PROFESSOR ALIYU TAMBUWAL UMAR

NCE, B.Sc. (Sokoto), M.Sc., Ph.D. (Ibadan), M.A.N.G, MNMetS, MHSN, FWMO
Professor of Climatology
Department of Geography,
Faculty of Social Sciences

USMANU DANFODIYO UNIVERSITY SOKOTO

LAND, SEA AND AIR: THE PILLARS OF CLIMATIC NOISE IN NIGERIA

37TH INAUGURAL LECTURE

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The Vice-Chancellor, Deputy Vice-Chancellor (Administration), Deputy Vice-Chancellor (Academic), Deputy Vice-Chancellor (Research, Innovation and Strategic Partnership), Registrar, Bursar, University Librarian, Provost, College of Health Sciences, Dean of the Postgraduate School, Dean of Students Affairs, Deans of Faculties and Directors of Centres and Institutes, Fellow Professors, Great Danfodites, Invited Guests, Distinguished Ladies and Gentlemen.

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Preamble

It is with deep sense of humility and gratitude to Allah (S.W.A.) that I stand before you this evening to deliver the 37th inaugural lecture of this great University. Although, there is no universally acceptable definition of inaugural lecture that encompasses the nature, content and timing, I see inaugural lecture as:

> '*an opportunity for a newly promoted Professor to showcase his/her intellectual wealth and contributions in extending the frontiers of research in his/her choosing field of specialization in a less technical manner for the understanding of his/her audience*'.

It is therefore an obligation that needs to be fulfilled by all Professors before their retirement. Today's is the 37th in the series of inaugural lectures at the Usmanu Danfodiyo University, Sokoto, fourth from the Faculty of Social Sciences and second from the Department of Geography. The first inaugural lecture from the Department of Geography was delivered by my teacher and Professor of Medical Geography in the person of Prof. (Mrs) D. J. Shehu shortly after she voluntarily retired from the services of this University. The title of her inaugural lecture was '*Know Thyself: The Transfer and Use of Appropriate Knowledge for Socio-Spatial Development in Africa: Lessons from the Geography of Health*' January, 2009). It was the first inaugural lecture on any aspect of human geography in this University and today's is also the first inaugural lecture on any aspect of physical geography in this University be it astronomy, meteorology, geomorphology, geology, pedology, hydrology, biogeography or climatology in which I specialized.

The reason for choosing the title of my inaugural lecture is not far-fetched. Since the establishment of the Inter-governmental Panel on Climate Change (IPCC) in 1988 and its seminal report of 1990, there has been an increasing concern about the effects of the changing climate in different parts of the world as manifested through the occurrence of extreme climatic events such as droughts, floods, desert encroachment, outbreaks of climate-dependent diseases, resource conflicts, etc. Several attempts have been made, with limited success, to discern the nature and characteristics of climate across the globe. The nations of the world have responded and are still responding to the challenges of climate change through several fora such as the World Meteorological Organization (WMO), United Nations Framework Convention on Climate Change (UNFCCC), and more recently through the Conference of Parties (CoP) with the latest, CoP27 held in Egypt.

> '*Just last month (10th September 2023), Libya, an African country, came under siege as it experienced a devastating flash flood that killed over 11,000 people and left about 250,000 people in dire humanitarian needs. The UN has called for urgent financial aid to the tune of seventy-one million dollars for flood victims in Libya* (According to Daily Trust, 15th September 2023).'

Therefore, it is only pertinent that today's inaugural lecture be titled: '*Land, Sea, and Air: The Pillars of Climatic Noise in Nigeria'* since I have been investigating different aspects of climate change in the last fifteen years or so. This title will serve as a platform for me to share some of my thoughts with the general public on land-sea-air interactions and how such interactions trigger climatic noise across the globe but with particular reference to Nigeria.

The distribution of inaugural lectures by faculties since the establishment of this great university to date is given in Table 1 while Figure 1 shows the year distribution of inaugural lectures. It is gratifying to note that the Faculty of the Social Sciences has so far contributed four out of the 37 inaugural lectures delivered in this University. The yearly distribution shows that the first inaugural lecture in this University was delivered in 1990 and since then the number is gradually going up with the 2019 – 2023 period recording the highest numbers of such lectures in this University.

Table 1: Distribution of inaugural lectures by faculties from 1975-date

S/No.	Faculty	Number of Inaugural Lectures Delivered
1	Faculty of Social Sciences	04
2	Faculty of Law	02
3	Faculty of Chemical and Life Sciences	07
4	Faculty of Physical and Computing Sciences	01
5	Faculty of Arts	06
6	Faculty of Arabic and Islamic Studies	02
7	Faculty of Agriculture	03
8	Faculty of Education and Extension Services	01
9	Faculty of Engineering and Environmental Sciences	Nil
10	Faculty of Management Sciences	01
11	Faculty of Pharmaceutical Sciences	Nil
12	Faculty of Vet. Medicine	02
13	Faculty of Allied Health Sciences	Nil
14	Faculty of Basic Sciences	Nil
15	Faculty of Basic Medical Sciences	Nil
16	Faculty of Basic Clinical Sciences	07
17	Faculty of Dental Sciences	Nil
18	School of Medical Laboratory Science	01
Total		037

Source: Inaugural and Seminar Committee of UDUS.

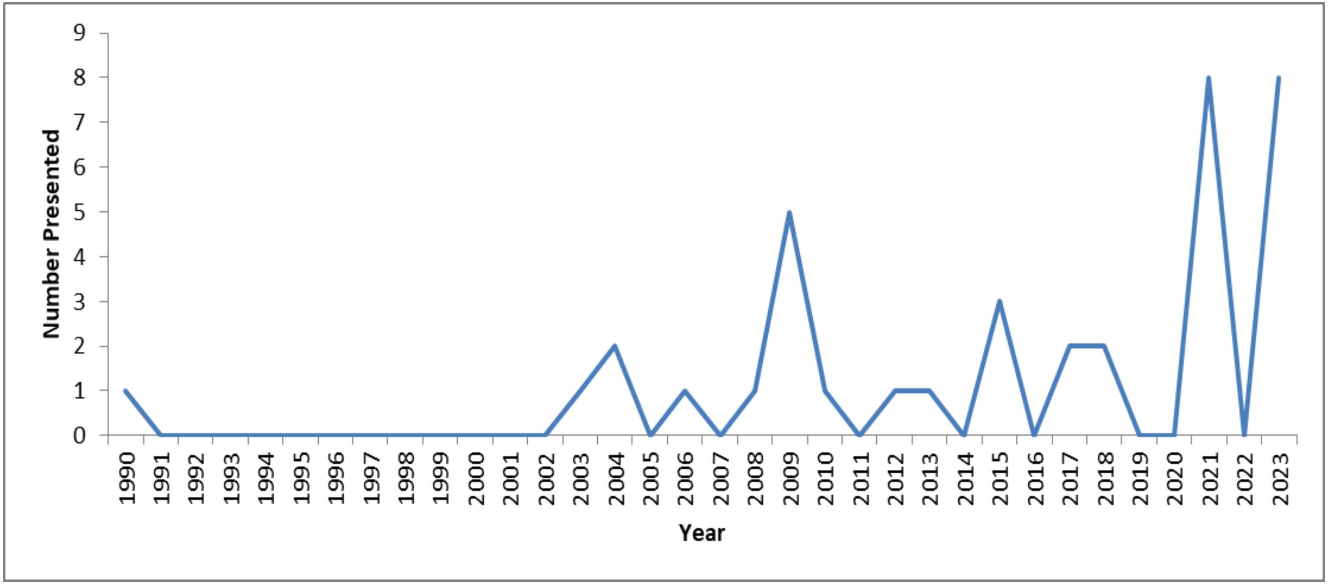


Figure 1. Yearly distribution of inaugural lectures in UDUS (1990-2023)

Source: Inaugural and Seminar Committee of UDUS.

Definition of Terms

Land – the part of the earth's surface that is not covered by water (Oxford Dictionary)

Sea – a great body of salt water that covers much of the earth; broadly, the waters of the earth as distinguished from the land and air; a body of salt water of second rank more or less landlocked (Oxford Dictionary)

Air - the invisible gaseous substance surrounding the earth, a mixture mainly of oxygen and nitrogen (Oxford Dictionary)

Pillar - a large post that helps to hold up something (such as a roof); someone who is an important member of a group; a basic fact, idea, or principle of something; something that rises into the air in a tall, thin shape (Oxford Dictionary)

Climatic Noise - variations in the state of the climate system that have little or no organized structure in time and/or space. This can be a relative term, since variations with a small degree of structure may be regarded as noise in one context but not in another (Glossary of Meteorology)

Climatic Anomalies - anomalies denote the departure of an element from its long-period average value for the location concerned. For example, if the maximum temperature for June in Melbourne was 1 degree Celsius higher than the long-term average for this month, the anomaly would be +1 degrees Celsius (Bureau of Meteorology).

Drought - a prolonged period of abnormally low rainfall, leading to a shortage of water (Oxford Dictionary).

Flood – *a large amount of water covering an area that is usually dry* (Cambridge Dictionary)

Onset Date of Rain - the general definition of the onset day is the first day of a number of consecutive days receiving a certain amount of precipitation (wet spell) and not followed by a number of consecutive dry days receiving less than 5 mm within a given time span (Oxford Dictionary)

Cessation Date of Rain - the cessation date is the last wet day followed by a period of d-days without precipitation (Oxford Dictionary).

Dry Spell - a prolonged period of dry weather (Oxford Dictionary)

El-Nino/Southern Oscillation (ENSO) - the El Niño-Southern Oscillation (ENSO) is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean (National Weather Service).

NINO Regions - Niño Regions. El Niño (La Niña) is a phenomenon in the equatorial Pacific Ocean characterized by a five consecutive 3-month running mean of sea surface temperature (SST) anomalies in the Niño 3.4 region that is above (below) the threshold of +0.5°C (-0.5°C) (National Centre for Environmental Information)

Walker Circulation - the Walker circulation, also known as the Walker cell, is a conceptual model of the airflow in the tropics in the lower atmosphere (troposphere). According to this model, parcels of air follow a closed circulation in the zonal and vertical directions (Wikipedia)

Hadley Circulation - Hadley cell, a model of the Earth's atmospheric circulation that was proposed by George Hadley (1735). It consists of a single wind system in each hemisphere, with westward and equatorward flow near the surface and eastward and poleward flow at higher altitudes (Britannica).

History of Geography as an Academic Discipline

Mr. Vice-Chancellor Sir. Geography is a scientific discipline that concerns itself with the study of complex interactions between man and his environment. The foundation of Geography was laid down by the Greek Philosophers such as Hipparchus, Eratosthenes and Plato, and Roman philosophers such as Strabo and Ptolemy. Several other scholars including Arab geographers such as Al-Kawarazimmi, Ibn-Batuta and Ibn-Khaldun, and Chinese geographers such as Pei Xiu, Fan Chendga, Shen Kuo and Xu Xiake have all contributed to its development. Geography was largely descriptive in nature throughout the Ancient period up to the Medieval period. The emergence of Modern Geography can be traced to the likes of Alexander Von Humboldt and Carl Ritter and several other scholars that followed them.

Geography, however, did not become a university-level discipline despite its long history of existence until much later in the 19th century due to several arguments and counter-arguments concerning its relevance, nature and methodology. In fact, it was only in the early 1870s that geography first became a university discipline in Switzerland and Germany. Thereafter, other European countries, followed towards the end of the decade. In Britain and the United States, however, the establishment of Geography as an academic discipline met with stronger resistance (Holt-Jensen, 1990; Encarta Encyclopedia, 2007). In Britain, the first departments of geography were not established until the beginning of the 20th century, precisely Oxford in 1900; and Cambridge in 1908. Similarly, in the United States, although individuals were appointed to teach geography from the late 1870s, the first department was not established until 1903 in Chicago. Detailed discussions on geographic thoughts, theories and methods can be found in Ofomata (2008).

Dualism in Geography

Mr. Vice-Chancellor Sir, the concept of *Dualism in Geography* can be traced back to Bernhard Varenius (1622-1650). Dualism simply means the dichotomy or break up of Geography into two broad divisions namely: Human Geography and Physical Geography. Human geography concerns itself with the study of man and his socio-economic activities. This branch of geography consists of several sub-divisions such as Population Geography, Demography, Political Geography, Economic Geography, Industrial Geography, Medical Geography, Agricultural Geography, Rural Geography, Urban Geography, and Settlement Geography. Physical Geography deals with the study of man's physical environment. This consists of several sub-divisions such as Astronomy, Meteorology, Geomorphology, Geology, Pedology, Hydrology, Biogeography, and Climatology to which I belong.

Geography at Usmanu Danfodiyo University, Sokoto

Mr. Vice-Chancellor Sir, the Department of Geography at Usmanu Danfodiyo University, Sokoto is as old as the University itself. It was one of the foundation departments established in 1975, and began its academic activities in the 1977/78 session with Dr. K. Swindell from Britain as the pioneer head, leading the affairs of the department from 1977 to 1979. He worked with a number of other expatriates such as Prof. P. D. A. Perera, Dr. R. B. Benning, and Dr. I. A. Dei. The only indigenous geographer who joined the department as a lecturer in the 1977/78 session is no other person than the father of the department, retired Professor M. A. Iliya, who later served as the head four times. He equally served as the Dean of the Faculty of Social Sciences and Administration for two terms.

Professor M. A. Iliya was later joined by other indigenous scholars such as the late Prof. A. B. Mamman, Prof. (Mrs.) D. J. Shehu and Prof. S. A. Yelwa. Professors A. B. Mamman, D. J. Shehu, and S. A. Yelwa also had the privileges of heading the department at different times. These academic giants, along with other expatriates, worked very hard in building and putting the department on a very high academic pedestal. They brought into the department the culture of hard work, discipline, and collegiality. The department has produced several undergraduates and postgraduates over the last 48 years. Among the notable Ph.D. graduates produced by Department are the late Dr. M. A. Abdulrahman, Prof. I. A. Adamu, Prof. S. D. Abubakar, Prof. I. M. Dankani (Current Head of Department) and Dr. M. Y. Fakai. These scholars have distinguished themselves locally and internationally and made the department proud. There are still several M. Sc. and Ph.D students in the department that are undergoing academic surgery, and it is my wish that they will come out alive.

Climatology and its Development in Nigeria

Mr. Vice-Chancellor Sir, climatology is an aspect of physical geography that deals with the study of climate. Climate is the average condition of the atmosphere and deviations from the mean state of climate over a long period of time, 30 years and above. This is different from weather which is the atmospheric condition of an area within a short period of time, for example, within 24 hours. Meteorology on the other hand deals with the physics of the atmosphere. Climatology as a scientific discipline has several subdivisions such as Synoptic Climatology, Precipitation Climatology, Radiation Climatology, Agro-Climatology, Econo-Climatology, Bio-Climatology, Paleoclimatology and Dynamic Climatology. Most of my research activities focus on Synoptic Climatology, Radiation Climatology, Precipitation Climatology and Agro-

Climatology. Synoptic Climatology deals with the generation, propagation and decay of meso-scale convective systems such as thunderstorms, West African Disturbance Line/Line Squalls and West African Monsoon while Precipitation Climatology deals with the analysis of the changing rainfall regime. Radiation Climatology deals with the energy and mass fluxes while Agro-Climatology deals with the crop-climate relationships. Detailed discussions of these subdivisions can be found in Ayoade (2004).

