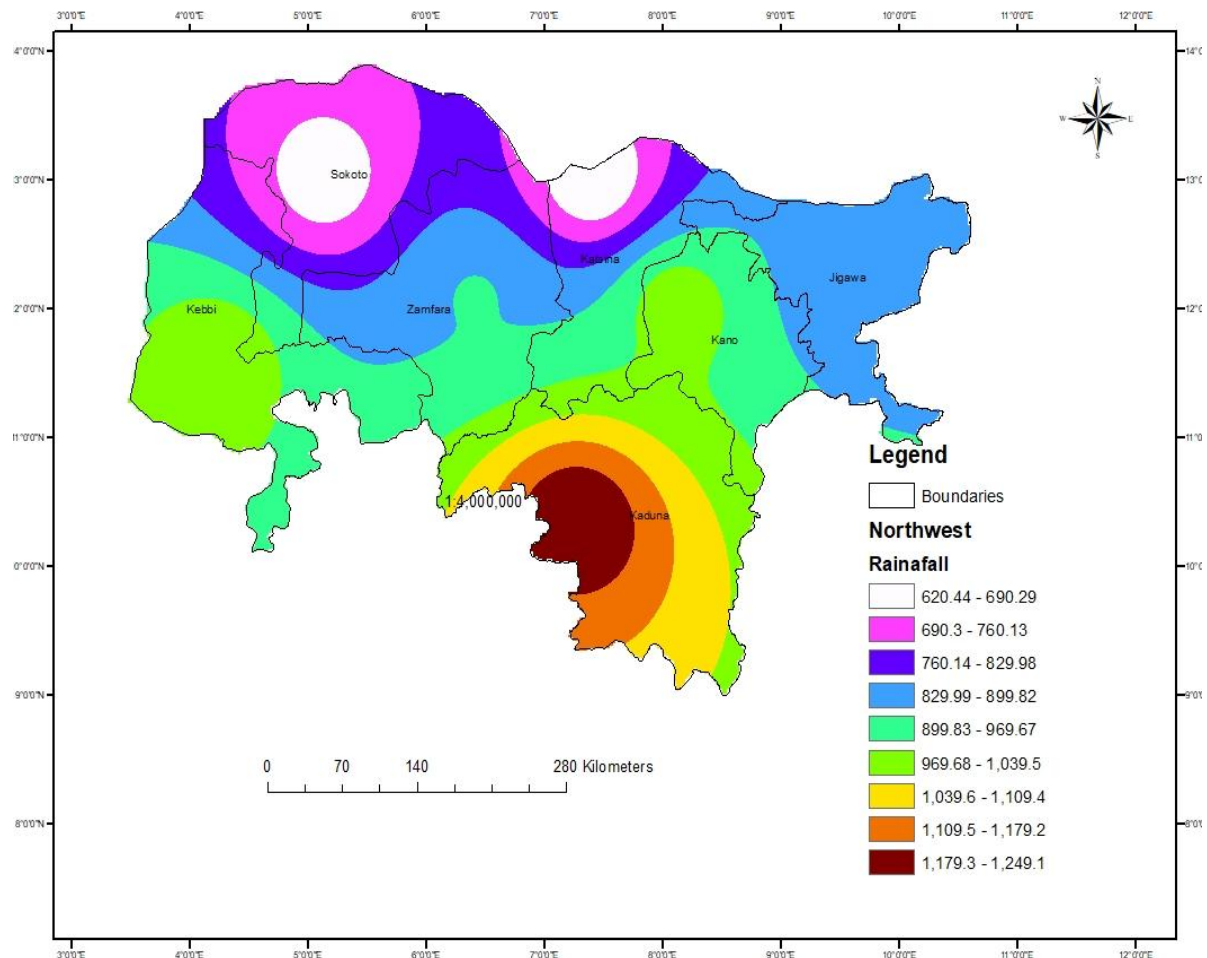


Fig 1. Rainfall of the Study Area (NIMET, 2023)

Maximum Consecutive Dry and Wet Spells

An analysis of dry and wet spells was carried out using daily rainfall data. The frequency of the Maximum Consecutive Dry Days (MCDD) and Maximum Consecutive Wet Days (MCWD) during the growing season months of June, July, August, and September was counted using the threshold value of precipitation ≥ 1 mm and < 1 mm.

Trend Analysis

The Mann-Kendall was used to determine if a time series of data in the study has a monotonic upward or downward trend. It does not require that the data be normally distributed or linear. It does not require that the data be normally distributed or linear. It does require that there is no autocorrelation. The null hypothesis for this test is that there is no trend, and the alternative hypothesis is that there is an upward or downward trend. It has been suggested by the World Meteorological Organisation (WMO) to determine the existence of statistically significant trends in climate and hydrologic data time series (Rahmat et al., 2012). Many researchers have earlier

used the Mann-Kendall test to test the trend of climatic data. (Aditya et al., 2021; Mehta & Yadav, 2022; Ogunrinde et al., 2019; Yildirim & Rahman, 2022) and the results obtained were quite comparable with many published literature. A Pearson correlation was used to evaluate a linear relationship between drought indices and maximum consecutive dry spells and crop yield estimation of rice, maize, and millet.

Drought Indices

The daily rainfall data was used and subjected to a Standardized Precipitation Index (SPI) analysis for quantification of a meteorological drought. The SPI developed by McKee, et al. (1993) is a widely used drought index based on the probability of precipitation for multiple time scales, e.g. one, three, six, nine, twelve, and a twenty-four months, etc. Another advantage SPI over other meteorological drought indices, it includes the capability to quantify precipitation surplus or deficit on multiple time scales and because it has been recommended by World Meteorological Organisation in any location of the world. Several scholars have used the SPI for meteorological drought assessment. (Abdulrahim et al., 2016; Chunming, 2010; Diani et al., 2019; Guenang & Kanga, 2014). Although it is principally considered a meteorological drought index, it has also been used in many studies related to hydrological and agricultural drought. (Tigkas et al., 2019).

Standardized Precipitation Evapotranspiration Index (SPEI). A relatively new drought index, developed by Vicente-Serrano et al., (2010) was used for drought quantification. SPEI uses the basis of a SPI but includes a temperature component, allowing the index to account for the effect of temperature on a drought development through a basic water balance calculation (Svoboda & Fuchs, 2016). The inclusion of temperature and precipitation data allows an SPEI to account for the impact of temperature on a drought situation. Previous study (Anandharuban & Elango, 2021; Qaisrani et al., 2021) used SPEI in drought study.

Results and Discussion

Frequency of Maximum Consecutive Days of Dry and Wet Spells

In order to achieve maximum benefit in dry land agriculture, the descriptive knowledge of the distribution of dry spells within a year is useful. The pattern of modal duration of wet spells and dry spells is shown in Table 1. The result depicts several days of dry and wet spells across the states. The characteristics of wet spells are not similar to those of dry spells. In other words, the main contribution to the dry part of the season, in terms of the number of non-rainy days, appears to be 4-7 days of maximum consecutive dry spells, as opposed to a study by (Ratan & Venugopal, 2013) whose findings range between 3 and 4 days, while (Basse et al., 2024) observed West African region exhibits low probabilities of 7-day dry spell areas, particularly in the mountainous areas such as the high plateau of Fouta Djallon, the plateau of Jos. According to (Umar et al., 2019) A very long dry spell can certainly expose crops to serious water stress at their early stage of germination and can even lead to crop failure, because of the associated heat stress, from a high rate of evapotranspiration.

Further analysis revealed that the maximum consecutive wet spell ranges from 1 to 5 days as recorded. This implied 1-5 days of length of rainy days contributing to seasonal rainfall distribution and amount in the study area. This finding revealed that of 2 days scenario was the highest in wet spell appearances, which was about 40 times in June and 28 times in August (Table 1). This follows a seasonal climate prediction (Gibson et al., 2022) As rain progresses, the number of dry

spells decreases, while wet days increase. Another related finding conducted by (Otun & Adewumi, 2010) The analysis of dry spells and their application to crop planning in the Sudano-Sahelian region of Nigeria reported the high probability of a 2-day dry spell in August.