Mr. Vice-Chancellor Sir, even though some research works on the meteorology and climatology of West Africa had been carried out in the earlier half of 20^{th} century by the Nigerian Meteorological Services (now Nigerian Meteorological Agency), it was the founding of the University College, Ibadan in 1948 that gave a fillip to the development of climatology in Nigeria. The Department of Geography, which was one of the pioneer departments established at the time, had as its Head from 1951 till 1961, Professor B. J. Garnier from New Zealand, who pioneered the study of climatology in Nigeria. Professor B, J, Garnier equally delivered his inaugural lecture in 1951 titled '*The Contributions to Geography*'. One of the major contributions of Professor B. J. Garnier to the development of climatology in Nigeria was the publication of his book '*Weather Conditions in Nigeria*' published by McGill University Press, Montreal, Canada in 1967 (Garnier,1967). Several other textbooks on climatology were written by some of the former students of Professor B. J. Garnier. These include '*Climate of West Africa*' written by Professors Hayward and Oguntoyinbo, published by Hutchinson, London in 1978 (Hayward and Oguntoyinbo, 1978), '*Introduction to Climatology for the Tropics*' written by Professor J. O. Ayoade, published by John-Wiley, Chichester, U.K in 1983 (Ayoade,1983) amd 'Tropical Hydrology and Water Resources' written by Professor J. O. Ayoade, published by MacMillan, London (Ayoade,1988). Detailed discussion on the contributions of Professor B. J. Gariner to the development of climatology in Nigeria can be found in Areola and Okafor (1998). Some of the Professors of Climatology in Nigeria that benefited from the seeds of climatology sown at the University of Ibadan by Professor B. J. Garnier are listed in Table 2

Table 2. Some of the Professors of Climatology that had one of their degrees from Ibadan

S/No.	Name	University/College
1	J. S. Oguntoyinbo	Professor of Climatology at University of Ibadan
2	O. Ojo	Professor of Climatology at University of Lagos
3	J. O. Ayoade	Professor of Climatology at University of Ibadan
4	J. O. Adejuwon	Professor of Climatology at Obafemi Awolowo University, Ile-Ife
5	B. L. Oyebande	Professor of Climatology at University of Lagos
6	O. J. Olaniran	Professor of Climatology at University of Ilorin
7	C. Y. Oche	Professor of Climatology at University of Jos
8	P. O. A. Udjugo	Professor of Climatology at University of Benin
9	I.O. Adelekan	Professor of Climatology at University of Ibadan
10	A.A. Adebayo	Professor of Climatology at Ado-Ekiti University
11	A.T. Umar	Professor of Climatology at Usmanu Danfodiyo University, Sokoto
12	W.Vincent	Professor of Climatology at University of Port Harcourt

Source: S/No. 1-7 Areola and Okafor (1998)

S/No. 8-10 (Personal communication with Prof. Udjugo)

An Overview of Global Climate

Mr. Vice-Chancellor Sir, there has been an upsurge in research activities in climatology and other related disciplines with the aim of understanding the nature and characteristics of climate particularly since the rainfall failures of 1968 which persisted through the 1970s, 1980s and 1990s and leading to catastrophic droughts of 1972-73, 1982-87 and 1992-94 in different parts of Africa as extensively discussed in the literature (See Adedoyin; 1986; Oladipo, 1993; Nicholson, 2000; Odjugo, 2006; Ayoade, 2016; Umar, 2018). The occurrence of rainfall anomalies such as droughts or floods is not limited to tropical areas of the world but also the extra-tropical areas. In the United States and Britain for example, several drought episodes have been reported in the literature (see Tushal and Cai, 2021). However, in an extra-ordinary nature of global climate occasioned by the inter-hemispheric teleconnections, the climatic anomalies such as floods and droughts have been occurring simultaneously in different parts of the world.

Flood is defined as a body of water which rises to overflow land which is not normally submerged (Ward, 1978; Ayoade,1988). There is no universally acceptable definition of drought in the literature. It is, however, acknowledged that drought is a meteorological phenomenon which is associated with a sustained period of significantly below normal precipitation (see Oladipo, 1985; Glantz, 1994). In this lecture, attempt was made to re-examine the nature and characteristics of climate with reference to Nigeria in an attempt to understand whether or not the climate is changing or it has already changed. This was achieved by making reference to some of the research activities that I personally carried out and those that have been conducted jointly with some of my colleagues and postgraduate students.

Mr, Vice-Chancellor Sir, in this section, we shall consider a brief history of global climate in two major phases namely: before the instrumental era (geologic period) and the instrumental era (recorded period). While the former covers the period before the Pleistocene period, a million or so years ago, the latter covers the more recent period of the Holocene, less than one million years before the present (Ayoade, 2003). From various palaeoclimatological studies, it has now been established that the climate of the earth has experienced significant variations since the Pre-Cambrian period (more than 500 to 600 million years ago) (Ayoade, 2016), even though the causes of these variations are still not fully understood as there are several theories put forward by various climate scientists in explaining the nature and characteristics of global climate during the geologic period. Table 3 provides a summary of the global climate since the Cambrian period.

Table 3. Global Climate since the Pre-Cambrian Period

Era	Period	Age by Radioactivity in million years	Nature and Characteristics of Climate
Quaternary	Recent (Holocene)		Glaciations in temperate latitudes
	Pleistocene	1	
Tertiary	Pliocene	13	Cool
	Miocene	30	Moderate
	Oligocene	60	Moderate to warm
	Eocene		Moderate
			Becoming warm
Mesozoic	Cretaceous	110	Moderate
	Jurassic	155	Warm and Equable
	Triassic	190	Warm and Equable
Palaeozoic	Pre-Cambrian	560	Glacial

Source: Ayoade, 2016.

The Concept of Climate Change

Mr. Vice-Chancellor Sir, from time immemorial, man, has through his anthropogenic activities, interfered with climate system either advertently or inadvertently. However, the situation became more noticeable in the mid-1970s when the advancement in science and technology increased with more industries springing up especially in the North America, South America, Europe, Asia and some countries in Africa. These industrial activities gradually increased the emission and concentration of the heat-trapping gases in the lower atmosphere. These gases are called the '*Green House Gases (GHGs)*'. These include carbon dioxide (CO_2), Methane (CH_4), Chlorofluorocarbons (CFCs) and Ozone (O3). These GHGs gases gradually help in trapping and interfering with the energy budget of the earth and hence lead to gradual increase in the earth's average temperature leading to a phenomenon called '*global warming*' as reported by the Inter-governmental Panel on Climate Change (IPCC, 1988). This increase in the average global temperature of the earth which began in the early 1970s and the disruption in the global patterns of climate, leading to weather anomalies such as droughts and floods in various parts of the world seem to provide the signals for impending change in the climate of the world as we know it today (Ayoade, 2016).

Climate Change in Perspective

What is Climate Change? This is defined as a statistically significant shift in the mean values of the climatic elements concerned over two intervening long periods of at least 30-35 years (Landsberg, 1975). It should however be noted that climate has never been static in any part of the world. Climate is defined as the synthesis of weather at a given location or area over a long period of time of at least 30 years including the variabilities or departures from the average conditions. Climate therefore represents a generalization of weather conditions over an area by at least 30 years . The convention of using 30-year weather data in characterizing the climate over an area has been adopted by the World Meteorological Organization (WMO) which has recommended the use of a period of 30 years as sufficient for calculating climatic normal, whether of temperature or precipitation (Hobbs, 1997; Ayoade, 2016).

Climate of Nigeria: Mechanisms and Characteristics

Nigeria enjoys a tropical continental climate characterized by two distinct seasons viz: the wet season and dry season. The country receives rainfall from the south westerlies emanating from the Gulf of Guinea coast. This moist air stream is overlain by the northeast trades which originate from above the Sahara and therefore are dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter-Tropical Discontinuity (ITD) which advances inland as far as 22-25^0 N in August at the margin of the Sahara. This is considerably beyond Nigeria's northern border (Ayoade, 2011). The ITD does not retreat equatorward beyond 4^{0}N during the 'Harmattan' dry season (see Odekunle *et al*, 2008, Ayoade, 2011). The five weather zones that are associated with the ITD over Nigeria are illustrated in Figure 2, below.

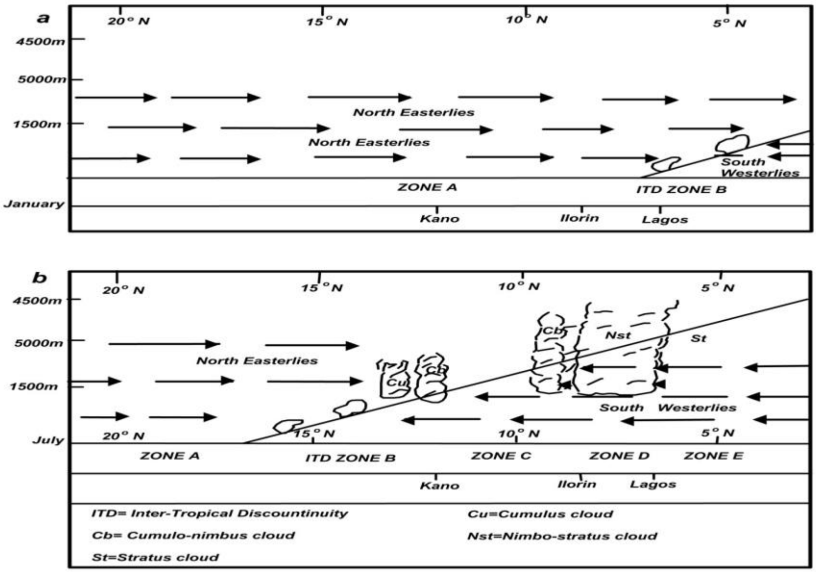


Figure 2 *The ITD and the weather zones in an idealized atmospheric cross-section from South to North over Nigeria (After Ojo, 1977).*

Land-Sea-Air Interactions and Global Climatic Noise

Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, the term '***Climatic Noise also called Climate Noise'*** simply means, '*variations in the state of climate system that have little or no organized structure in time and/or space'. This can be a relative term, since variations with a small degree of structure may be regarded as noise in one context but not in another* (Glossary of Meteorology, 2023). The role of the land, sea, and air in global climatic noise cannot be over-emphasized. The climatic anomalies of the 1950s, 1970s, and 1980s in Africa, for example, were characterized by devastating floods in most parts of West Africa, and the subsequent droughts of the 1970s and 1980s that ravaged most countries in the West African sub-region attracted the attention of several climate scientists within and outside Africa. This led to the formulation of several theories in an attempt to account for the mechanisms of such large-scale climatic noise in West Africa. Among the theories put forward include the Surface Feedback Mechanism (Charney, 1975), and Displacement of the Mean Surface Position of the Inter-tropical Discontinuity (ITD) (Ayoade, 1983). However, the global climatic noise experienced in different parts of the world as manifested in the form of floods or droughts suggests that some factors other than the surface feedback mechanism and displacement of the ITD also played a role in the global climatic noise experienced in different parts of the world.

It has now been established that the complex interactions among the land, sea, and air are responsible for most of the climatic anomalies experienced in different parts of the world and are likely to remain the dominant factors in global climatic variability in future. This coupled ocean-atmospheric interactions result in the development of the El-Nino/Southern Oscillation (ENSO) which dominates the climatic variability in many parts of the world (Popelewiski and Halpert,1987). The complex interactions among the land, sea, and air can be demonstrated even with the local example of the **land and sea breezes**. A local thermal low develops over the land with winds blowing from the sea towards the land. This is a sea or lake breeze as shown in Figure 3. At night the land cools off rapidly while the sea is still warm, the pressure gradient is thus reversed and wind now blows from the land towards the sea. This is land breeze. The sea breeze is usually stronger than the land breeze and the effect is sometimes felt as far as 60 km inland. (Ayoade, 2004). The sea breeze starts a few hours after sunrise and is most intense during the early afternoon. It is strongest when the insolation is most intense. Sea breeze is therefore best developed during the dry season in the tropics and in summer in the temperate region. It rarely brings rain but it brings welcome relief from the oppressive heat during the day in many tropical areas.

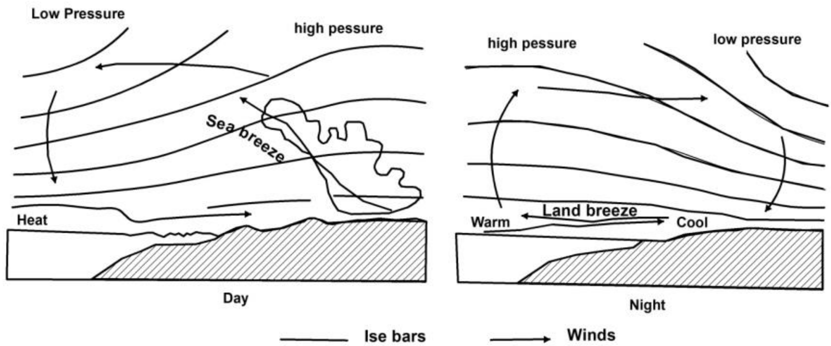


Figure 3: land and Sea Breezes

Source (Ayoade,2004)

The History and Science of El-Nino/Southern Oscillation (ENSO) Events

Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, the global climatic noise (flooding as a result of too much rainfall or drought as a result of too low rainfall) that has been experienced in different parts of the world and that is likely to be experienced in future has now been linked to the recent global climatic phenomenon of the El-Nino/Southern Oscillation (ENSO) event. The history of ENSO is well documented in the New World Encyclopedia. The term 'El Niño/Southern Oscillation (ENSO)' commonly referred to as simply (El Niño) is a global coupled ocean-atmosphere phenomenon. The Pacific Ocean signatures, **El-Nino and La-Nina** are important temperature fluctuations in surface waters of the tropical Eastern Pacific Ocean. The name El Niño, from the Spanish word for "the little boy," refers to the Christ child, because the phenomenon is usually noticed around Christmas time in the Pacific Ocean off the west coast of South America (see Figure 4).

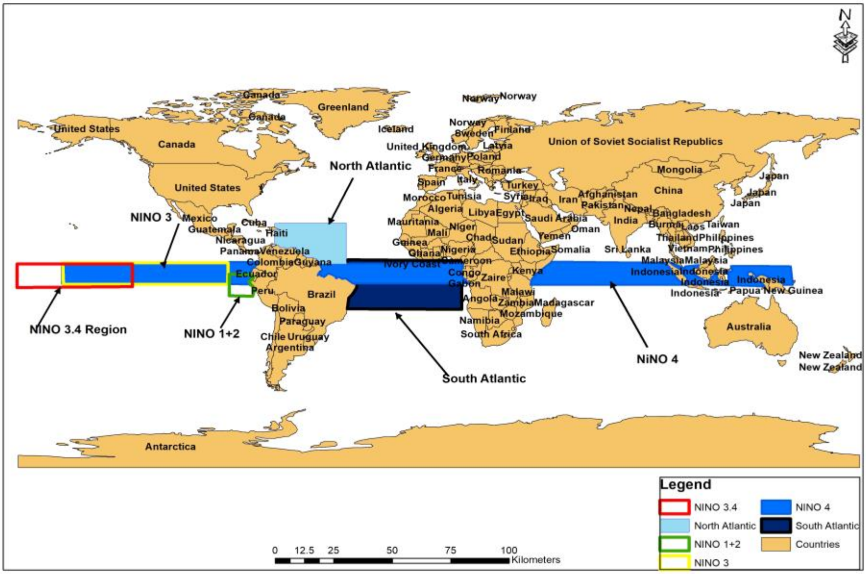


Figure 4. Geographical extent of Pacific El-Nino regions and Atlantic Ocean

La Niña, similarly, means "the little girl." These effects were first described in 1923 by Sir Gilbert Thomas Walker from whom the Walker circulation, an important aspect of the Pacific ENSO phenomenon, takes its name.

ENSO is an irregular periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and sub-tropics. The warming phase of the sea surface temperature is known as

El-Nino and the cooling phase as **La-Nina**. The Southern Oscillation is the accompanying atmospheric component, coupled with the sea temperature change. **El-Nino** is accompanied by high air surface pressure in tropical western Pacific and **La-Nina** with low air pressure there. The two periods last several months each and typically occur every few years with varying intensity per period. Some of the observed El-Nino and La-Nina years are given in Table 4.

Table 4. Some of the observed El-Nino and La-Nina years over the period 1901-date

El-Nino Years	La-Nina Years
1925	1951-52
1972-73	1957-58
1982-83	1965-66
1987-88	1969-70
1997-98	1973-74
2002-03	1974-75
2004-05	1983-84
2014-16	1988-89
2018-19	1998-99
Beginning in 2023	2000-01, 2008-09, 2010-11, 2016-17

Source : https://en.wikipedia.org › wiki › El_Niño

Mr. Vice-Chancellor sir, the two phases of ENSO relate to the **Walker Circulation**, which was discovered by Gilbert Walker during the early 20th century. The Walker Circulation is caused by the pressure gradient force that results from a high-pressure area over the eastern tropical Pacific Ocean, and a low-pressure system over Indonesia. The weakening or reversal of the Walker Circulation (which includes the trade winds) decreases or eliminates the upwelling of cold deep-sea water, thus creating El-Nino by causing the ocean surface to reach above-average temperatures. A very strong Walker circulation causes La-Nina, resulting in cooler ocean temperatures due to increased upwelling as shown in Figure 5. ENSO is a single climatic phenomenon that periodically fluctuates between three phases: Neutral (Normal) condition, La-Nina condition or El-Nino condition as shown in Figures 6-8.

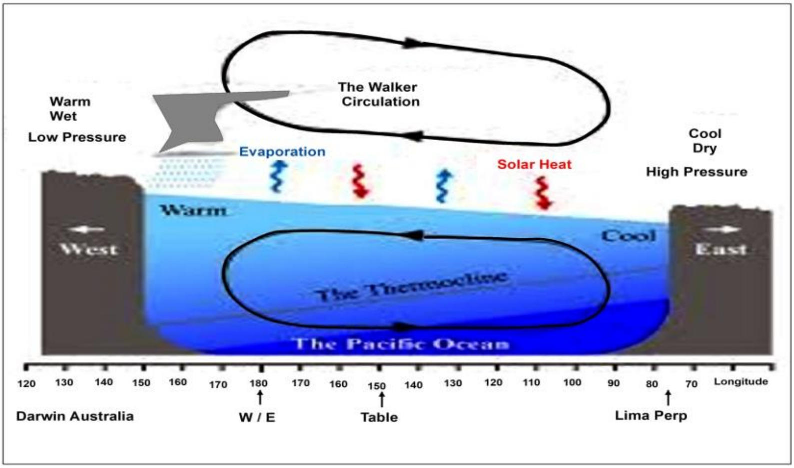


Figure 5. Walker Circulation

Source: https://en.wikipedia.org › wiki › El_Niño

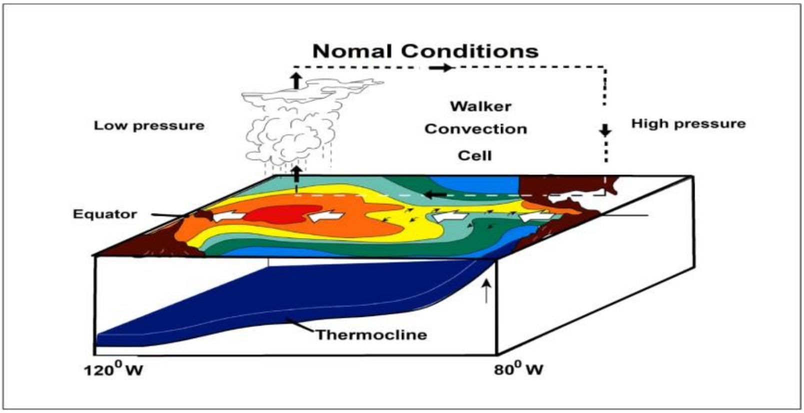


Figure 6. ENSO Neutral (Normal Condition)

Source: https://en.wikipedia.org › wiki › El_Niño

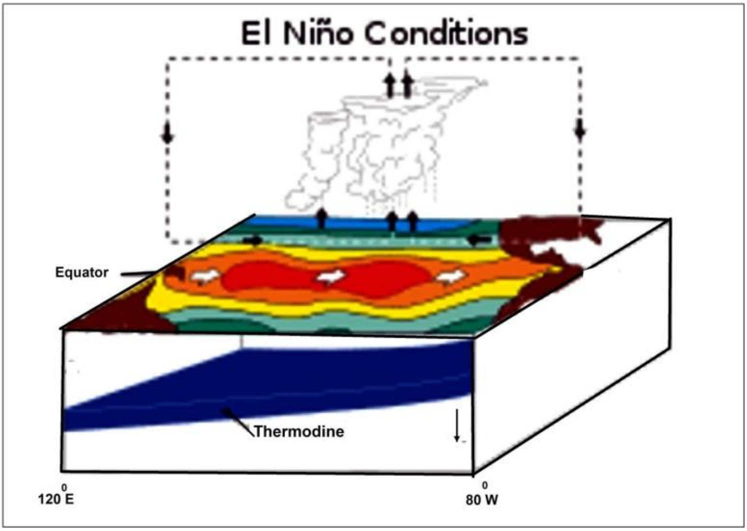


Figure 7. El-Nino Condition

Source : https://en.wikipedia.org › wiki › El_Niño

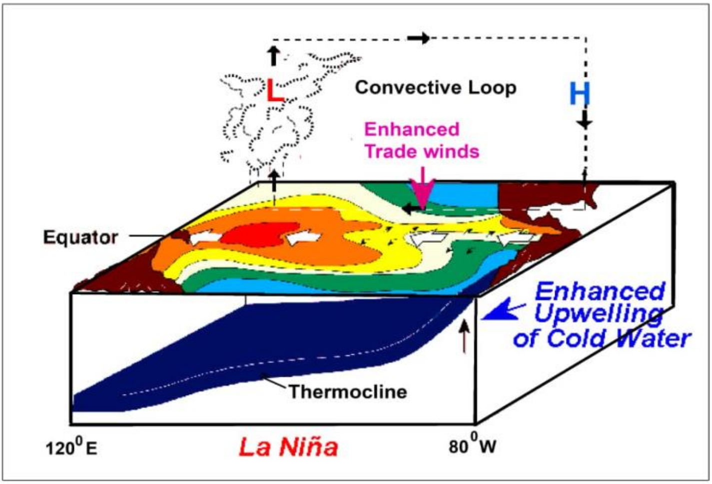


Figure 8. Cold-ENSO (La-Nina Condition)

Source: https://en.wikipedia.org › wiki › El_Niño

During an El Nino event, sea level pressure tends to be lower in the eastern Pacific but higher in the western Pacific while the reverse is true for La Nina. This see-saw in atmospheric pressure between the eastern and western tropical Pacific is called the *Southern Oscillation*, often abbreviated as SO. A standard measure of SO is the difference in sea level pressure between Tahiti and Darwin, Australia. Since El Nino and the Southern Oscillation are related, the two terms are often combined into a single phrase, the El Nino/Southern Oscillation, abbreviated as ENSO. Often the term "ENSO Warm Phase" is used to describe El Nino while "ENSO Cold Phase" describes La Nina (Ayoade, 2011).

Once developed, the El Nino and La Nina events typically persist for about a year and so the altered rainfall patterns associated with them typically persist for several seasons as well. This can impact significantly on people living in areas of tropical pacific since the usual precipitation patterns would be greatly disrupted by either excessively wet or dry conditions. In addition, the altered tropical rainfall pattern during El-Nino and La-Nina does not only affect the tropical Pacific region but areas away from the tropical Pacific as well. This may include several tropical locations and regions outside the tropics within the Northern and Southern hemispheres (Popelewiski and Halpert, 1987). Studies of the Southern Oscillation (SO), the El Niño and La Niña phenomena, and their associated effects over the entire atmosphere have assumed greater economic and social importance and have been given considerable scientific attention in recent times.

Rainfall trends in Africa between 1901 and 1985 have been shown by Hastentrath (1984) and Folland **et** *al.* (1986) to be directly influenced by contrasting patterns of SST anomalies on a global scale. Also, by extending the global circulation model experiments of Folland **et** *al.* (1986), Palmer (1986) studied the model's response to SST anomalies in individual oceans and found that over the western Sahel, the Atlantic, and Pacific SST anomalies tend to reduce total rainfall amount whereas the Indian Ocean anomalies produce slight enhancement.

It is likely that these global-scale SST anomalies directly influence rainfall in Africa by altering tropical circulations. For instance, Pacific El-Ninoo events alter the concept of the Walker Circulation by causing a shift, to the east, of the Pacific ascending branch and creating subsidence over some parts of Africa (World Meteorological Organization, 1985). On the other hand, warming of the South Atlantic SST reduces the meridional gradient of **SST** south of the Inter Tropical Discontinuity (ITD) (Palmer, 1986), and as a result, there is a weakening of the Hadley meridional circulation. The weakened circulation reduces the intensity of the south-west monsoon flow into west and central Africa.

Atmospheric Circulation

Atmospheric circulation describes the pattern in which air flows around the Earth. Each hemisphere is split into three convection cells, shown in the tricellular model below (see Figure 9).

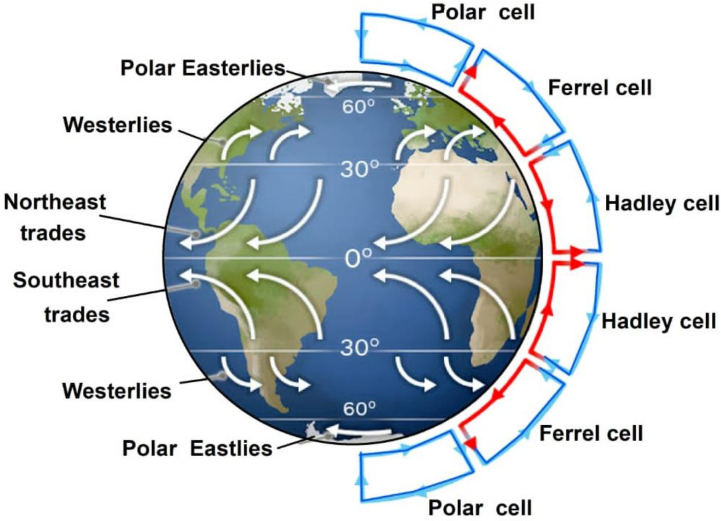


Figure 9. Tricellular model

Source : : https://theory.labster.com/atmospheric-circulation/

Due to the sun's position relative to the Earth, the equator receives the most direct sunlight and the southern hemisphere receives more sun than the northern hemisphere due to the Earth's tilt. The poles receive a low angle of incoming sunlight which is scattered over a large area, resulting in a much colder climate. Without atmospheric circulation, the equator would be much hotter and the poles would be much colder. The movement of air disperses heat to different regions around the Earth, influencing local climates and biomes. Each cell also causes particular prevailing winds that blow eastward or westward. The reason the winds do not blow directly from north to south (or vice versa) is due to the Earth's rotation, in a process known as the Coriolis Effect.

Hadley Cell

As sunlight is more concentrated at the equator this heats the Earth's surface, which warms the air. As air warms its density decreases causing it to rise, creating an area of low pressure. The air that rises at the equator reaches the tropopause (boundary of the troposphere), splits and travels poleward (both north and south). At around latitude 30° N and S, the air cools, becomes denser, and sinks, creating high pressure. The sinking air travels towards the equator to replace the warm, ascending air, completing the closed circulation loop. The Hadley cell forms the northeast and southeast trade winds.

Ferrel Cell

The Ferrel cells are not driven by temperature (like the Hadley and Polar cells) and they flow in the opposite direction. A large part of the energy that drives the Ferrel cell is provided by the Polar and Hadley cells circulating on either side, which drags the Ferrel cell with it. As surface air in these cells flows away from the equator, the Earth's rotation deflects the air to the east and forms the westerlies.

Polar Cell

The Polar cells are the furthest cells from the equator and have the coldest climate. The warm air that travels to the poles from the Ferrel cells cools and descends at the highest latitudes, creating a dry, high-pressure area. The air circulation of the polar cell is caused by cold air sinking at the poles and flowing towards the mid-latitudes, producing sporadic winds known as the polar easterlies.

Contributions to the Understanding of the Dynamics of Global Climatic Noise with Particular Reference to Nigeria

Mr. Vice-Chancellor Sir, I may not be the first to pontificate on climatic crises in Nigeria. As far back as 1982, the first indigenous Professor of Climatology in Nigeria, Prof. J. S. Oguntoyinbo of the Department of Geography, University of Ibadan had pondered on climatic crises in Nigeria as reported in his inaugural lecture titled *Climate and Mankind* (Oguntoyinbo, 1982). The lecture summarized various issues on climatic variations in Nigeria and attributed most of the observed changes in micro-climates to the variations in *albedo* of different surfaces in Nigeria. A few years later, my Doctoral Thesis Supervisor, Prof. J. O. Ayoade, also of the Department of Geography, University of Ibadan, re-examined the issues concerning mechanisms of Nigeria's climate as documented in his own inaugural lecture titled '*Climate and Human Welfare*' (Ayoade, 1995). Ayoade's inaugural lecture concentrated more on the dominant role or influence of the Inter-Tropical Convergence Zone (ITCZ)/Inter-Tropical Discontinuity (ITD) on the dynamics of rainfall climatology as it relates to physiologic comfort in Nigeria.

Similarly, another eminent scholar and Professor of Climatology, Prof. O. J. Olaniran of the Department of Geography, University of Ilorin pondered on the climatic anomalies in Nigeria and delivered his inaugural lecture titled *Rainfall Anomalies in Nigeria: A Contemporary Understanding* (Olaniran, 2002). The thrust of Olaniran's lecture was on the role of the African Easterly Jet (AEJ), Tropical Easterly Jet (TEJ), Madan Julian Oscillations (MJO), Geophysical Feedback Mechanisms and tropical oceans in global climate with reference to Nigeria's climate. In a more recent time, Adelekan (2023) also delivered her inaugural lecture titled *Climate Change, Cities and Society: Drivers and Designs of Risks* in which she dealt with issues of vulnerability of cities and societies to hydrometerological disasters and how their resilience could be enhanced.

Mr. Vice-Chancellor Sir, the results of the various research activities reported in these inaugural lectures and in several other fora that have not been reported here point to that fact that, climate change has been a topical issue within and outside Nigeria. In the light of this development, I am glad to stand before you this evening to share some of our research findings with the general public concerning the frequency and spatial patterns of climatic anomalies in Nigeria based on the results of our modest research activities in the last fifteen years or so in order to possibly answer the question on whether or not the climate is changing. Syntheses of results of various climatological researches that have been carried out on some of the indices of the changing climate are presented in this lecture. These indicators of a changing climate include, but not limited to the following:

i. Changes in Rainfall Patterns due to El-Nino/Southern Oscillation (ENSO) events
ii. Changes in Rainfall Amounts
iii. Changes in Seasonal Rainfall Regime
iv. Variations in the dates of onset and cessation of the rain, length of the growing season/rainy season and dry spell occurrences
v. Changes in water balance parameters
vi. Seasonal Variations in Air Temperature
vii. Variations in ground water level

Changes in Rainfall Patterns due to El-Nino/Southern Oscillation (ENSO) events

Mr. Vice-Chancellor Sir distinguished ladies and gentlemen, a comprehensive study on the response of rainfall to ENSO events at global level could be credited to the classical study of the Popelewiski and Halpert in 1987. Popelewiski and Halpert (1987) investigated the "typical" global and large-scale precipitation patterns that are associated with the El-Nino/Southern Oscillation (ENSO) using monthly precipitation time series of 1700 weather stations across the globe with varying lengths of records over the period 1875-1983. These data were sourced from various sources including the NCAR data set. The study revealed that in addition to the Pacific Ocean basin where precipitation patterns could be directly related to the ENSO event, several other regions, which showed consistent ENSO-related precipitation, were identified. Specifically, four regions in Australia, two regions each in North America, South America, the Indian subcontinent, and Africa, and one region in Central America were all found to have ENSO-related precipitation.

Mr. Vice-Chancellor Sir, at continental level, Nicholson and Kim (1997) examined the relationship of the El-Nino/Southern Oscillation (ENSO) to African rainfall. The harmonic method utilized by Ropelewski and Halpert in 1987 was also applied to 90 regionally averaged rainfall time series for the period 1901–1990, and the results identified 15 multi-region sectors where ENSO appears to modulate rainfall. The strongest signals were in eastern equatorial and south-eastern Africa.

The curiosity about these results prompted Umar and Kehinde (2020) to examine the relationship between the El-Nino/Southern Oscillation (ENSO) and rainfall patterns in Nigeria using historical climate data consisting of daily rainfall records from 27 synoptic weather stations with uniform length of records from 1951-2000. The period consists of two contrasting moisture conditions in the country, the wet period of the 1950s, the dry periods of the 1970s, 1980s and late 1990s which signaled a gradual recovery of rainfall in the Sahel. The rainfall data were sourced from the archives of the Nigerian Meteorological Agency (NiMet). The location of the selected synoptic weather stations is given in Figure 10.

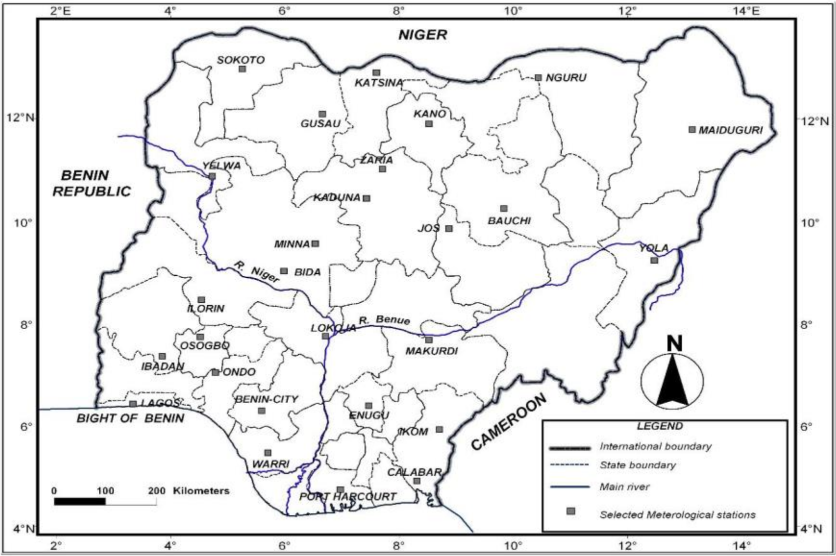


Figure 10. Location of the synoptic weather stations whose daily rainfall data were used in the study.