Table 1. Frequency Maximum Consecutive Dry and Wet Spell days (Author Computation, 2024)

Dry and Wet Spell	Gusau		Kaduna		Kano		Kastina		Sokoto		Kebbi	
	Mode	Frequency	Mode	Frequency	Mode	Frequency	Mode	Frequency	Mode	Frequency	Mode	Frequency
Dry Spell June	5	11	5	17	6	10	7	11	7, 9	15	7	13
Wet Spell June	2	24	2	27	2	19	2	19	2	40	2	18
Dry Spell July	5	12	3	21	3, 4	9	4, 6	8	4, 5	17	4, 5	10
Wet Spell July	4	15	4	25	3	15	3	17	2	34	3, 4	11
Dry Spell August	3	13	2	28	3	17	4	12	4	26	4	17
Wet Spell August	3, 5	10	5	17	3	13	3	16	3	28	3	14
Dry Spell September	4	9	4	16	10	8	6	7	6	14	5	13
Wet Spell September	3	15	3	19	2	18	2	19	2	32	4	12

Trend Pattern of the Maximum Length of Dry and Wet Spells

Trend direction reveals whether there is an increasing (positive) or decreasing (negative) trend. The results of the trend analysis showed that all states under study have a mix of both positive and negative trends (Table 2). The negative and positive values cut across the length of dry and wet spells as seen. The measure of the magnitude of the slope showed zeros dominated Sen's slope values except in the following areas, as indicated. The breakdown of MK values of the dry spell in August across the states is as follows: Gusau (-0.04), Kaduna (0.07), Kano (-0.26), Katsina (-0.06), Sokoto (-0.08), and Kebbi revealed an August dry spell of -0.28. The decrease in dry spells, findings confirmed that historically August receives a higher amount of rainfall, as reported by several authors. (AbdulrahiResult and Discussionm et al., 2013; Garba et al., 2018; Umar and Ismaila, 2017). A careful look revealed a dry spell pattern in August and September in Kano and Sokoto. A level of Significant trends were observed in Sokoto and Kebbi during August, with P-values of 0.03 for wet spells and 0.02 for dry spells, respectively. In September, the wet spell and dry spell trend was also significant (P= 0.01 and P = 0.03). An increase in dry spells was observed in Kaduna, although the trend was not statistically significant (P = 0.07) (Table 2)

The result supported the report by (NAERLS, 2021) Twenty-one (21) states across Nigeria witnessed dry spell occurrences, which the situation affected the growth and development of different types of crops. This finding has an important implication for the socio-economic development of the states, as most of the people are farmers whose agricultural activities solely depend on the climate. It also agreed with the previous studies (Matazu et al., 2020; Nnoli et al., 2020) That information on dry and wet spell patterns is highly needed for agricultural planning and adaptation strategies.

Detection of temporal trends is one of the most important objectives of environmental monitoring and analysis. It is important to recognize that some increasing or decreasing patterns in climate data, especially over short periods, are not trends. (Holbert, 2018). Trend analysis in Figures 2, 3, 4, 5, 6, and 7 generally showed a pattern of a gentle slope across the states. A critical look at the trend line from Figures 2 and 3 displayed three characteristics, which are a slightly upward and

downward direction, and a relative nature of straight-line movement. This finding is in tandem with the study by , who estimated the duration of dry events in Northern Tunisia, where the analysis of extreme trends revealed a slight upward trend in wet spells during the growing season. Similarly, in a related study by , the authors suggest that the number of extreme drought days is likely to increase throughout most of the cropping season and future periods, which may affect future agricultural production as a result of the increasing pattern of consecutive dry days.

Table 2. Trend of Maximum Consecutive Dry and Wet Spells during the Growing Season

States	Dry and Wet spell	Kendall's tau	Sen's slope	S	Var(S)	p-value	alpha
GUSAU	Dry Spell June	-0.10	0.00	-77.00	8175.00	0.40	0.05
	Wet Spell June	-0.16	0.00	-109.00	6746.33	0.19	0.05
	Dry Spell July	0.04	0.00	34.00	8124.67	0.71	0.05
	Wet Spell July	0.13	0.00	96.00	7767.33	0.28	0.05
	Dry Spell August	-0.04	0.00	-33.00	7949.00	0.72	0.05
	Wet Spell August	0.13	0.00	103.00	8105.00	0.26	0.05
	Dry Spell September	0.03	0.00	21.00	8339.00	0.83	0.05
	Wet Spell September	0.08	0.00	62.00	7964.67	0.49	0.05
KADUNA	Dry Spell June	-0.09	0.00	-72.00	8112.67	0.43	0.05
	Wet Spell June	0.05	0.00	40.00	7863.33	0.66	0.05
	Dry Spell July	0.12	0.00	92.00	7918.00	0.31	0.05
	Wet Spell July	-0.02	0.00	-13.00	8285.67	0.90	0.05
	Dry Spell August	0.07	0.00	48.00	7220.00	0.58	0.05
	Wet Spell August	-0.07	0.00	-54.00	8330.67	0.56	0.05
	Dry Spell September	-0.03	0.00	-25.00	8099.00	0.79	0.05
	Wet Spell September	0.05	0.00	40.00	7863.33	0.66	0.05
KANO	Dry Spell June	-0.16	-0.04	-129.00	8302.33	0.16	0.05
	Wet Spell June	0.09	0.00	65.00	7467.00	0.46	0.05
	Dry Spell July	0.09	0.00	70.00	8256.00	0.45	0.05
	Wet Spell July	-0.05	0.00	-36.00	7907.33	0.69	0.05
	Dry Spell August	-0.26	0.00	-187.00	7561.00	0.03*	0.05
	Wet Spell August	0.06	0.00	44.00	8072.00	0.63	0.05
	Dry Spell September	-0.10	0.00	-83.00	8353.67	0.37	0.05
	Wet Spell September	-0.19	0.00	-142.00	7640.67	0.11	0.05
KASTINA	Dry Spell June	0.08	-0.06	62.00	7523.33	0.48	0.05
	Wet Spell June	0.08	0.00	62.00	7523.33	0.48	0.05
	Dry Spell July	0.09	0.00	71.00	8301.00	0.44	0.05

Wet Spell July	0.05	0.00	35.00	7424.33	0.69	0.05
Dry Spell August	-0.06	0.00	-46.00	8115.33	0.62	0.05
Wet Spell August	0.15	0.00	114.00	7801.33	0.20	0.05
Dry Spell September	-0.09	0.00	-71.00	8389.00	0.44	0.05
Wet Spell September	0.18	0.00	135.00	7530.33	0.12	0.05

		Dry and Wet Spell	Kendall's tau	Sen's slope	S	Var(S)	p-value	alpha
SOKOTO	Dry Spell June	-0.07	0.00	-60.00	8356.67	0.52	0.05	
	Wet Spell June	0.15	-0.03	102.00	6919.33	0.22	0.05	
	Dry Spell July	-0.22	0.00	-171.00	8154.33	0.06	0.05	
	Wet Spell July	0.07	0.00	50.00	7463.33	0.57	0.05	
	Dry Spell August	-0.08	0.00	-62.00	8094.67	0.50	0.05	
	Wet Spell August	0.34	0.04	262.00	7999.33	0.03*	0.05	
	Dry Spell September	-0.18	-0.05	-143.00	8348.33	0.12	0.05	
	Wet Spell September	0.29	0.03	218.00	7875.33	0.01*	0.05	