`Source: Umar and Kehinde (2020)

The seven climatic regions of Nigeria derived by Olaniran (1986) were re-grouped into four major regions based on the prevailing climatic conditions for each of the regions namely: the northern region, middle belt/central, south-west and south-east (see table 5)

Table 5. Selected synoptic weather stations grouped by regions

Region	**Stations**	**Length of Record**
North	Sokoto Kano Katsina Yelwa Yola Bauchi Gusau Maiduguri Nguru	1916-2023 1905-2023 1918-2023 1926-2023 1914-2023 1908-2023 1953-2023 1915-2023 1942-2023
Middle Belt/Central	Kaduna Zaria Minna Bida Jos Lokoja Makurdi Ilorin	1930-2023 1943-2023 1916-2023 1928-2023 1923-2023 1916-2023 1927-2023 1916-2023
South-West	Lagos Ibadan Ondo Osgogbo Benin Warri	1901-2023 1905-2023 1906-2023 1935-2-23 1906-2023 1906-2023
South-East	PortHarcourt Enugu Calabar Ikom	1902-2023 1916-2023 1902-2023 **1972-2023**

Source: NiMet 2023

Olaniran's (1986) regions (i) and (ii) which are grouped as southern region in the present study, is further divided into south-west and south-eastern regions. Hence, the country is divided into four regions which are characterized by distinct rainfall patterns. The northern region consists of nine stations which are representative of the Sudano-Sahelian zone. The middle belt region, which contains eight stations, separates the semi-arid zone of northern Nigeria from the sub-humid tropical zone of the south. The climate of the middle belt region is complicated by the topographical features of the highlands. Six stations are grouped into the south-western region which experienced double-rainfall maxima in May/June and September/October with a particularly well-marked "little dry season" in July/August (Adejuwon and Odekunle, 2006).

The little dry season is associated with a temperature inversion above the surface layer which inhibits convective activity and rainfall (Adefolalu, 1986; Olaniran, 1991). Local divergence was primarily responsible for the stability in the monsoon air masses during this period. In the south-east region, which was represented by four synoptic weather stations, showed a tendency for somewhat less rainfall in August than during July and September; however, rainfall amounts remained considerably high throughout the entire wet season. The high rainfall amount within the south-eastern region was a common feature of the more humid equatorial zone.

Other categories of data analyzed included the daily sea level pressure (SLP) over the Eastern and Western Pacific Ocean, and daily sea surface temperature (SST) over the NINO regions, North and South Atlantic and global SST. These NINO regions are:

NINO 1+2 (Extreme Eastern Tropical Pacific) (Lat. 0-10^{0}S, Long. 80-90^{0}W): This region typically warms first when an El-Nino event develops.

NINO 3 (Eastern Tropical Pacific) (Lat. 5^{0}S-5^{0}N; Long. 150^{0}W-90^{0}W): This region of the tropical Pacific has a large variability in sea surface temperature on El Nino time scales.

NINO 3.4 (East-Central Tropical Pacific) (Lat. 5^{0}S-5^{0}N; Long. 170^{0}W-120^{0}W): This region has the largest variability on El Nino time scales, being closer (than NINO 3) to the region where changes in local sea surface temperature are important for altering a larger region of rainfall typically located in the far western Pacific.

NINO 4 (Central Tropical Pacific) (Lat. 5^{0}S-5^{0}N; Long. 160^{0}E-150^{0}W): This is the region where changes of sea surface temperature lead to total values around 27.5^{0}C, which is an important threshold in producing rainfall. The geographical extent of these NINO regions, South and North Atlatic as well as global tropics is given in Figures 4.

These categories of data were sourced from the official websites of the Climatic Prediction Centre (CPC) and the National Oceanic and Atmospheric Administration (NOAA), U.S.A. The step-wise multiple regression model was applied to the composites of annual rainfall amounts for each of the four regions considered as well as its growing season rainfall amounts. The annual rainfall amounts, growing season rainfall amounts of the five selected weather stations in the Sudano-Sahelian region of Nigeria as well as the region's composite of annual and growing season rainfall amounts were also subjected to the indices of SST anomalies to detect the link between rainfall and ENSO events in the region. The independent variables used in the model include the SST anomalies for each of the NINO regions and those of the South and North Atlantic and the global SST anomalies. The results of the step-wise multiple regression model are presented in Tables 6-9.

Table 6: Summary of the Regression between Annual Rainfall Amounts and Anomaly Indices of SST and ENSO index in Nigeria

Country/Region	Variable(s)	R	R2	Significance
North	South Atlantic SSTA	0.35	0.120	0.01
Central	North Atlantic SSTA	0.35	0.124	0.01
South-West	-	-	-	-
South-East	-	-	-	-

Source: Umar and Kehinde (2020)

Table 7: Summary of the regression between growing season rainfall amounts and anomaly indices of SST and ENSO index in Nigeria

Country/Region	Variable(s)	R	R2	Significance
North	South Atlantic SSTA	0.356	0.127	0.01
Central	North Atlantic SSTA	0.319	0.102	0.01
South-West	South Atlantic SSTA	0.282	0.080	0.01
South-East	-	-	-	

Source: Umar and Kehinde (2020)

Table 8: Summary of the regression of Annual Rainfall Amounts on SSTs and ENSO Indices at the Selected Sudano-Sahelian stations of Nigeria

Synoptic Station	Variable(s)	R	R2	Significance
Katsina	Global SST	0.45	0.198	0.00
	North Atlantic SST	0.60	0.359	0.00
	NINO 3.4 SST	0.67	0.442	0.00
Nguru	South Atlantic SST	0.52	0.274	0.00
	Global SST	0.61	0.366	0.00

Maiduguri	Global SST	0.36	0.129	0.01
	North Atlantic SST	0.54	0.288	0.00
Kano	North Atlantic SST	0.46	0.207	0.00
Sokoto	South Atlantic SST	0.40	0.160	0.00

Source: Umar and Kehinde (2020)

Table 9: Summary of the Regression of Growing Season Rainfall Amounts on SSTs and ENSO Indices at the Selected Sudano-Sahelian stations of Nigeria

Synoptic Station	Variable (s)	R	R2	Significance
Katsina	Global SST	0.44	0.189	0.00
	North Atlantic SST	0.54	0.290	0.00
	NINO 3.4 SST	0.64	0.408	0.00
Nguru	South Atlantic SST	0.54	0.294	0.00
	Global SST	0.61	0.377	0.00
Maiduguri	South Atlantic SST	0.35	0.121	0.01
	ENSO Index	0.47	0.218	0.00
Kano	North Atlantic SST	0.46	0.207	0.00
Sokoto	South Atlantic SST	0.39	0.151	0.01

Source: Umar and Kehinde (2020)

Mr. Vice-Chancellor Sir, the results of the step-wise multiple regression model presented in Tables 3-5 have a range of implications on food crop production in Nigeria especially in the Sudano-Sahelian region of Nigeria Among these implications are as follows:

i. that the rainfall pattern in Nigeria is also ENSO-related as revealed by higher p-values of some of the indices of ENSO such as SST anomalies over the East-Central tropical Pacific and the SST anomalies over the South Atlantic Ocean.
ii. that during warm-ENSO characterized by warmer than normal conditions over the East-central tropical Pacific, the influx of the southwesterly monsoon into the country from the Gulf of Guinea in the Atlantic Ocean

will be suppressed/weakened and hence less convective activities, creating an anomalous condition in which rainfall will be too much in the southern part of the country and too little in the northern part of the country.

iii. that the north-ward movements of the ITD will be hampered. The reverse holds true for the cold phase of ENSO. Fair or normal rainfall conditions can occur in most parts of the country if the ENSO phase is neutral.

iv. that crops will be greatly affected especially if it is a warm-ENSO cycle since rainfall will be highly irregular with varying degrees of dry spells occurring immediately after the onset of the rainy season has been established. This can also create moisture stress to crops towards the maturing stage if rainfall ceases before the expected cessation date of the rainy season due to the effects of the warm-ENSO.

v. that the effects of ENSO will be more pronounced on crops since the growing season rainfall composites showed higher correlations with anomalous SSTS over the Pacific and Atlantic oceans.

Changes in Rainfall Amounts

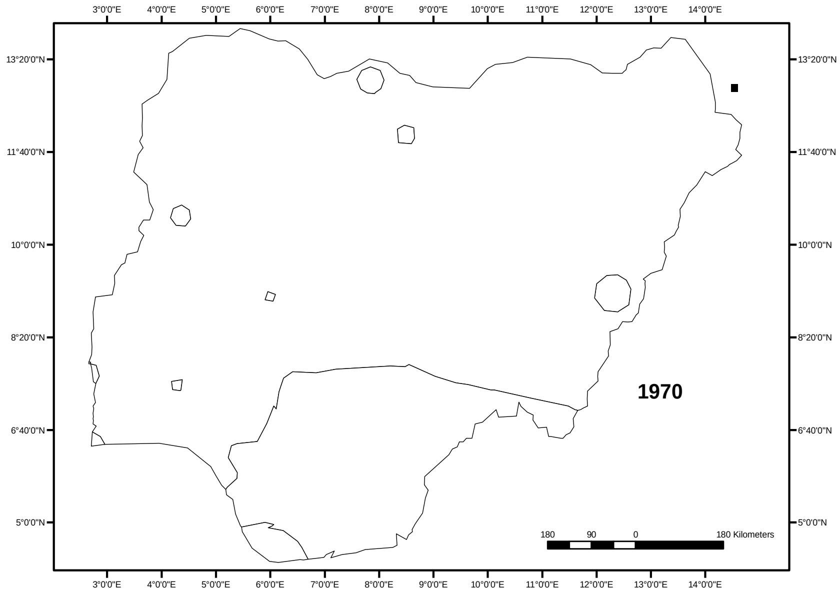
Mr. Vice-Chancellor Sir, one of the indicators of a changing climate of an area is the change in the daily, monthly and annual rainfall amounts. The deviations from the long-term mean of either daily, monthly or annual rainfall amounts over a given period are regarded as anomalies. The positive departures from the long-term mean (positive anomalies) give an indication of the above normal rainfall condition which in most cases leads to floods of different magnitudes. The negative departures (negative anomalies) on the other hand, give an indication of below normal rainfall condition which if persisted could lead to meteorological drought.

Mr. Vice-Chancellor Sir, an examination of rainfall records in Nigeria over the period 1901-2000 revealed significant variations in the monthly and annual rainfall amounts with a mixture of both negative and positive rainfall anomalies. The study on the frequency and spatial patterns of droughts using the PDBM index on monthly rainfall records of twenty-seven selected synoptic weather stations in Nigeria with varying lengths of records over the period 1901-2000 did not reveal any spatial coherence in the occurrence of droughts in Nigeria as shown in Figure 11 (Umar,2013a).The droughts of various intensities could be read using the scales presented in Table 10.

Table 10. Drought category based on the PDBM index

Scale	Drought Category
11-25%	Slight Drought
26-45%	Moderate Drought
46-60%	Severe Drought
More than 60%	Disastrous Drought

Source: Ayoade, J. O. (2008).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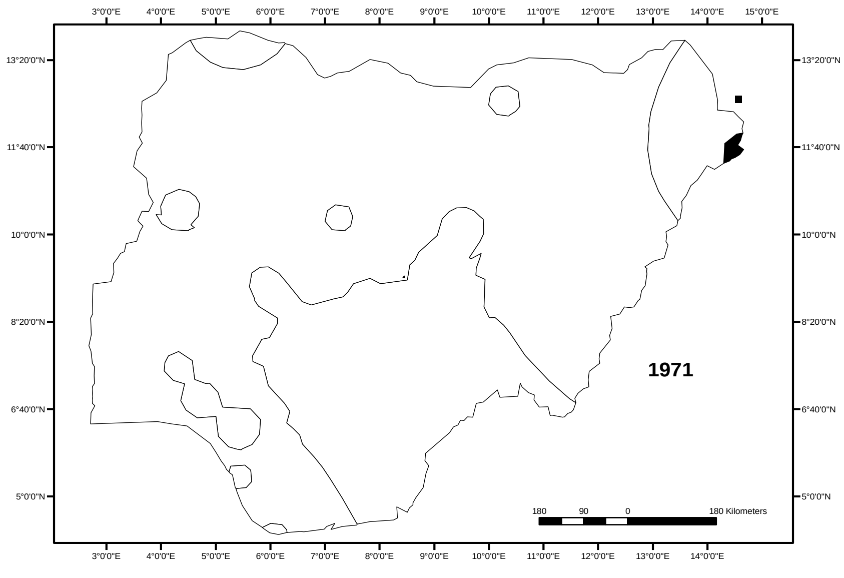
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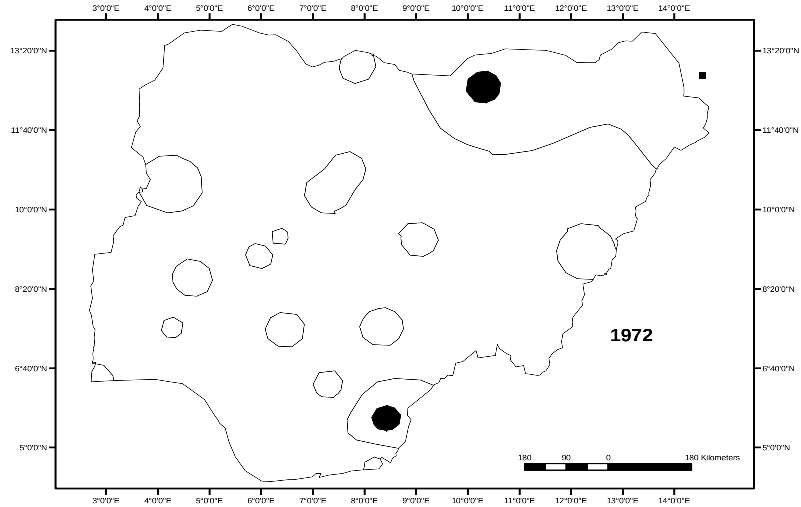
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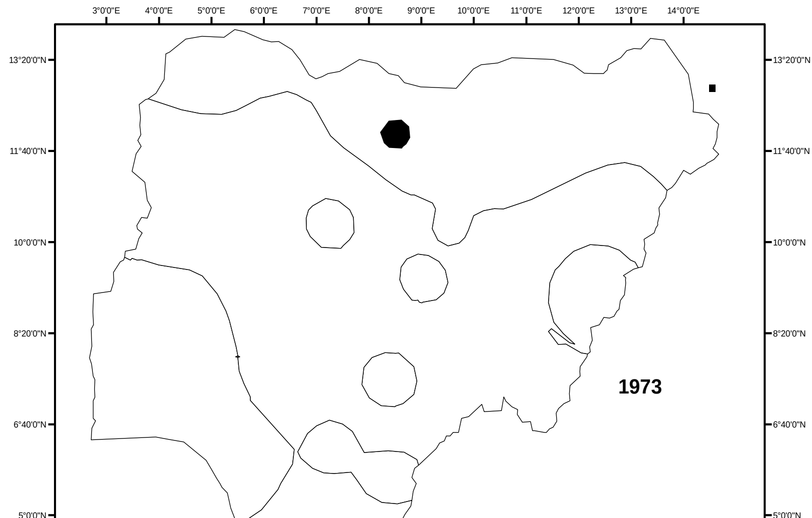
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1973
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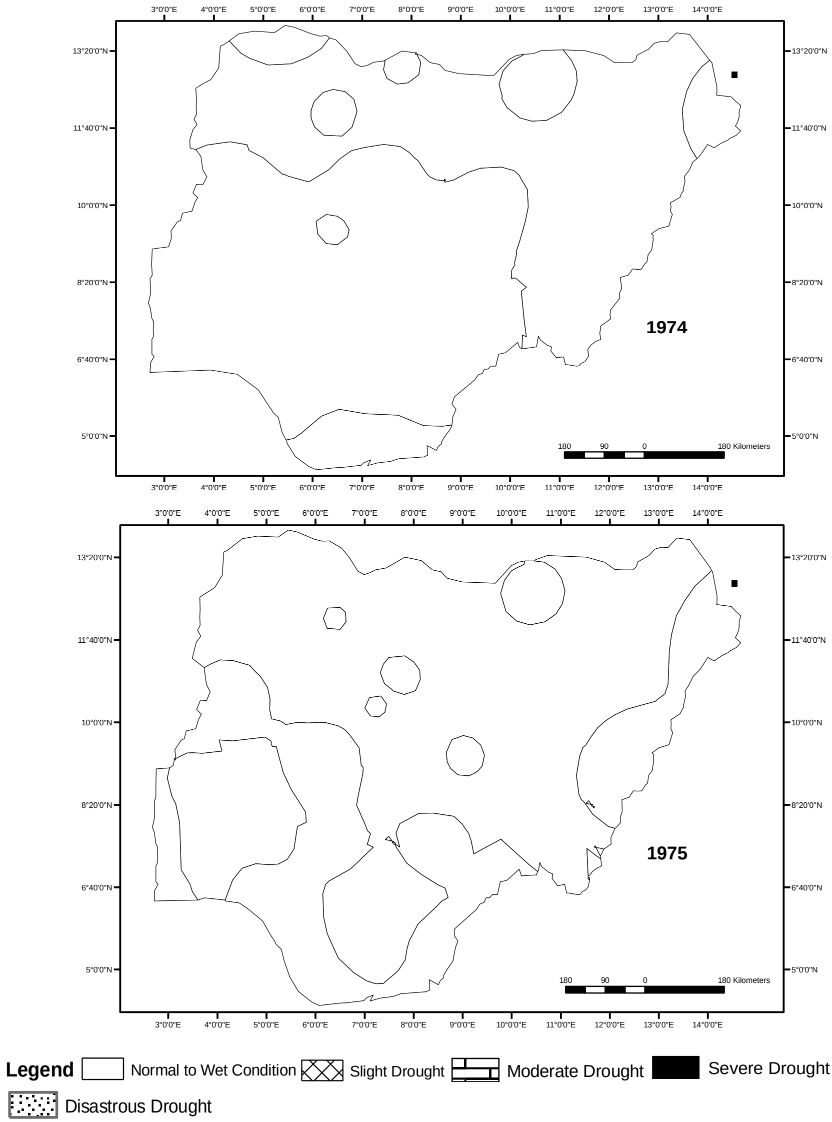
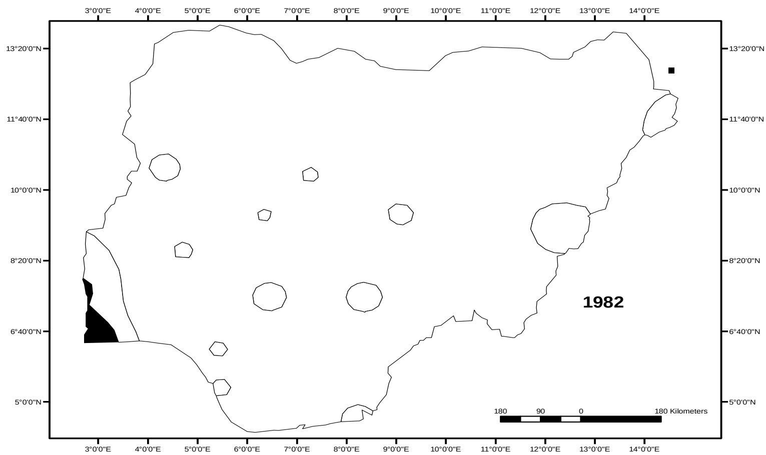


Figure 11. Drought areal variations for some years in Nigeria.

Source: Umar (2013a)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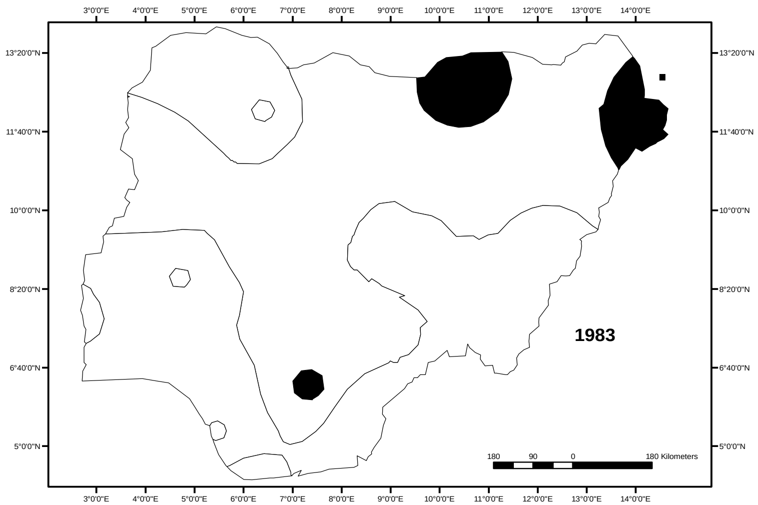
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1983
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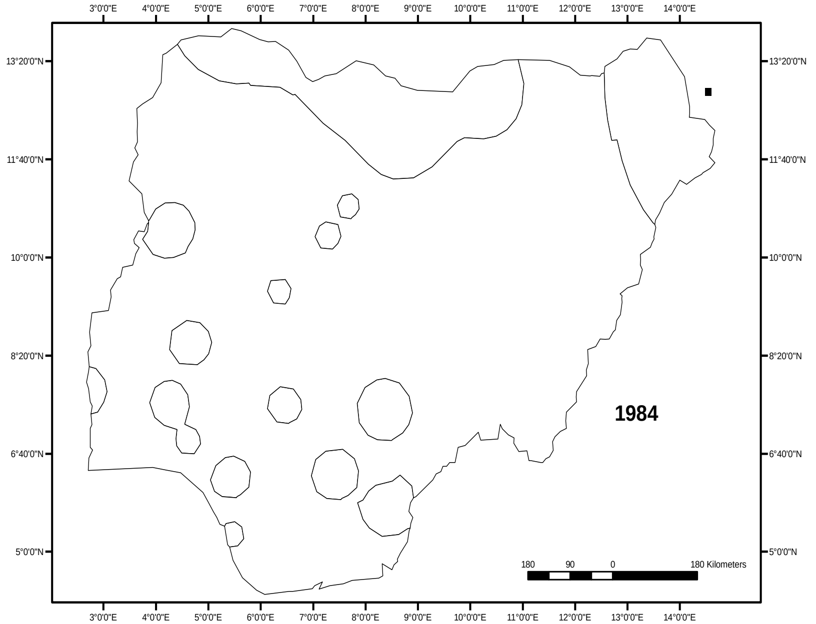
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13°20'0"N
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1984
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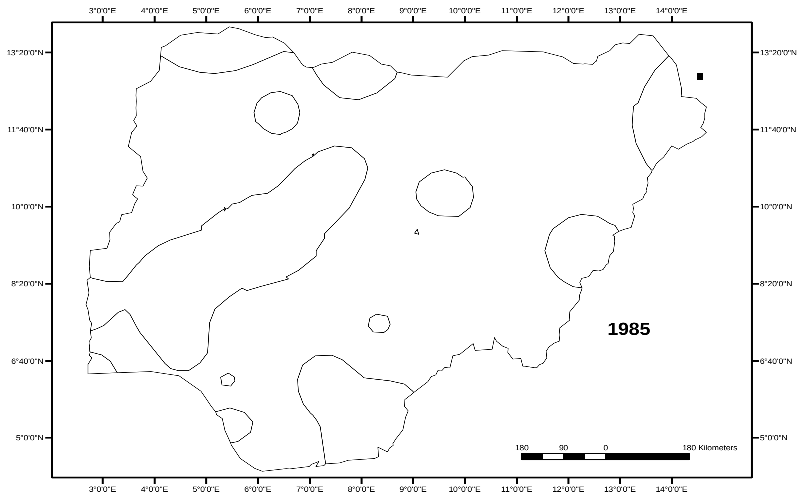
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14°0'0"E
13°20'0"N
11°40'0"N
10°0'0"N
8°20'0"N
6°40'0"N
5°0'0"N
1985
180 90 0 180 Kilometers

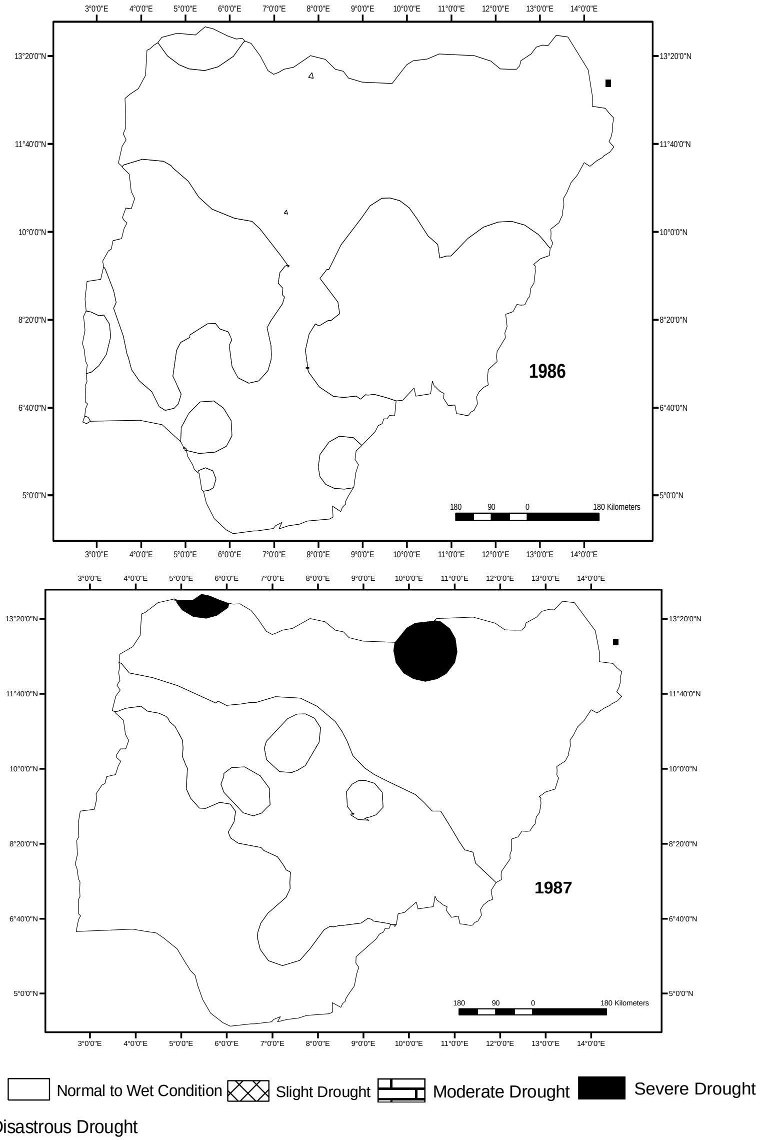


Figure 11. Contd. Source: Umar (2013a)

Drought as a creeping phenomenon occurred sporadically in Nigeria with the north-east, north-west, south-west and small portion of the south-east bearing the brunt of such anomalies (Umar,2013a). The spatial maps of various drought categories suggest a significant change in monthly and annual rainfall amounts in Nigeria which is an indication of the changing climate as further shown in figure 12.

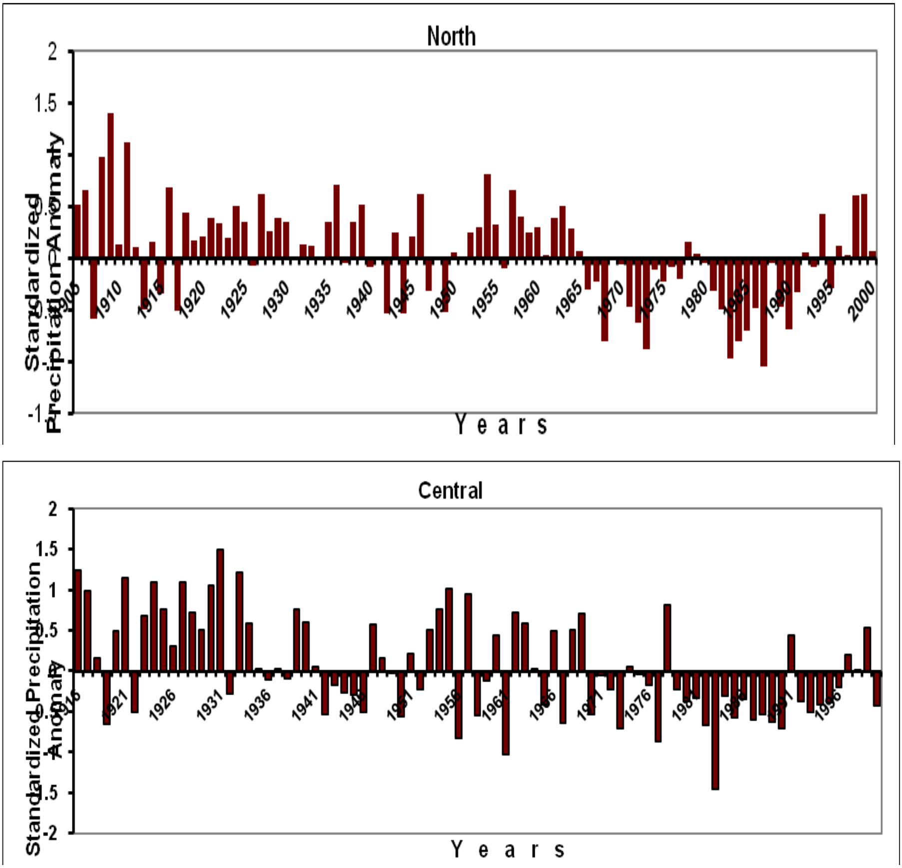


Figure 12. Standardized Precipitation Anomalies for the North, Central, South-West and South-Eastern regions of Nigeria, 1901-2000 (After Umar, 2013a)

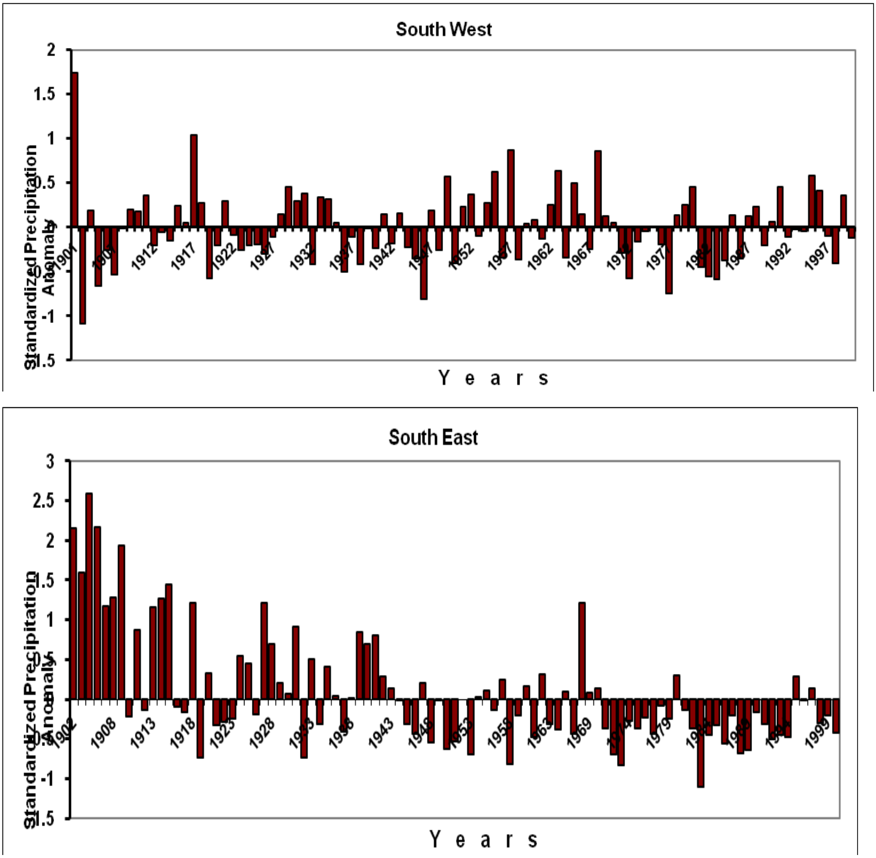


Figure 12. Cont.