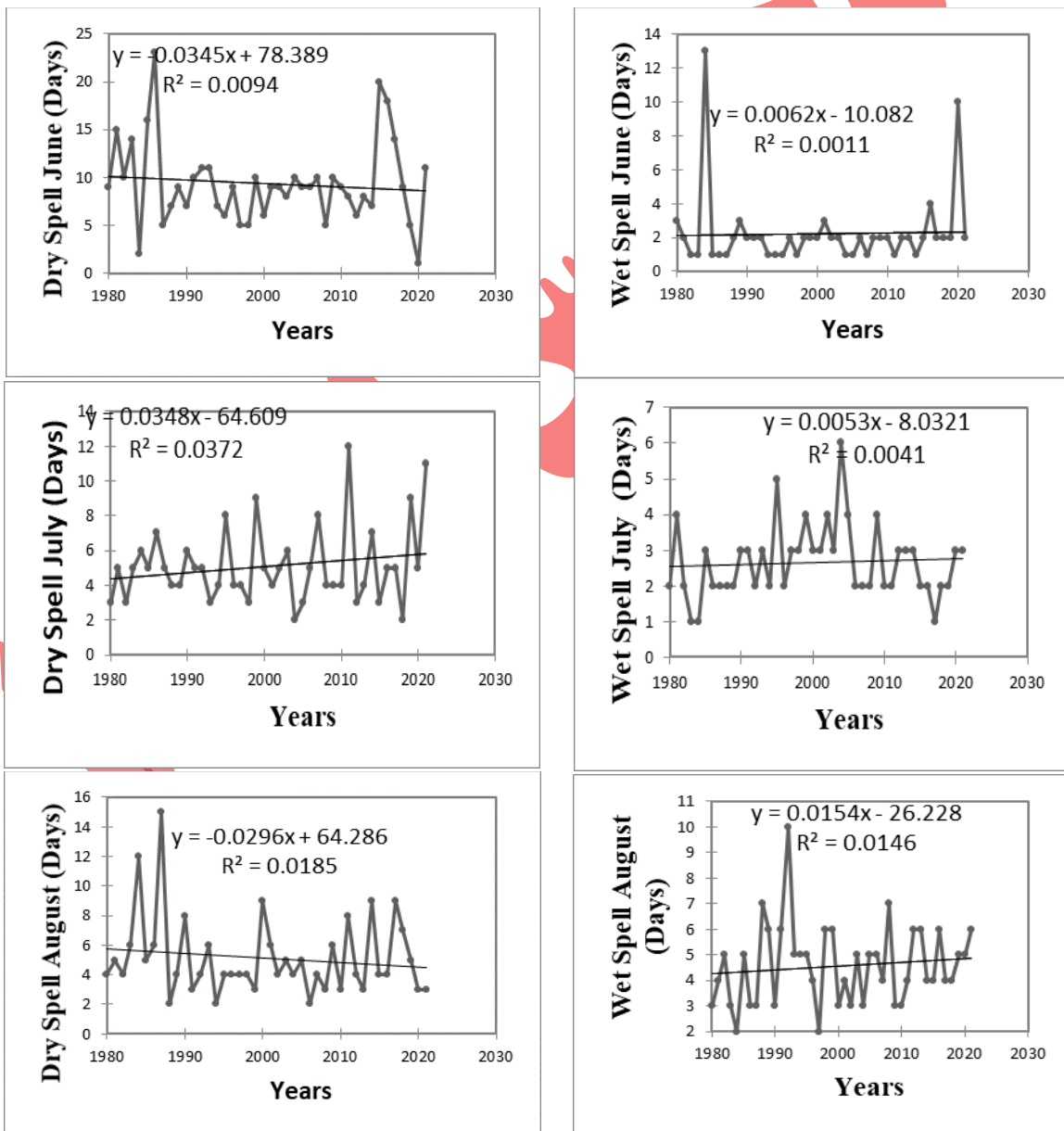
		Dry and Wet Spell	Kendall's tau	Sen's slope	S	Var(S)	p-value	alpha
KEBBI	Dry Spell June	-0.07	0.00	-52.00	8141.33	0.57	0.05	
	Wet Spell June	0.05	0.00	35.00	7618.33	0.70	0.05	
	Dry Spell July	-0.06	0.00	-51.00	8163.00	0.58	0.05	
	Wet Spell July	-0.01	0.00	-4.00	8082.67	0.97	0.05	
	Dry Spell August	-0.28	-0.03	-208.00	7786.00	0.02*	0.05	
	Wet Spell August	-0.27	-0.04	-213.00	8033.00	0.02*	0.05	
	Dry Spell September	-0.25	-0.04	-197.00	8051.00	0.03*	0.05	
	Wet Spell September	0.08	0.00	63.00	8129.67	0.49	0.05	

*Significant at 0.05

The linear trend observed in Figure 2 revealed an increasing trend of dry spell in July ‘ $Y=0.034.8x+64.609$ ’ a slight decrease was also observed in August ($-0.02296x+64.286$). This finding is consistent with (NIMET, 2025) Annual Seasonal climate prediction. In Kaduna, Figure 3 shows a stationary movement for both dry and wet spells, except in June, in which the dry spell shows a slight decrease. This could be as a result of the geographical classification of the state, where the onset of the rainy season starts earlier compared to other states. A downward movement of dry spells in June and August was observed in Kano (Figure 4), while a significant decrease in wet spell in September. Previous study (Abaje et al., 2013; Ati et al., 2022) confirmed the high frequency mild drought without a negative effect on crop yield. A down and upward trend direction of the trend line in June and September in Kastina (Figure 5). The result implies a favourable condition of cultivation because, as the rainy season progresses, the dry spell decreases. The decrease in the pattern of wet spells in September (Figure 6) could be related to the recent flood disaster experienced in the following years, 2020, 2022, and 2024, in conformity with (NIHSA, 2021) Annual flood prediction in Nigeria. The slight decrease in the trend line with corresponding downward trend of wet spells in Figure 7 (September). The finding supports (NAERLS, 2023) Wet

Season Agricultural Performance in Nigeria: National Report that cases mid-season drought affect the yield of crops in some local government areas in Kebbi State.

The increased number of wet days and decrease in dry spell length in the recent decade in the study area have been associated with recurrent case flood disasters experienced (NIHSA, 2021). The impact of climate change is pronounced, with devastating effects on people's livelihoods in Kano, Sokoto, and Kebbi states. Floods are becoming a recurring decimal in many states of the federation in Nigeria, with those in the Sahelian region becoming more vulnerable (Yakubu and Daiyabu 2015). The increased dry spells and decreased wet days pose a serious threat and affect crop growth and development in the year 2024, which in turn causes pest and disease infestations on various crops. (NAERLS, 2024). Long-term dry spells and irregular rainfall patterns throughout Nigeria in the year 2024, especially in the north-central region, severely affected agricultural production, endangering food security.



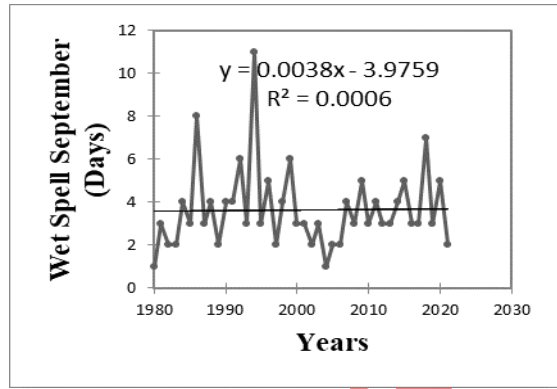
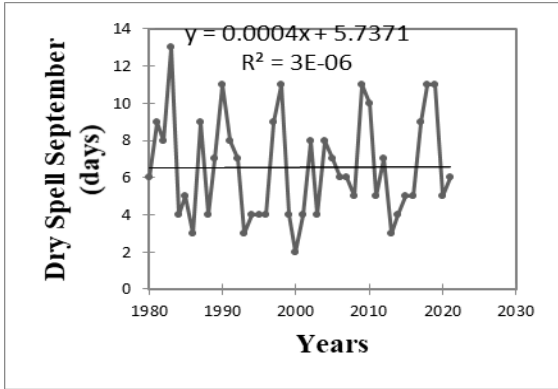
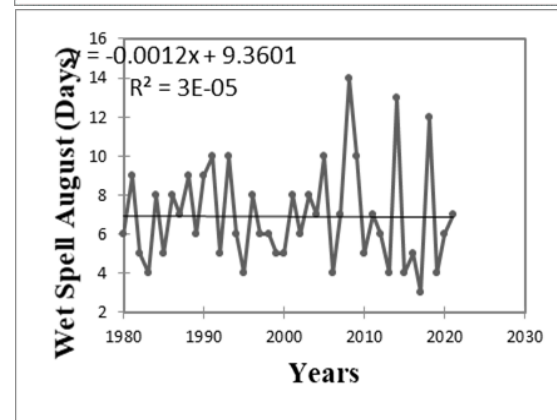
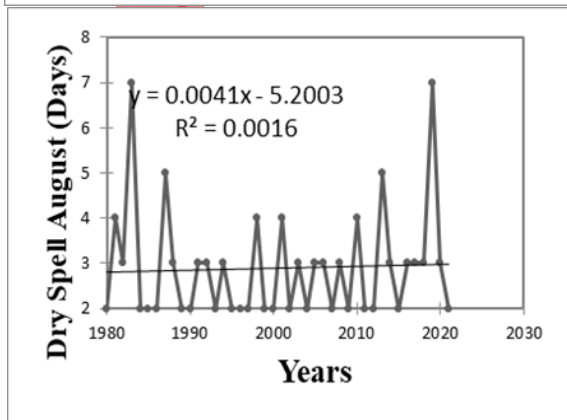
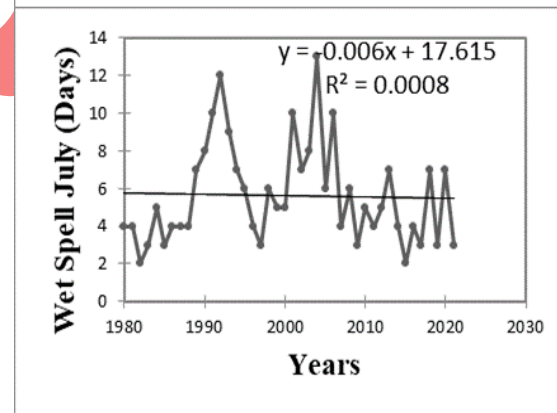
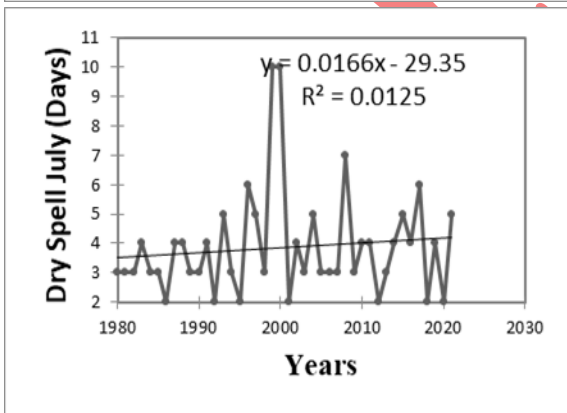
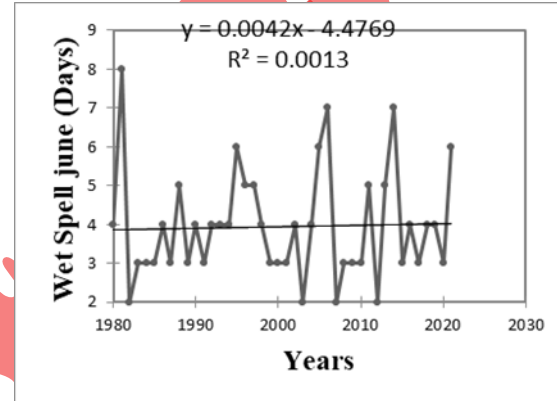
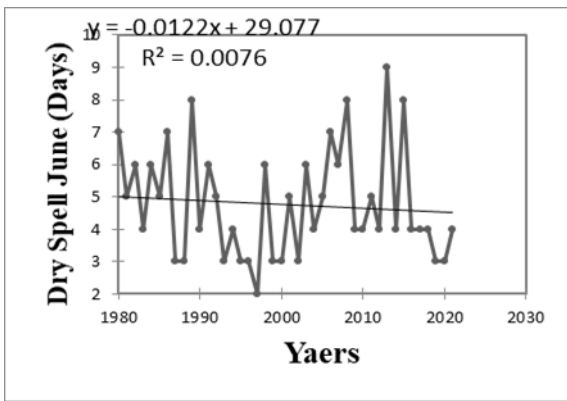