In a related study, Umar (2013b) investigated the changing pattern of rainfall and rain days in Nigeria over the period 1903-2012, using the monthly rainfall and rain days records of the synoptic weather stations used in the earlier study (Umar, 2013a). The deviations from the long-term mean of annual rainfall for each station under three different selected periods: 1931-60, 1961-90 and 1991-2012 were derived (see table 11)

Table 11. Mean annual rainfall departures from the long-term mean for three different sub-periods in Nigeria

Station	(1931-1960)	(1961-1990)	(1991-2012)	Long-term mean (mm): 1903-2012
Sokoto	+59	-76	+5	687
Kano	-32	-181	+333	904
Katsina	+107	-59	-90	642
Yelwa	-26	-63	+81	1011
Yola	+31	-51	-28	916
Bauchi	+35	-103	+77	1077
Gusau	Nil	-68	+55	935
Maiduguri	+24	-58	+20	621
Nguru	+99	-40	-31	**468**
Kaduna	+53	-6	-48	1230
Zaria	+33	-87	+92	1082
Minna	-6	-76	-10	1284
Bida	+57	-26	-57	1198
Jos	+77	-46	-65	1342
Lokoja	-104	-15	+72	1202
Makurdi	+110	-89	-55	1287
Ilorin	+36	-47	-38	1241
Lagos	+50	+28	-122	1779
Ibadan	-82	+2	+109	1269
Ondo	+47	+17	+89	1598
Oshogbo	-127	+8	+88	1302
Benin	-82	-34	+253	2127
Warri	+10	-21	+27	2785
Portharcourt	+71	-286	-311	2644
Enugu	+18	-88	-23	1792
Calabar	-23	-157	+76	**2994**
Ikom	Nil	-16	+14	2252

Source: Umar (2013b)

Table 11 revealed that the pattern of annual rainfall amounts in Nigeria changed from positive rainfall anomaly pattern between 1931-60 to negative rainfall anomaly pattern in 1961-90 and to positive rainfall anomaly pattern in 1991-2012 as presented in figure 13, further suggesting a changing climate with most stations having above mean rainfall condition from 1931-60, to below mean rainfall condition in 1961-90 and above mean rainfall condition in 1991-2012 period.

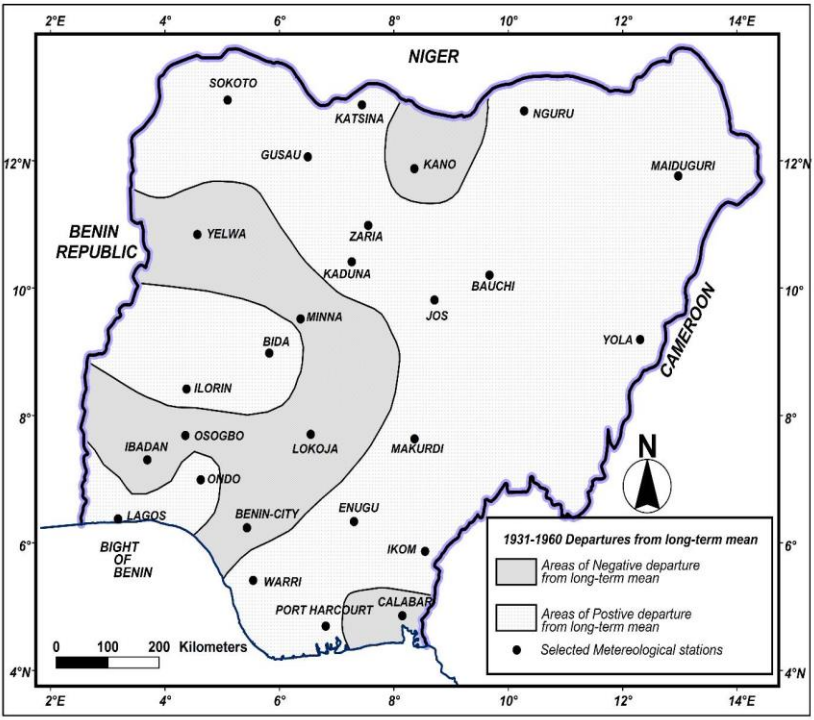


Figure 13a, 1931-1960

Figures 13a-c. Spatial patterns of mean annual rainfall departures from the long-term mean for the 1931-60, 1961-90 and 1991-2012 sub-periods in Nigeria

Source: (Umar,2013b)

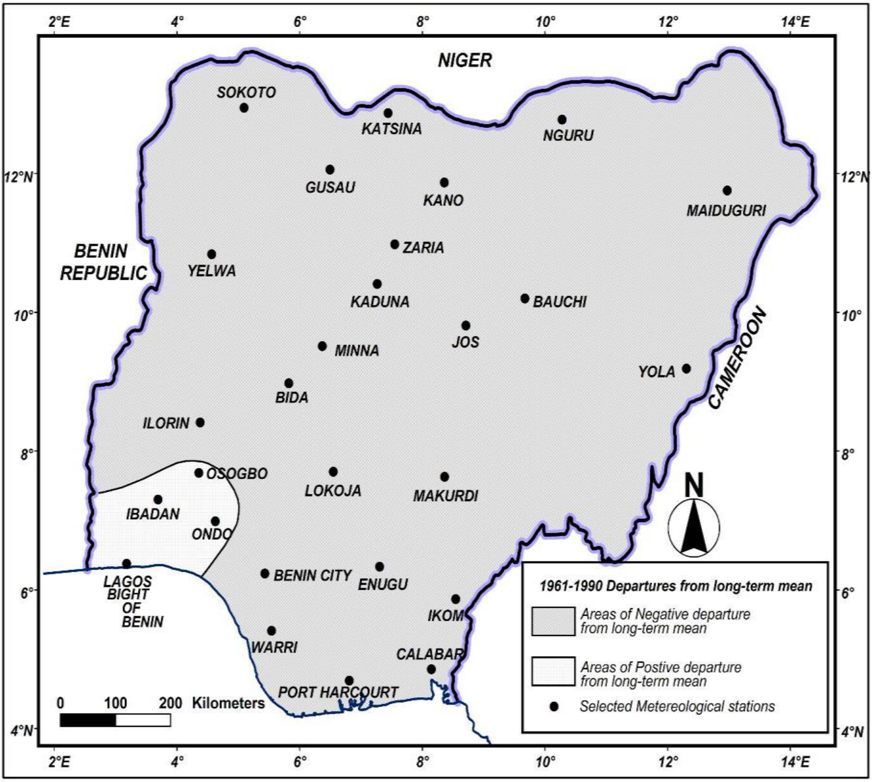


Figure 13b, 1961-1990

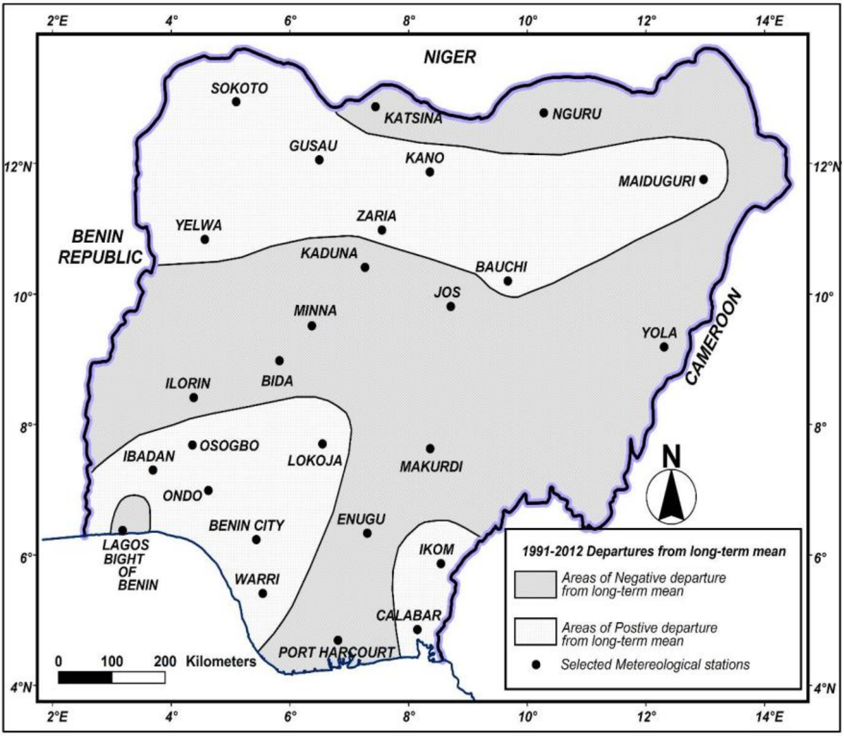


Figure 13c, 1991-2012

Source: Umar (2013b)

The inter-decadal variability in rainfall over Nigeria further revealed that rainfall increased at the rate of 87mm per decade in the south-west, while decreased at the rate of 82mm, 85mm and 960mm per decade in the north, middle-belt and south-east respectively as shown in Table 12.

Table 12. Inter-Decadal variability in rainfall over Nigeria

Decades	Decadal Mean (mm)	Decadal Change (mm)	C. V. (%)	Decadal Mean (mm)	Decadal Change (mm)	C. V. (%)	Decadal Mean (mm)	Decadal Change (mm)	C. V. (%)	Decadal Mean (mm)	Decadal Change (mm)	C. V. (%)
	North			Central/Middle Belt			South-West			South-East		
1903-12	959	-	19.7	-	-	-	1804	-	31.4	3350	-	19.3
1913-22	849	-110	25.3	1323	-	16.4	1884	+80	34.4	2710	-640	23.3
1923-32	869	+20	27.8	1405	+82	16.2	1834	-50	32.9	2705	-5	31.6
1933-42	832	-37	27.8	1296	-109	20.4	1787	-47	31.5	2702	-3	26.0
1943-52	801	-31	30.0	1215	-81	17.9	1792	+5	39.0	2362	-340	21.8
1953-62	885	+84	23.4	1282	+67	18.4	1907	+115	33.0	2407	+45	27.4
1963-72	760	-125	31.3	1250	-32	15.6	1888	-19	35.2	2402	-5	23.9
1973-82	745	-15	30.3	1182	-68	15.6	1755	-133	33.7	2326	-76	20.0
1983-92	660	-85	38.6	1128	-54	17.0	1804	+49	33.9	2171	-155	21.4
1993-2002	849	+189	39.9	1195	+67	16.0	1864	+60	32.8	2355	+184	23.3
2003-2012	877	+28	36.6	1238	+43	24.0	1891	+27	31.2	2390	+35	27.0

Source: (Umar, 2013)

Nigeria, like other West African countries within the Sub-Saharan Africa suffered from devastating climatic anomalies in form of droughts which began in the 1968 and persisted intermittently up to 1990s. However, some of the recent studies on rainfall climatology in the Sudano-Sahelian region of Sub-Saharan Africa suggest that the Sahel has started recovering in its annual rainfall. Nicholson (2005) examined the question of the “recovery” of rains in the West African Sahel, using seasonal and August rainfall time series over the period 1998-2003 for eight zones within latitudes 12^0 N to 20^0 N. The study showed that, in the three zones to the south, seasonal rainfall totals exceeded the long-term means in all years, and the conditions were comparable to or wetter than those during the wet decade of the 1950s. The wettest years were 1998, 1999 and 2003 respectively.

Mr. Vice-Chnacellor Sir, the hypothesis of a recent rainfall recovery was further confirmed by Umar (2012a) in a separate study on rainfall trends in Nigeria using linear regression model. The annual rainfall series for twenty-seven selected synoptic weather stations in Nigeria over the period 1911-2000 revealed a slight recovery in rainfall from the 1998 to the year 2000, even though, the overall trend showed a significant downward trend over the period of the study. The overall downward trend in annual rainfall observed in most of the stations over the period 1911-2000 was due to the tremendous influence of the drought conditions that prevailed in the 1970s and 1980s in the Sudano-Sahelian region of West Africa. However, using a more recent annual rainfall records for Sokoto basin over the period 1970-2020 as presented in Figure 14 showed a general upward trend in annual rainfall over the region. This could be attributed to the recent wet years being experienced in the region from the year 2000 to date as evidenced from some of the catastrophic floods recorded in the region especially in 2010, 2012 and 2020. Some of the high impacts of extreme rainfall events in the basin over the last fifteen years are summarized in Table 13.

The apparent rainfall recovery in the Sudano-Sahelian region as a whole from 1998 to date signals an indication that the climate is changing and resulting in another form of anomalies (flood disasters). Several cases of floods with different spatial coverage and intensity in Nigeria since the year 2000 have been reported in the literature (Umar, *et al*, 2015). Table 13 provides a summary of some of the high impact weather events in the Sokoto Basin. From Table 13, it is obvious that the Sokoto basin is not spared in terms of the effects of climatic variability and change. Some of the factors that can make the societies vulnerable to flood disasters include natural and man-made factors. The natural factors may include heavy downpour, collapse of dams etc. The man-made factors that mostly contribute to the problem of flooding in the Sokoto basin include poor drainage, indiscriminate dumping of refuse in water ways, poor sanitation, reclaiming of the water ways, poor urban and regional planning etc.

Table 13: High Impact Weather Events in the Sokoto Basin

S/NO	INCIDENT	STATE/AREA OF OCCURRENCE	DATE OF OCCURRENCE	DETAILS
1.	Rainfall (Fluvial Flood/Sokoto and Rima River)	Sokoto	5th September,2007	500 people rendered homeless
2.	Rainfall (Fluvial Flood/Zamfara river)	Zamfara	5th October, 2006	Farmlands, roads, houses and culverts were washed away.
3.	Rainfall (Fluvial Flood/Sokoto river)	Kebbi	28th August, 2007	3000 people rendered homeless; 300 houses submerged (Dakingari village worst affected)
4.	Rainfall (Flood)	Sokoto	9th September, 2010	About seven local governments that are along the River Rima were devasted by flood. This includes Wurno, Goronyo, Rabah, Sokoto North, Sokoto South, Wamakko and Sabon Birni. Many houses, farmlands and agricultural produce were washed away by flood waters. The main course-way linking UDUS to town was also cut-off and the immediate shut down of the University for about three months

5.	Rainfall (Flood)	Sokoto	30th May,2020	Sokoto witnessed heavy downpour with gusty winds which destroyed properties such as shops, houses, roofing and educational facilities such as lecture halls in some tertiary institutions within the state
6.	Rainfall 1(Flooding)	Sokoto	9th August, 2020	It destroyed properties in some local governments in the state. Five people killed, thousands of farm lands destroyed in Goronya local government area of the state. Several livestock and crops were lost due to the flood. 200 houses were destroyed inn Rimawa town, houses and farmlands destroyed at Katsira, Kagara, Gorau, Birjingo, Sahinaka and part of Sabon Garin Dole. Other places affected by the flood were Tulaske, Kwakwza, Illela Huda, Danwaru and other riverine communities.
7.	Rainfall (Flooding)	Kebbi	28th August, 2020	Flood washed away five bridges located in different parts of the state. The incident cut-off many communities from the state capital
8.	Rainfall (Flooding)	Kebbi	9th September, 2020	The Nigerian Correctional Service Centre buildings and farmlands were

				submerged by flood in Bagudo local government area of kebbi state. The flood affected 22 local government areas in the state
9	Rainfall (Flooding)	Kebbi	12th September, 2020	32 people killed, hundreds of houses submerged and thousands of residents displaced.
10	Rainfall (Flooding)	Zamfara	July to October 2022	3,845 people affected, 14,628 ha of farmland destroyed, 7,656 houses partially damaged while 2,107 houses were totally damaged
	Rainfall (Flooding)	Sokoto	August 2022	250 houses and food destroyed in Tangaza local government area .
11	Rainfall (Flooding)	Kebbi	August 2022	A ravaging flash flood has destroyed no fewer than 1000 houses in at least six local government areas in Kebbi State. The affected local councils' areas are Birnin Kebbi, Jega, Shanga, Koko/Besse, Ngaski and Arewa.

Source: Bako and Umar (2023)

Figure 14 shows the annual rainfall pattern in Sokoto basin while Figure 15 shows standardized annual rainfall anomalies for the Sokoto basin. It is evidently clear from Figures 14 and 15 that annual rainfall pattern in the area is highly variable and the region also suffered from the catastrophic droughts of the 1970s and 1980s that ravaged the West African sub-region over the period 1970-1980. The region recorded several years of rainfall failures such as 1972-73, 1982-83, and 1987 as widely reported in the literature (Nicholson, 2005).