Fig 2. Trend of Maximum Consecutive Dry and Wet Spells in Gusau



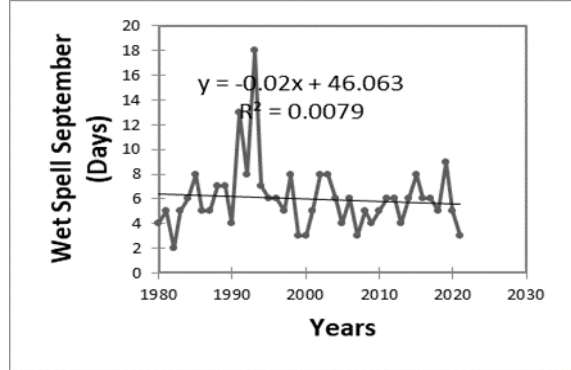
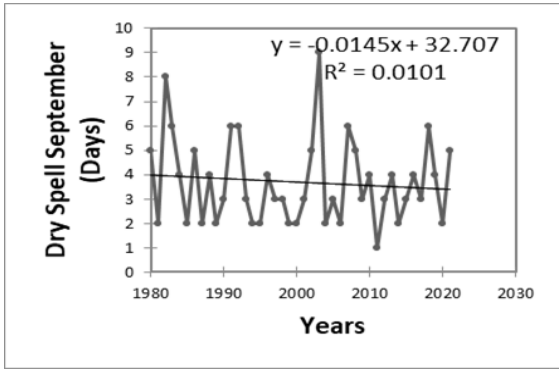
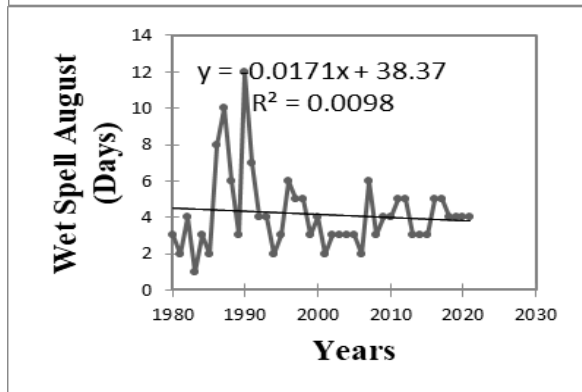
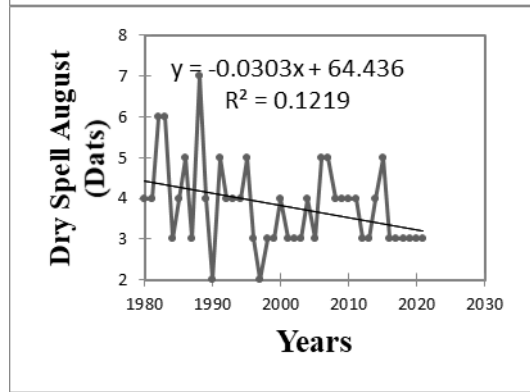
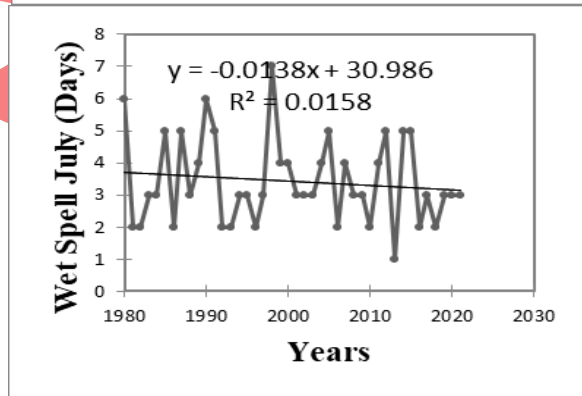
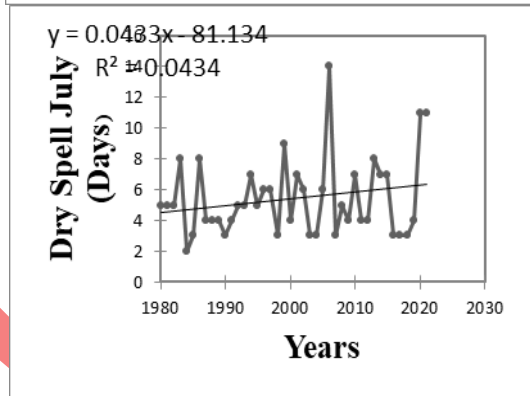
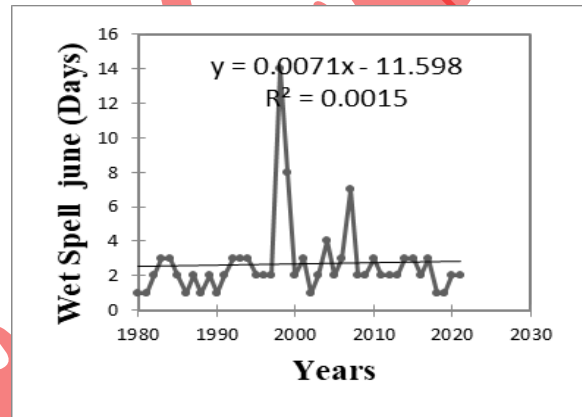
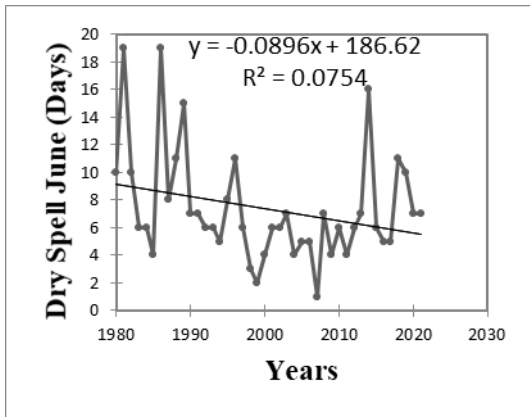


Fig 3. Trend of Maximum Consecutive Dry and Wet Spells in Kaduna



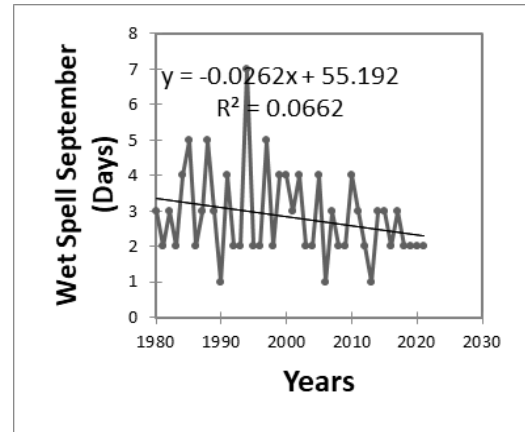
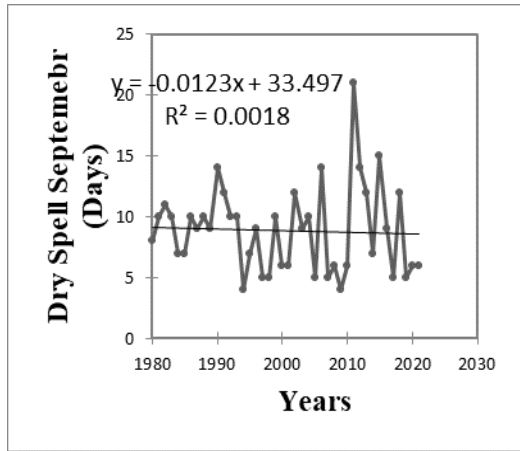
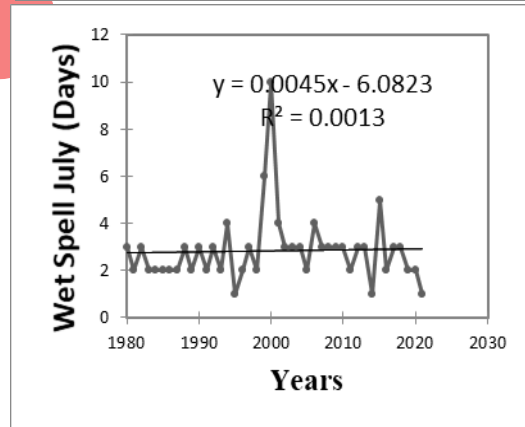
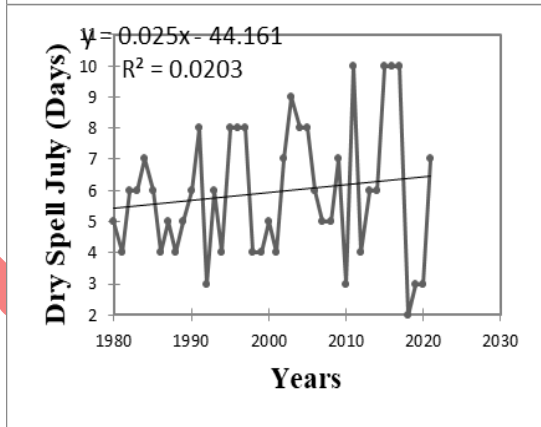
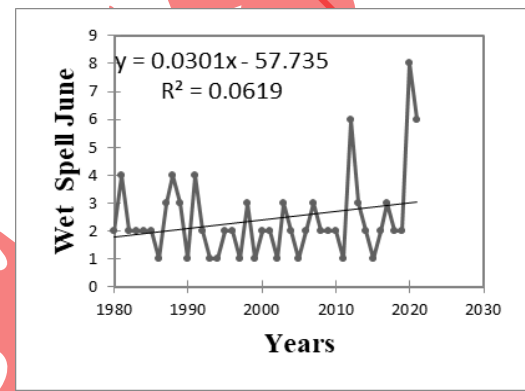
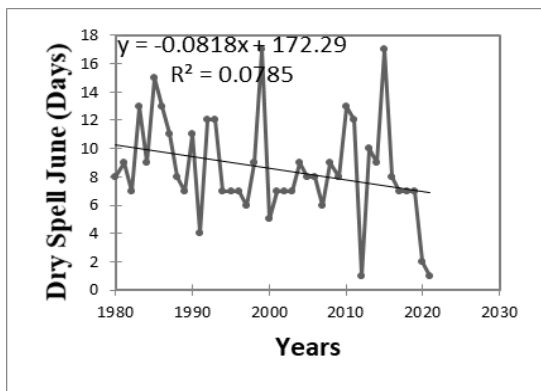


Fig 4. Trend of Maximum Consecutive Dry and Wet Spells in Kano



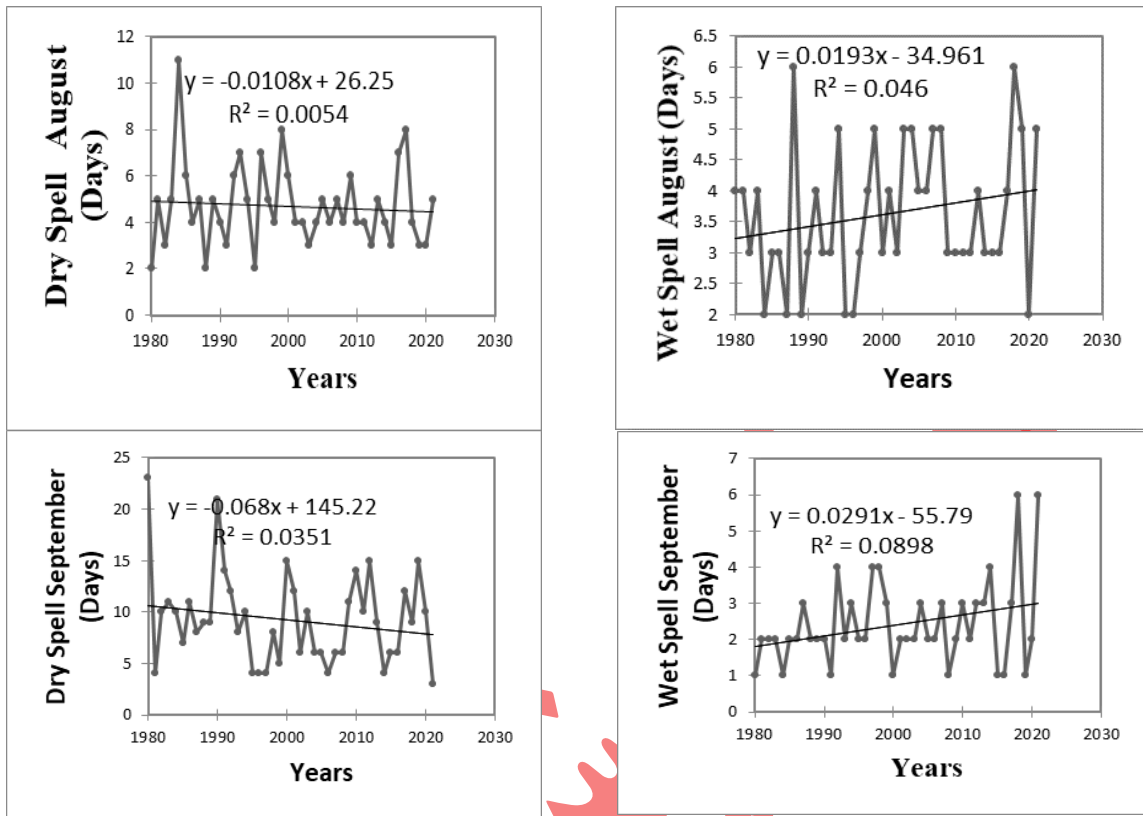
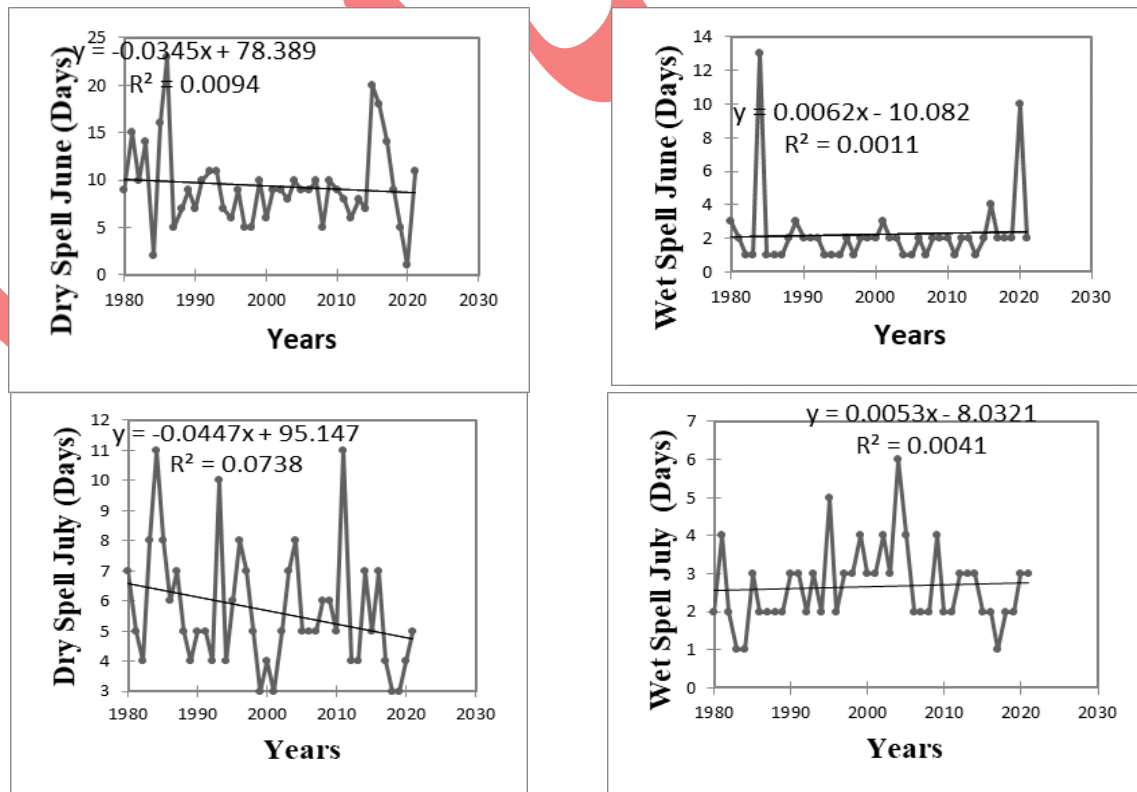