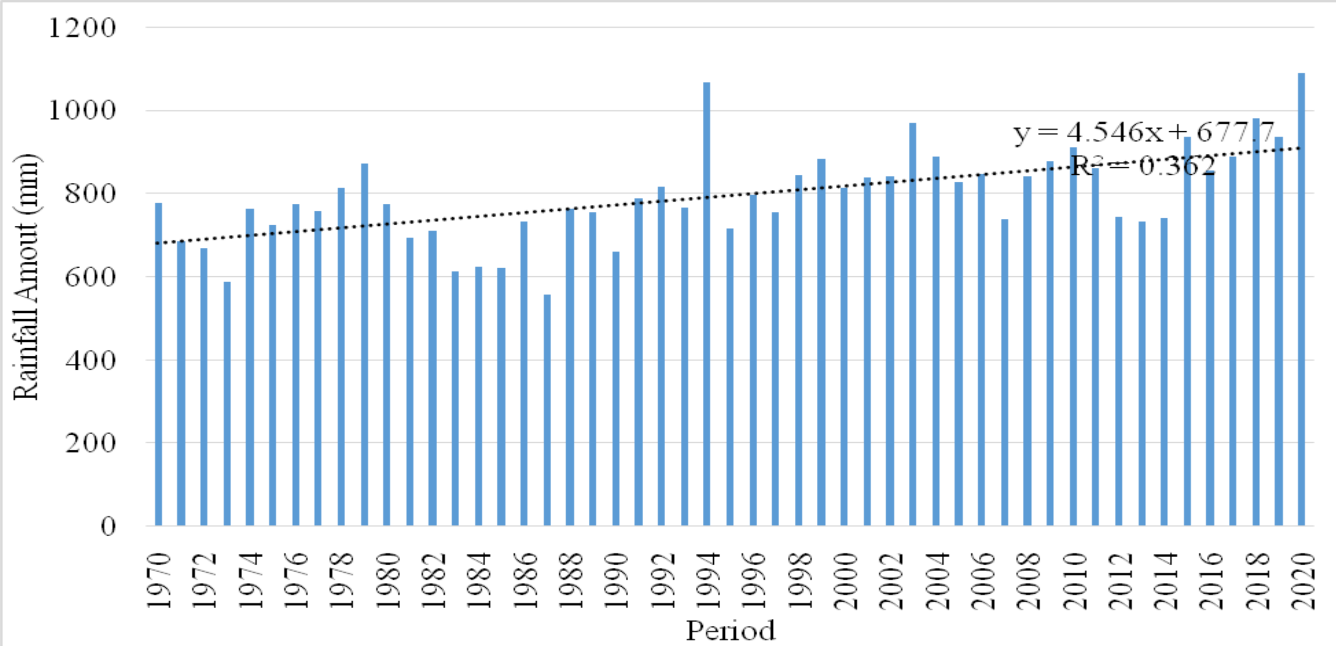


Figure 14 Total Rainfall of Sokoto Basin (1970-2020)

Source: Bako and Umar (2023)

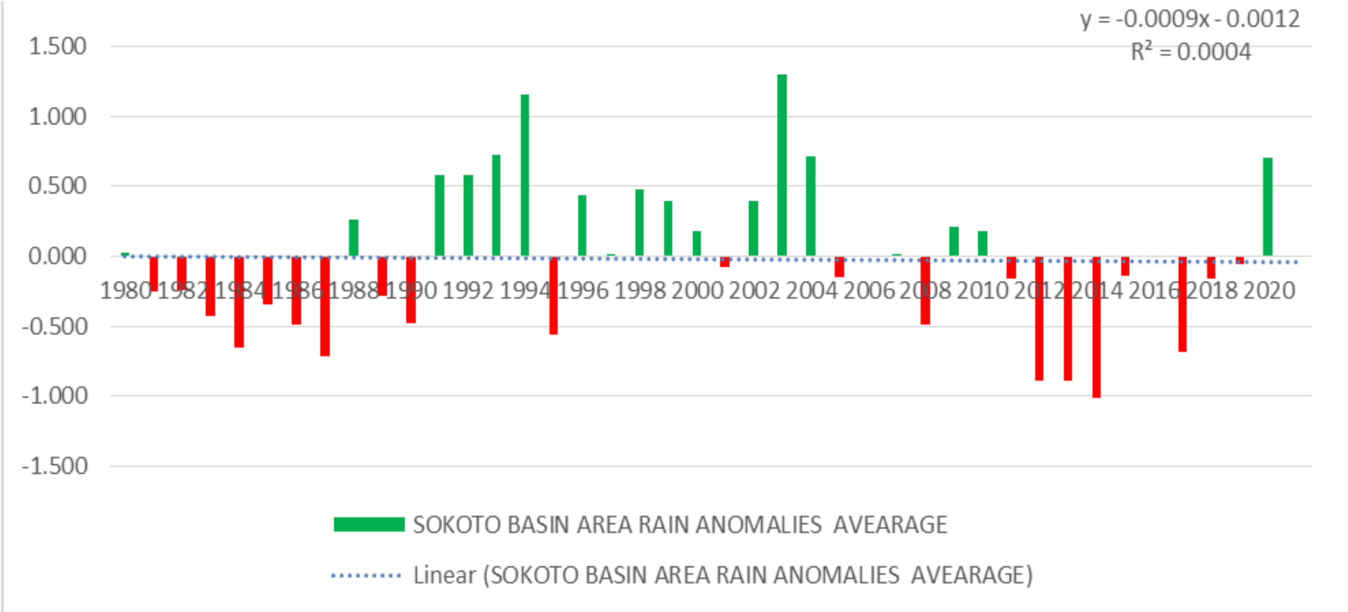


Figure 15. Annual rainfall anomalies for the Sokoto basin (1970-2020)

Source: Bako and Umar (2023)

The Nigeria Hydrological Services Agency (NIHSA), following the unveiling of the 2023 Seasonal Climatic Prediction (SCP) by Nigerian Meteorological Agency (NiMet), released the 2023 Annual Flood Outlook and cautioned that many local government areas including those within the Sokoto basin would be devastated by flood in the course of the 2023 rainy season (see Table 14).

Table 14: Flood risks local government areas within the Sokoto Basin.

	Highly Probable Flood Risk LGAs			Probable Flood Risk LGAs		
State	April/June	Jul/Sep	Oct/Nov	April/June	Jul/Sep	Oct/Nov
Katsina	Nil	Nil	Nil	Nil	Bakoro, Batsari, Kaita, Kurfi	Jibia
Kebbi	Bagudo	Bagudo, B/Kebbi	Nil	Suru, wasagu, Danko, Fakai, Ngaski, Yauri	Suru, Koko/Besse, Augie, Dandi, Ngaski, Kalgo, Bunza, Yauri	Bunza, Yauri
Niger	Bargu	Bargu	Nil	Agwara	Agwara	Agwara
Sokoto	Nil	Goronyo, Sabon Birni, Isa, Shagari	Nil	Nil	Nil	Goromyo, Bodinga, Sokoto North, Sokoto south, Silame, Shagari, Yabo, Dange Shuni, Kware, Wamakko
Zamfara	Nil	Zurmi	Nil	Nil	Nil	Anka, Bakura, Maradun, Bungudu, Talata Mafara, Shinkafi, Zurmi

Source: NIHSA, 2023

A slight recovery in annual rainfall in Nigeria was believed to have started in 1998 and ever since, the annual rainfall amounts at individual locations in Nigeria including those within the Sokoto basin, has been on the increase as further demonstrated by Umar and Bako (2019) using monthly rainfall records of five selected synoptic weather stations located within the Sudano-Sahelian region of Nigeria over the period 1986-2015. The location of these stations is presented in Figure16 .

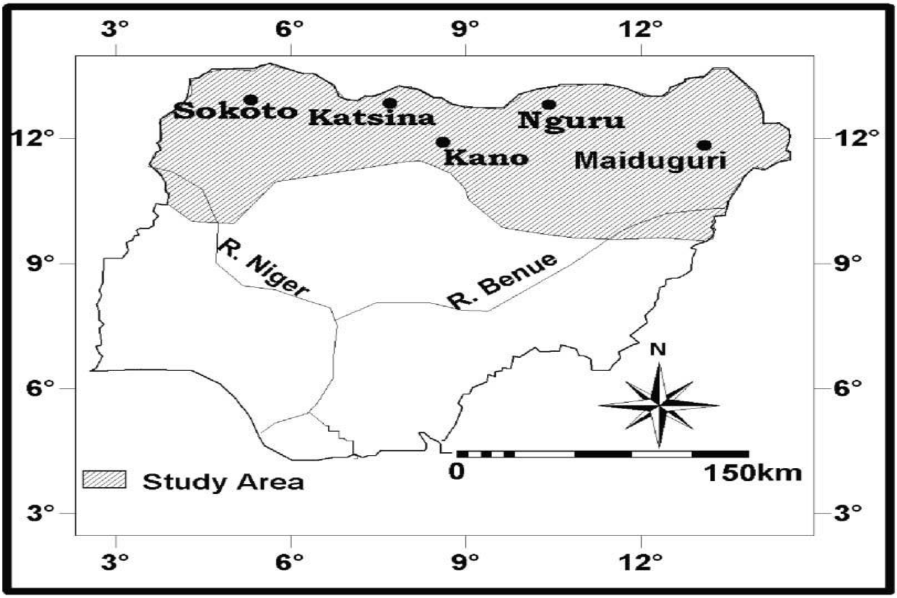


Figure 16. *Generalized map showing the areal entent of the Sudano-Sahelian region of Nigeria* (After Odekunle *et al*, 2008)

The recent trends and variability in rainfall over the region showed a significant upward trend in annual regional rainfall composite of the region with similar patterns in annual rainfall series at all selected stations except Sokoto. The patterns of annual rainfall trend at individual stations did not reflect the patterns in their individual months as presented in figure 17.

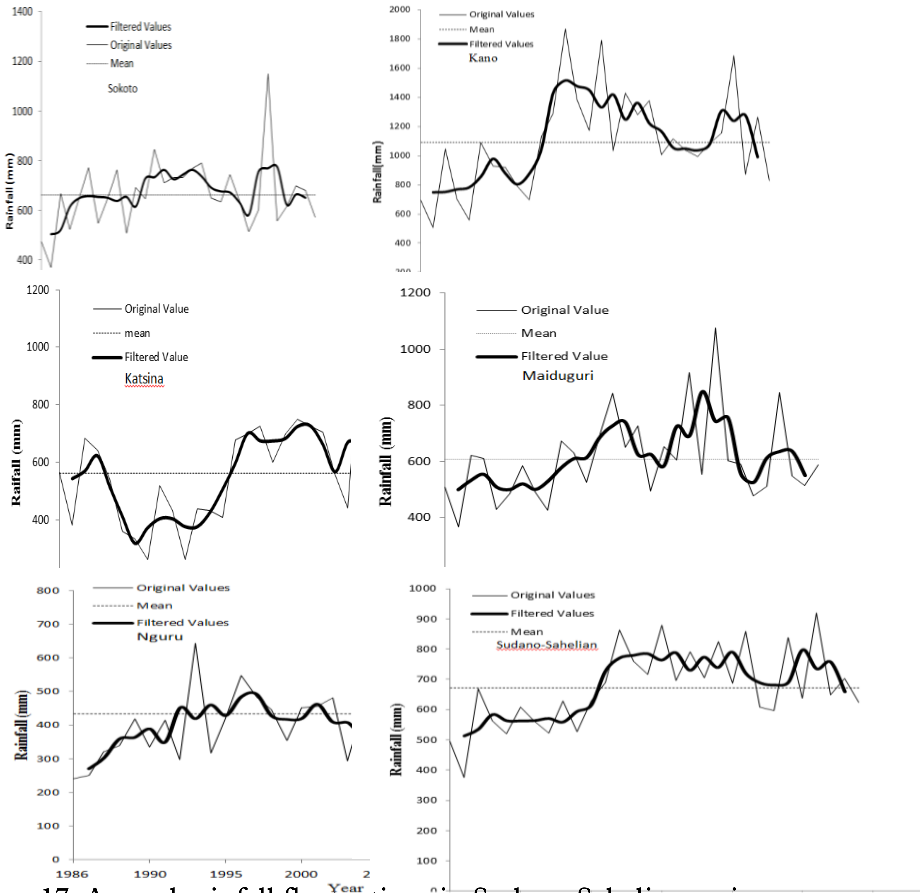


Figure 17. Annual rainfall fluctuations in Sudano-Sahelian region (1986-2015).
Source: Umar and Bako (2019)

Mr. Vice-Chancellor Sir, the patterns of the mean monthly rainfall distribution presented in Figure 18 suggests that, the major rain-producing systems – the thunderstorms and line squalls, for Sahelian stations located between latitude 12^0 N – 14^0N had single maxima with the month of August being the peak of their occurrences, which could explain the consistency in the occurrence of '*single rainfall maxima*' with the month of August being the rainiest month at each of the stations and for the entire Sahelian region of Nigeria. It is interesting to note that, that was the period when the Inter-tropical Discontinuity (ITD) also attained its northernmost position around latitude 22^0 N, and the whole country comes under the influence of rain-bearing south-westerly air mass as extensively discussed by (Ayoade,1983; Omotosho, 1985).

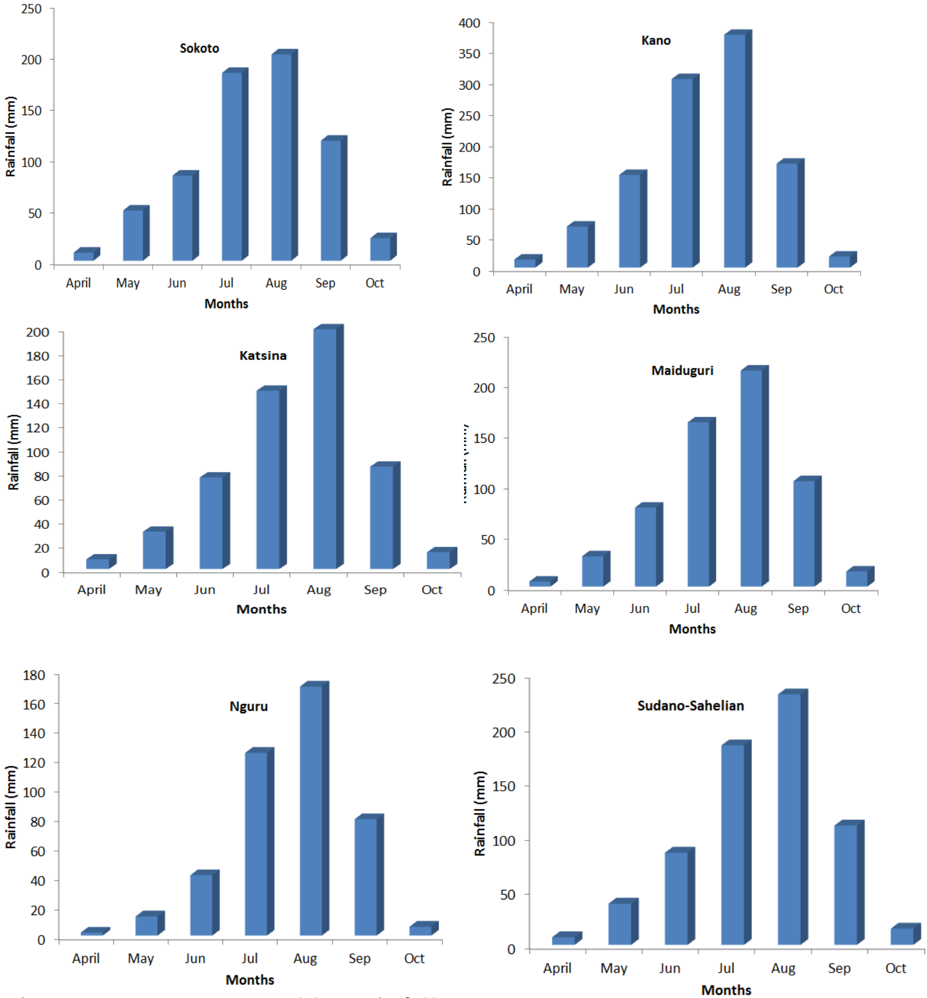


Figure 18: Mean monthly rainfall distribution patterns for selected stations and entire Sudano-Sahelian Region (1986-2015).

Source: Umar and Bako (2019

Umar, *et al*, (2015) examined the changing frequency of extreme daily rainfall events and its implications for flood occurrence in northern Nigeria using daily rainfall data from nine selected synoptic weather stations in northern Nigeria over the period 1971-2010. The highest daily rainfall amounts ever recorded for each year and each of the stations were extracted from the daily rainfall registers for each station over the period 1971-2010. Figure 19 shows the distribution of the selected stations in northern Nigeria.