Fig. 5. Trend of Maximum Consecutive Dry and Wet Spells in Kastina



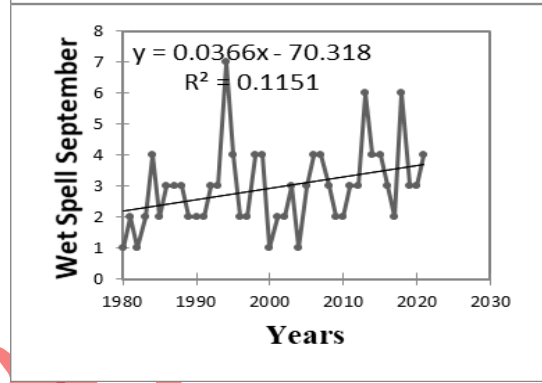
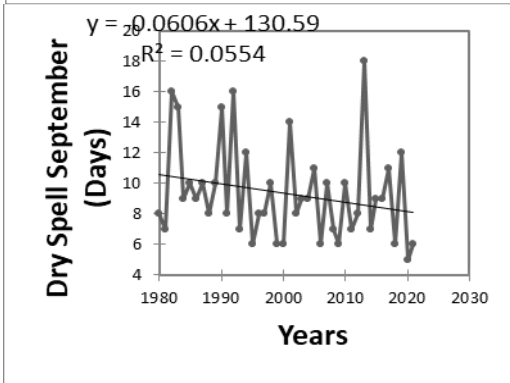
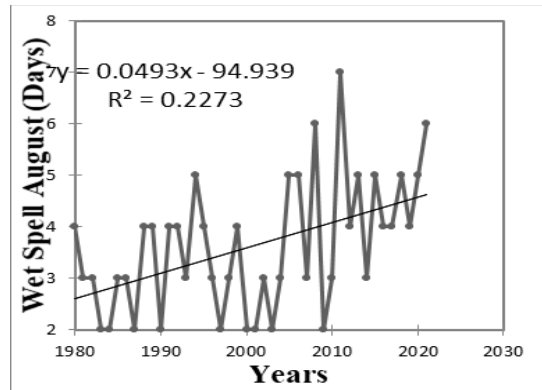
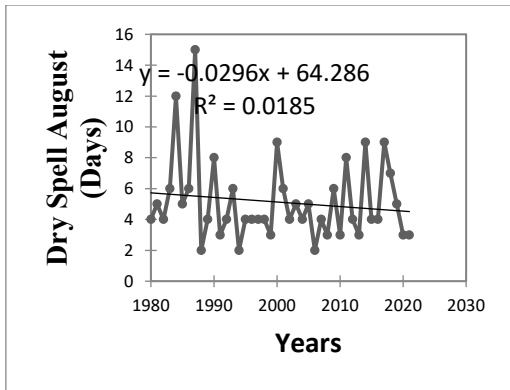
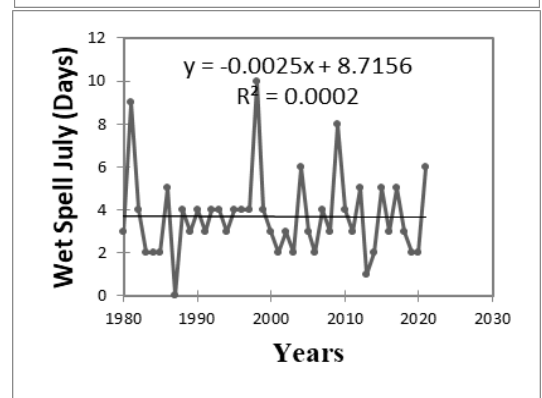
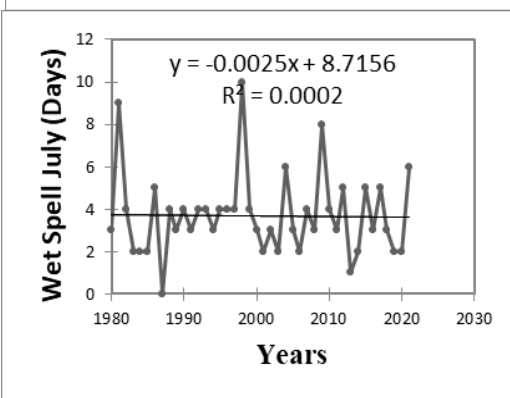
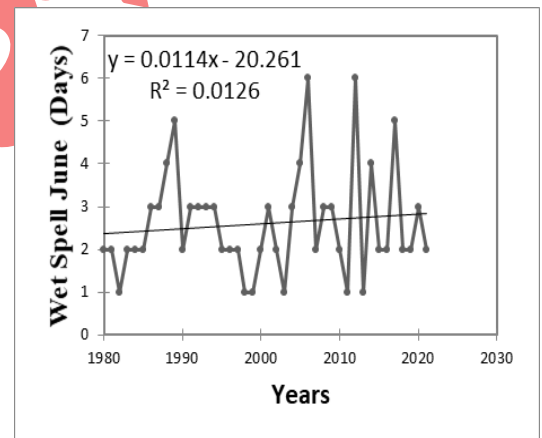
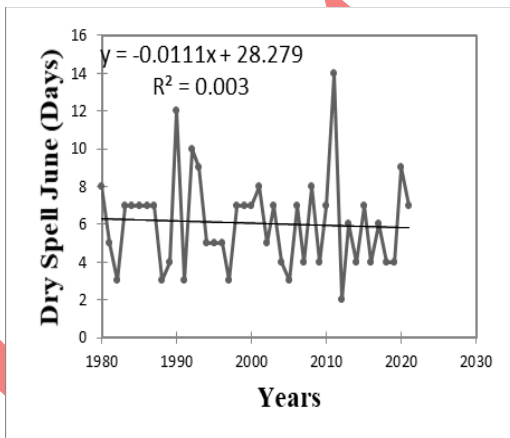


Fig 6. Trend of Maximum Consecutive Dry and Wet Spells in Sokoto



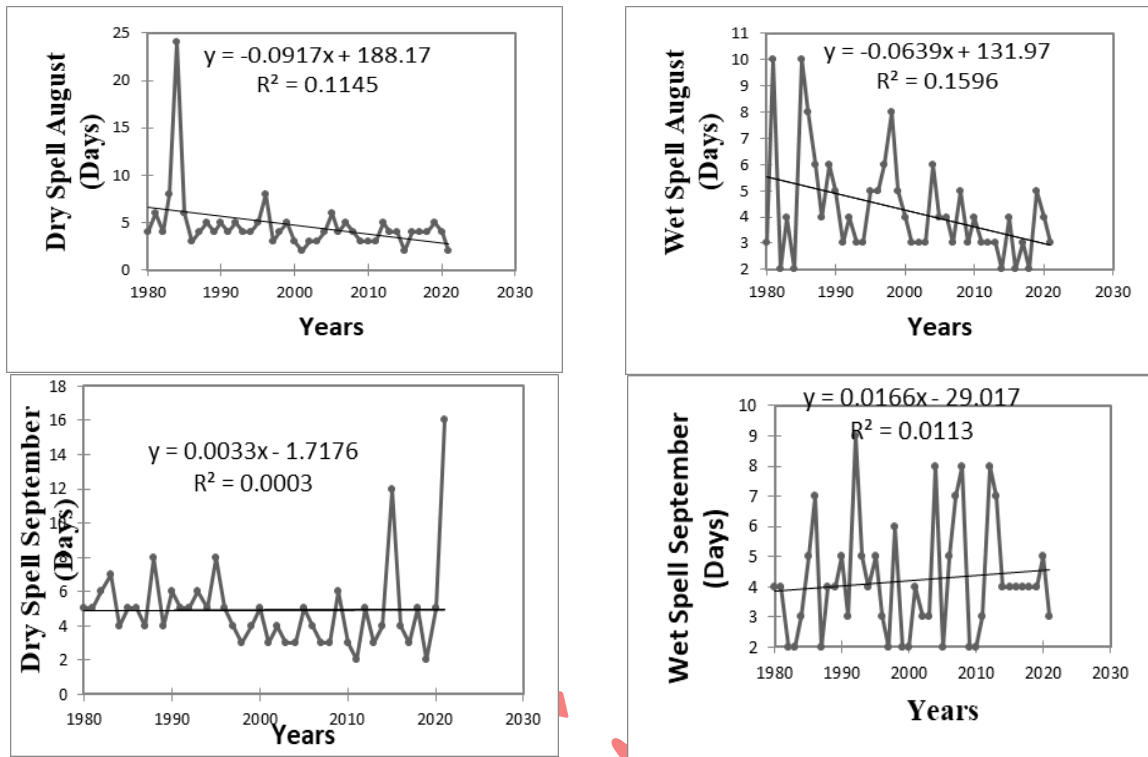


Fig 7. Trend of Maximum Consecutive Dry and Wet Spells in Kebbi

Relationship between Drought indices and frequency of maximum consecutive Dry and Wet Spells

Dry spells occur as a precursor to drought. Understanding their characteristics is as important as understanding the characteristics of drought. The analysis has been conducted on the total number of maximum consecutive dry and wet days in order to highlight an eventual change in dry and wet spell patterns from 1980 to 2021 as presented in Figures 8 and 9. The number of sequences of dry spells shows an increase around 1980-1990 and corresponds with a decrease in wet spells, as clearly depicted in the relationship between drought. This trend was observed throughout the entire period across the states, except in Kaduna, where both the dry and wet spell days show a slightly different pattern. Figure 9. The extreme dry spell has been referred to as a meteorological drought by (Breinl et al., 2020) which can cause negative implications for societies, including water resources and agriculture, which are equally related to the 1980s Sahelian drought and were characterized by a more widespread, more severe, and more persistent drought than the decade 1970-1979 (Abaje et al., 2013). Periods of extreme dryness and their significant impacts on lives and the economy have been investigated by earlier studies in Northern Nigeria. (Kayode & Francis, 2012; Oladipo, 1993).

However, a critical analysis showed that drought indices (negative) and (positive) equally correspond to a pattern of consecutive dry and wet spells. For instance, in Gusau 1994, a rise in SPI and SPEI indicates an increase in wet spells, while there is a slight decrease in consecutive dry days. Also, in Sokoto, the value for 2010 (Figure 9) showed an average relative increase in consecutive wet days, denoting an increase of SPI and SPEI toward positive higher values, which coincide with devastated flood of 2010 in Sokoto and Kebbi State. The increase in dry weather in Sokoto around 2017 has a direct impact on socio-economic activities, as reported by the Sokoto State Ministry of Water Resources in 2018. Sokoto metropolis experienced water supply

challenges, and it was attributed to low water supply from the Goronyo dam reservoir, which was about 90 percent depleted of its installed capacity of one billion cubic meters. In addition, the problem was linked to the low amount of rainfall (meteorological drought) recorded in 2017; other factors include climate change and a lack of dam desiltation. The situation seriously affected water supply and irrigation farming in Sokoto and Kebbi States.

This finding agreed with the work. Liu, et. al. (2022) that drought event is not only attributed to low precipitation, but also attributed to the increase in the duration of a dry spell, and conclude that the variability of daily precipitation can describe wet/dry spells, which helps understand the impacts of precipitation concentration. The finding also supports a study in Senegal. (Mathugama & Peiris, 2011) revealed that severe drought years and extreme dry spell events are interrelated. A critical review of the 2024 Wet Season Agricultural Performance in Nigeria reported that long dry spells result in high costs to the affected communities and that the success or failure of the crops under rainfed conditions is strongly related to the distribution of dry and wet spells. According to the report by (NAERLS, 2024) Incidents of the occurrence of dry spells were experienced across six geopolitical zones of the country, the magnitude of the impact in the Southwest and North-central are higher, and it's revealed that the duration of the dry spell was more than 5 weeks.

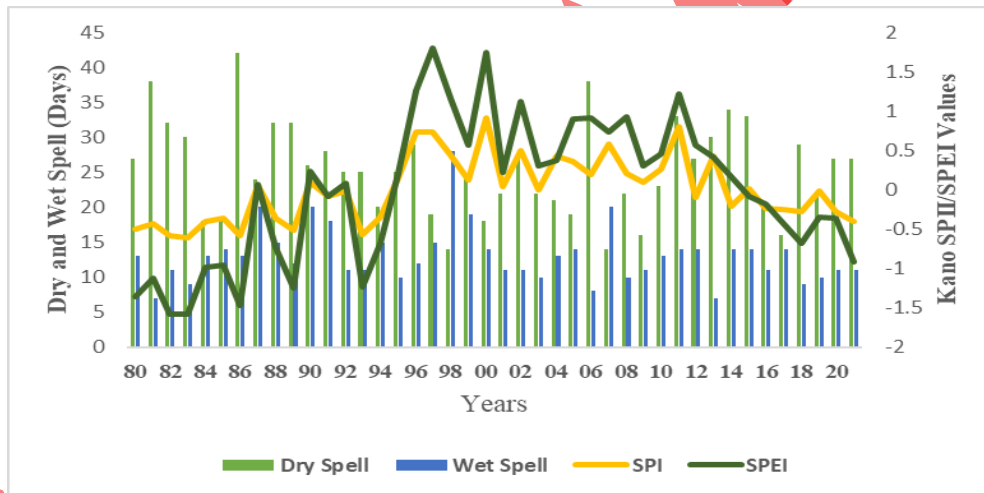


Fig 8. Relationships between Dry and Wet Spell Drought Indices in Gusau, Kaduna, and Kano

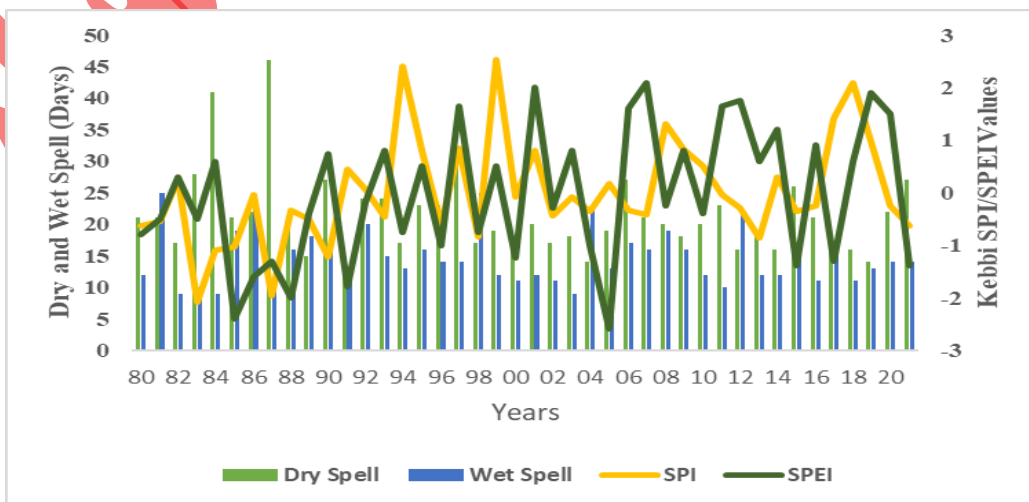


Fig 9. Relationships between Dry and Wet Spell Drought Indices in Katsina, Sokoto, and Kebbi

Table 3 shows the linear relationship between wet spell, dry spell, SPI, and SPEI using Pearson's product-moment correlation. The correlation coefficient ranges from -1 to +1. If one variable tends to increase as the other decreases, the correlation coefficient is negative. Conversely, if both variables tend to increase together, the coefficient is positive. The analysis indicated that in all six states, as the wet spell increases, the dry spell decreases: Gusau (-0.286), Kaduna (-0.157), Kano (-0.200), Kastina (-0.422), Sokoto (-0.434), and Kebbi (-0.201). The effects of climate change, especially on changing rainfall patterns and rainy days, were significantly heavy on agricultural productivity in Nigeria, as reported by (NAERLS, 2024).

Further analysis revealed that the findings showed a moderate positive correlation between SPI and wet spell in Gusau (0.531), a very weak positive correlation was recorded in the following states: Kaduna (0.015), Kano (0.115), Kastina (0.331), and Sokoto (0.115) (Table 3). However, a negative linear relationship was observed in Kebbi (-0.081) between SPI and wet spell, implying that as SPI values increase, the wet spell decreases. Overall, there was a fairly strong relationship between SPEI and SPI across the states, except in Sokoto and Kebbi, where the correlation values were 0.103 and 0.175, respectively. This suggests a very weak relationship. A study by (Qaisrani et al., 2021) showed that Pearson correlation coefficients indicated a positive relationship between SPI and SPEI. This finding aligns with the work of (Tefera et al., 2019), who observed that the minimum and maximum values for SPI and SPEI were close to each other at different time scales.

Table 3: Correlation between SPI, SPEI, Wet and Dry spells

Variables		Dry Spell	Wet Spell	SPI	SPEI
Gusau	Dry Spell	1.0000	-0.2856	-0.1663	0.0255
	Wet Spell	-0.2856	1.0000	0.5306	0.2470
	SPI	-0.1663	0.5306	1.0000	0.5845
	SPEI	0.0255	0.2470	0.5845	1.0000
Variables		Dry Spell	Wet Spell	SPI	SPEI
Kaduna	Dry Spell	1.0000	-0.1570	-0.1950	-0.0281
	Wet Spell	-0.1570	1.0000	0.0147	-0.1004
	SPI	-0.1950	0.0147	1.0000	0.6596
	SPEI	-0.0281	-0.1004	0.6596	1.0000
Variables		Dry Spell	Wet Spell	SPI	SPEI
Kano	Dry Spell	1.0000	-0.3936	-0.3240	-0.3357
	Wet Spell	-0.3936	1.0000	0.2554	0.2800
	SPI	-0.3240	0.2554	1.0000	0.9448
	SPEI	-0.3357	0.2800	0.9448	1.0000
Variables		Dry Spell	Wet Spell	SPI	SPEI
Katsina	Dry Spell	1.0000	-0.4224	-0.2736	-0.2366
	Wet Spell	-0.4224	1.0000	0.3306	0.1659
	SPI	-0.2736	0.3306	1.0000	0.7782
	SPEI	-0.2366	0.1659	0.7782	1.0000

	Variables	Dry Spell	Wet Spell	SPI	SPEI
Sokoto	Dry Spell	1.0000	-0.4336	-0.4854	-0.2193
	Wet Spell	-0.4336	1.0000	0.1021	0.1916
	SPI	-0.4854	0.1021	1.0000	0.1031
	SPEI	-0.2193	0.1916	0.1031	1.0000
		Variables	Dry Spell	Wet Spell	SPI
Kebbi	Dry Spell	1.0000	-0.2013	-0.4854	-0.0049
	Wet Spell	-0.2013	1.0000	-0.0811	-0.1914
	SPI	-0.4854	-0.0811	1.0000	0.1754
	SPEI	-0.0049	-0.1914	0.1754	1.0000

Relationship Between Crop yield and Dry and Wet spells

Results obtained in Table 4 show that dry spells in all states have a statistical association between the yield of rice, maize, and millet, and display a substantial relationship with wet spell days. The relationship ranges from moderately and very positive correlation to moderately and very weak negative correlation. Dry spells show a significant relationship with millet yield in Katsina (-0.563). Maize shows more sensitivity to dry spells than the other crops, revealing a negative relationship in the following states: Gusau (-0.234), Kano (-0.331), Katsina (-0.0239), and Sokoto (-0.412) while positive values are found between Maize and dry spell Kaduna (0.281) and Kebbi (0.052). They oppose the study of (Ozoemene et al., 2022) The frequency of dry spells and maize yield increased by 2 days over the decade, while the maize yield showed a negative trend with a z-score of -1.81. In a related study (Manikandan et al., 2017) The effect of dry spell durations that cause damage to crop yield has been reported. Millet demonstrates more resistance to dry spells in Gusau (0.344) and Kaduna (0.233) compared to other states. Climate change remains a significant challenge, with the frequently reported cases of dry spells being particularly severe, affecting major crops. Many local farmers needed to repeat the planting of seed twice or thrice because of the effect of early-season drought, which is directly related to dry spell occurrences. Further analysis revealed that rice shows a positive relationship in 4 states with the following values: Gusau (0.641), Katsina (0.043), Sokoto (0.189), and Kebbi (0.209), respectively. The finding implies that as the wet spell increases, so also yield of crops increase. Additionally, rice requires more water compared to millet and maize. Rainfed remains the main form of production in Northwestern Nigeria, and rice cultivation major source of livelihood for the people who cultivate it both during the dry and wet seasons.

Table 4. Correlation between crop yield and Dry and Wet spells

States	Variables	Dry spells	Wet Spells	RICE	Maize	Millet
Gusau	Dry spell	1.000	-0.575	-0.234	-0.286	0.346
	Wet Spell	-0.575	1.000	0.641	0.550	0.275
	RICE	-0.234	0.641	1.000	0.681	0.519
	Maize	-0.286	0.550	0.681	1.000	0.160
	Millet	0.346	0.275	0.519	0.160	1.000
	Variables	Dry spell	Wet Spell	RICE	Maize	Millet
	Dry spell	1.000	-0.273	0.216	0.281	0.233

Kaduna	Wet Spell	-0.273	1.000	-0.485	-0.209	0.244
	RICE	0.216	-0.485	1.000	0.065	0.129
	Maize	0.281	-0.209	0.065	1.000	-0.047
	Millet	0.233	0.244	0.129	-0.047	1.000
Kano	Variables	Dry spells	Wet Spells	Rice	Maize	Millet
	Dry spells	1.000	0.094	0.254	-0.331	-0.132
	Wet Spells	0.094	1.000	-0.411	-0.403	-0.537
	Rice	0.254	-0.411	1.000	0.502	0.628
	Maize	-0.331	-0.403	0.502	1.000	0.186
	Millet	-0.132	-0.537	0.628	0.186	1.000
Katsina	Variables	Dry spells	Wet Spells	Rice	Maize	Millet
	Dry spells	1.000	-0.692	0.100	-0.239	-0.563
	Wet Spells	-0.692	1.000	0.043	0.323	0.463
	Rice	0.100	0.043	1.000	0.779	0.415
	Maize	-0.239	0.323	0.779	1.000	0.750
	Millet	-0.563	0.463	0.415	0.750	1.000
Sokoto	Variables	Dry spells	Wet Spells	Rice	Maize	Millet
	Dry spells	1.000	-0.497	-0.078	-0.412	-0.573
	Wet Spells	-0.497	1.000	0.189	0.427	0.542
	Rice	-0.078	0.189	1.000	0.625	0.459
	Maize	-0.412	0.427	0.625	1.000	0.937
	Millet	-0.573	0.542	0.459	0.937	1.000
Kebbi	Variables	Dry spells	Wet Spells	Rice	Maize	Millet
	Dry spells	1.000	-0.174	0.209	0.052	-0.142
	Wet Spells	-0.174	1.000	0.085	0.073	0.068
	Rice	0.209	0.085	1.000	0.152	0.003
	Maize	0.052	0.073	0.152	1.000	0.661
	Millet	-0.142	0.068	0.003	0.661	1.000

Conclusion

The overall distribution of dry spells showed that the majority fall within short sequences: 1–10 days, followed by medium sequences of 11–20 days, and exceptional cases of very long sequences of 21–30 days were found in Kano and Kastina, while wet spell short sequences of 1-5 days, followed by 6-10 and 11-15 days. The study revealed that Northwestern region of Nigeria were at risk of dry spells during the early and late periods of the growing season, which is detrimental to the germination of seeds and final output. The highest contribution to the dry part of the season, in terms of the number of rainless days, comes from 4-7 days of maximum consecutive dry spells, while maximum consecutive wet days come from 1-5 days. The study provides insights into dry spell occurrence during June, with the possibility of it being related to the false start of the rainy season. The results showed that the probability of dry spells occurring was higher during the onset of the growing season than towards the cessation.

The increasing trend and sequential Mann-Kendall trend analysis of the number of dry and wet spells reveal some areas showing a rise in maximum consecutive dry days. Places like Kano,

Sokoto, and Kebbi are witnessing an increase in recent years, indicating a shift in the wet spell pattern. This trend has a significant impact and implications for agriculture, water resources, and disaster management. The increased number of wet days and decrease in dry spell length in recent years are exhibited by extreme wet days with corresponding positive values of SPI and SPEI, while increased dry spells and decreased wet days in 1983 to 1986 coincided with devastating drought over the Sudano Sahelian region of Nigeria. There is also evidence to demonstrate that the recurrent drought and flood increases in the area are at least attributed to the dry and wet spells, and the changes may be related to climate.

The increase in the occurrence and duration of dry spell has negative implications for agriculture and water resources pose a threat to food production and the water supply system in some parts of the study. The increase in maximum consecutive dry spells beyond 7 days during growing is unfavourable to the production of maize because it requires at least 1mm per day to grow well. However, the correlation between reveals that millet is a drought-resistant crop with ($r = 0.344$ in Gusau and $r = 0.233$ in Katsina). The positive relationship between wet spells and the yield of rice further confirms that rice requires more water when compared to other crops. This information generated by the rainfall analysis could find useful applications in crop planning and management of water resources. Therefore, farmers in the study area were guided in decisions for the selection of crops resistant to longer dry spells.

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