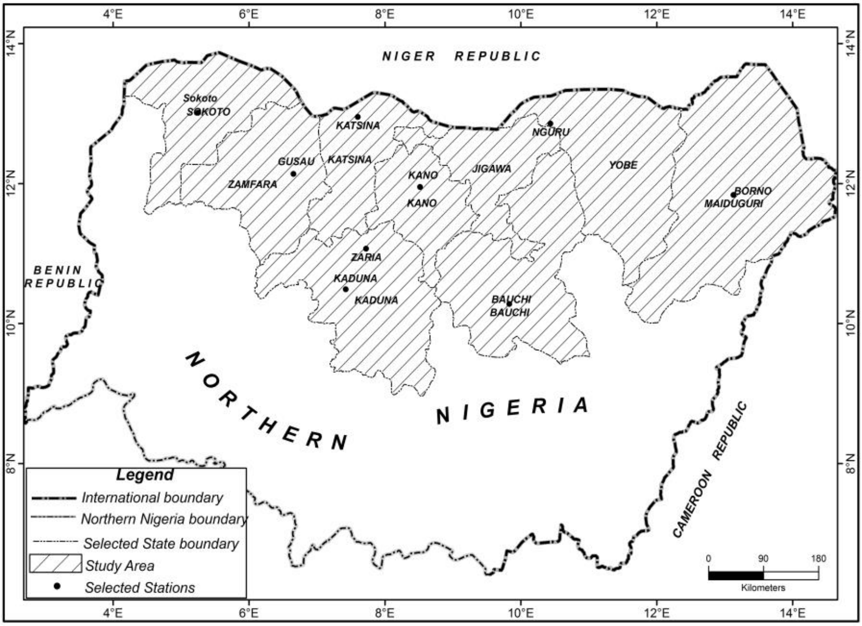


Figure 19. Distribution of selected stations

Umar *et al* (2015)

Mr. Vice-Chancellor Sir, the return periods of the highest daily rainfall events for each year and each of the stations over a period 1971-2010 were also computed via the Gumbel's Extreme Value technique. The return period is defined as the average interval in years in which a flood or precipitation of a given size will recur as an annual maximum. The return period was calculated using the formula:

$$T = n + 1/m$$

Where T is the recurrence interval in years, n is the number of observations in the series and m is the rank of a particular observation. The probability of an event occurring within its stated return period was calculated using the formula:

$$Pt = 1 - \left(1 - \frac{1}{T}\right)T$$

Where P_T is the probability of an event occurring, T is the return period in years. The study showed that the highest daily rainfall amounts ever recorded for each station over a period 1971-2010 were 145.2mm, 132.1mm, 106.5mm, 128.0mm, 163.8mm, 102.5mm, 139.8mm, 182.9mm and 156.0mm for Bauchi, Kaduna, Zaria, Maiduguri, Kano, Nguru, Sokoto, Gusau and Katsina respectively and with a return period of 41years each. The percentage probability of recurrence of such events within the stated return period of 41 years is 63.6%. Figure 20 shows a generalized map showing the month in which the highest daily rainfall amounts ever recorded occurred at the selected stations in northern Nigeria.

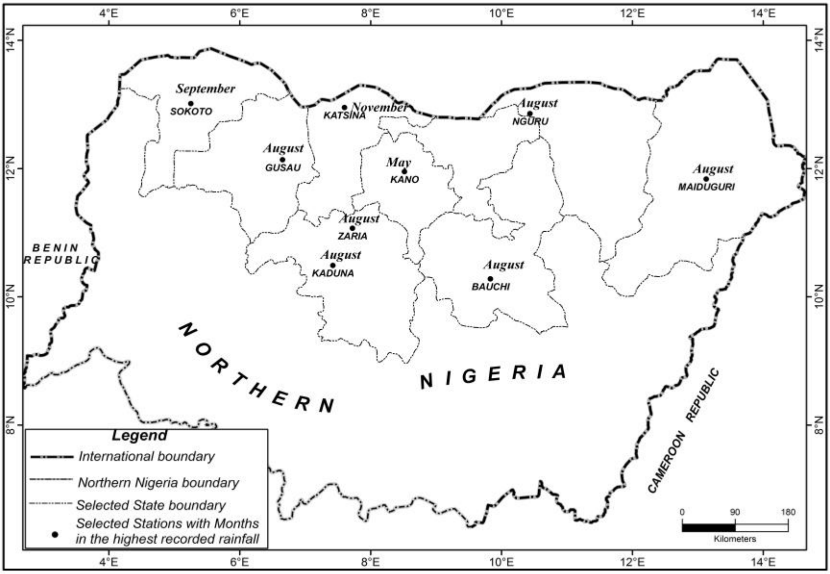


Figure 20. Generalized map showing the month in which the highest daily rainfall occurs at selected stations in northern Nigeria. Umar *et al* (2015)

Mr. Vice-Chancellor Sir, seasonal floods in northern Nigeria could be induced by an occurrence of the highest daily storm in a given year when preceded by soil moisture surplus. The flood events of 1994, 1997/98, 2003, 2005/06 and 2010 coincided with years of the highest return periods which are associated with maximum daily rainfall events in the region. The study further showed that the month of August still remained the peak of rainfall activity in Sudano-Sahelian region of Nigeria. The recent flood events in the region could be attributed in part to climatic phenomenon of La-Nina (a Cold-Phase) of El-Nino-Southern Oscillation (ENSO) which is characterized by abnormally high rainfall events. Olaniran (1981) examined the flood generating mechanisms using daily rainfall data from

Ilorin synoptic weather station over the period 1971-1980 and showed that heavy rains greater than 25.4mm/day could induce floods when they occur in a month about three or more times during the period of moisture surplus.

Mr. Vice-Chancellor Sir, in as much as we hope and pray for none occurrence of flood disasters such as that of 9th September, 2010 that ravaged Sokoto region and forced our great University to temporarily shut down academic activities because of the large volume of flood water that washed away of one of the culverts that linked the University with the township, the Sokoto region should be more prepared for more devastating seasonal floods in the future if the Gumbel's Extreme Value analysis is anything to go by. For example, the highest daily rain storm ever recorded at Sokoto synoptic weather station over the 40-year period (1971-2010) was 139.4mm which was recorded on 6th September, 1998 while the mean daily rainfall over the same period was 67mm (see Table 15).

Table 15. Highest daily rainfall amounts ever recorded at Sokoto synoptic weather station (1971-2010)

Year	Highest Amount (mm)	Date of Occurrence	Year	Highest Amount	Date of Occurrence
1971	47.2	19/07	1991	67.5	25/05
1972	40.6	02/08	1992	62.0	14/09
1973	37.6	10/07	1993	55.6	08/08
1974	33.7	18/08	1994	73.9	05/08
1975	38.4	23/08	1995	58.7	21/07
1976	76.7	23/07	1996	85.5	26/06
1977	76.1	02/08	1997	52.9	17/08
1978	74.3	26/07	**1998**	**139.4**	**06/09**
1979	78.2	17/08	1999	41.4	10/08
1980	65.5	28/06	**2000**	**102.7**	**04/07**
1981	52.8	06/07	**2001**	**118.8**	**20/07**
1982	49.0	23/07	2002	60.5	10/07
1983	73.7	16/06	2003	53.2	12/07
1984	75.6	14/08	2004	57.2	27/08
1985	46.7	17/06	2005	73.3	08/05
1986	81.7	27/07	2006	75.8	09/09
1987	40.2	26/08	2007	60.7	04/08
1988	58.5	23/07	**2008**	**116.7**	**18/07**
1989	38.6	20/06	2009	91.8	20/10
1990	51.1	01/07	**2010**	**94.4**	**07/07**

Source: Umar, et al (2015)

In the year 2010, the highest daily rainfall amounts recorded at Sokoto synoptic weather station was 94.4mm which occurred on 7th July, 2010 (see table 15) and triggered the flood disaster of 9th September, 2010 coupled with other environmental factors such as Goranyo dam factor. The sudden opening of the spill ways of the Goronyo dam on 9th Semptember,2010 to avert the possible break down of the dam due to large volume of water from heavy downpour recorded in the preceding months of July and August was responsible for the 9th September, 2010 flood disaster in Sokoto Rima River Basin. An increase in the frequency and intensity of extreme daily rainfall events in the last two decades as demonstrated in Umar *et al's* (2015) study is a further evidence of the changing climate in Nigeria.

Mr. Vice-Chancellor Sir, apart from the information on the return periods of extreme rainfall amounts and probability of occurrence of such extreme rainfall events within their stated return periods, the information on the probable maximum precipitation (PMP) is also critical in understanding the possible changes in the climate system. The Probable Maximum Precipitation (PMP) is defined *as the theoretical highest precipitation amount which is physically possible over a locality for given duration*. Umar, *et al*., (2015) also computed the PMP values for each of the selected nine synoptic weather stations using the Chow's general frequency formula given as :

$$PMP = \bar{y} + 15\delta$$

Where *PMB* is the probable maximum precipitation, y is the mean of the series and δ is the standard deviation of the series.

The spatial pattern of the PMP values is presented in Figure 21. It could be observed that the values of the PMP vary among the stations with Gusau having the highest value of 451mm, and therefore more wetter than the other stations. Nguru had the least value of 346mm and therefore more drier than the others (see Figure 21).

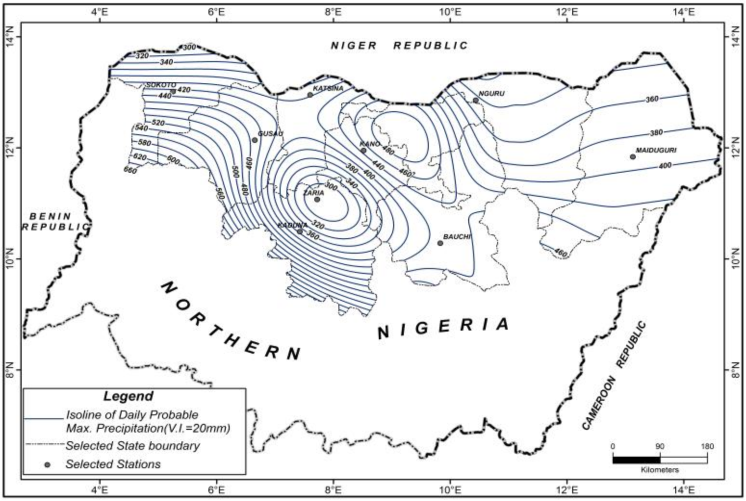


Figure 21. Probable Maximum Precipitation (PMP) for the selected station in northern Nigeria (1971-2010). Source: Umar *et al* (2015)

Mr. Vice-Chancellor Sir, In most cases, floods are associated with either abnormally high daily rainfall events or annual rainfall events. The flood risks can also be evaluated using information on probability of receiving more than the highest annual rainfall amounts ever recorded over a period of time in a given location. Using the annual rainfall data of 27 synoptic weather stations with varying lengths of records over the period 1901-2000, Umar (2012) estimates the probability of receiving more than the highest annual rainfall amounts ever recorded at individual stations in Nigeria using the Z-Score criterion. The procedure followed involves computation of the Z-Score (Z) using the formula:

$$Z = \frac{Xc - \overline{X}}{\sigma}$$

Where Xc is the critical rainfall amount (hereafter referred to as the highest annual rainfall amount) ever recorded. The X and σ are the mean and standard deviation respectively. Z-score indicates the extent to which the critical value differs from the mean in terms of 'so many' standard deviations. A guiding principle is that the mean has a 50% probability of being received in a given year. So, any rainfall amount higher than the mean will have lower probability of occurrence and vice-versa (Ayoade, 2008).

The probability of receiving more than the highest annual rainfall at each station in Nigeria was estimated and spatially mapped to further show areas with high risk of floods in Nigeria (see Figure 22).

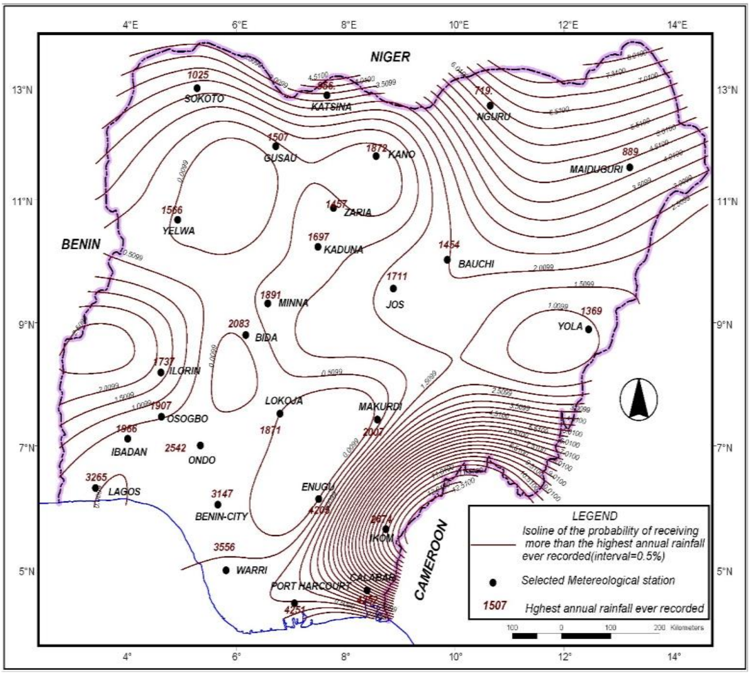


Figure 22: Spatial pattern of the probability of receiving more than the highest annual rainfall ever recorded at individual stations in Nigeria, 1901-2000.

Source: (Umar,2012b)

Mr. Vice-Chancellor Sir, it can be deduced from Figure 22 that Ikom, a southern station, records the highest probability (9.01%) of receiving more than the highest annual rainfall of 2674mm over the period 1972-2000. This suggests that Ikom stands the risk of flood than any other station in the country and that the risk of floods in the country tends to be localized rather than the large-scale pattern which is often associated with drought as also reported by Oladipo (1993).

Changes in Seasonal Rainfall Regime

Mr. Vice-Chancellor Sir, seasonal rainfall regime refers to the pattern of the rainfall distribution during the rainy season. The rainfall seasonality index gives an idea on the concentration of rainfall within certain months of the wet season. Walsh and Lawler's (1981) developed a rainfall seasonality index (SI) with the following classification scheme (table 16). The rainfall seasonality index (SI) was computed for Sokoto using the Walsh and Lawler's index given as:

$$SI = \frac{1}{R} \sum_{n=1}^{n=12} \left| Xn - R/12 \right|$$

Where $Xn =$ mean rainfall of the month n and $R =$ mean annual rainfall

Table 16. Classification of Rainfall Regimes According to Walsh and Lawler (1981).

SI class limits	Rainfall regime
≤ 0.91	Very equable
0.20 – 0.39	Equable but a definite wetter season
0.40 – 0.59	Seasonal
0.60 – 0.79	Markedly seasonal with a long dry season
0.80 – 0.99	Most rains in 3 months or less
1.00 – 1.19	Extreme, almost all rain in 1-2 months
≥ 1. 20	

Mr. Vice-Chancellor Sir, the computed rainfall seasonality index (SI) values for Sokoto using a monthly rainfall data over a period 1926-2015,under three different slices (30-year) intervals (Umar and Ismail,2017) revealed a shift of the Sokoto rainfall seasonality index from the SI value of 1.10 for stations in north-western part of Nigeria obtained by Olaniran (1982) using only a 10-year rainfall records (1969-1978) and thus describing the rainfall regime as the one with '*Extreme, almost all rain in 1-2 months*', Umar and Ismail (2017) however obtained the SI values of 0.95, 0.97

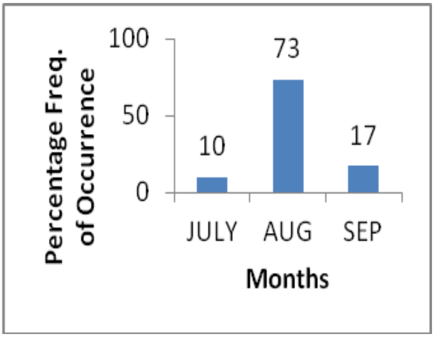
and 0.97 for 1926-1955, 1956-1985 and 1986-2015 periods respectively and thus described the rainfall regime of Sokoto as being *'Most rains in 3 months or less'* (see Table 17) and Figure 22. The difference between Olaniran's(1982) result and those obtained by Umar and Ismail (2017) stemmed from the variations in the length of rainfall records. The former study used the rainfall data spanning 1969-1978 which coincided with the catastrophic drought of the 1970s while the latter used data covering both drought and wet periods in the region.

Olaniran (1982) also obtained the ratio of SI/SIi value of 0.94 for stations in north-western Nigeria while Umar and Ismaila (2017) obtained the ratio of 0.96, 0.97, and 0.97 for 1926-1955, 1956-1985 and 1986-2015 periods respectively, having the same interpretation with Olaniran's. The ratio of the SI/SIi is the index of replicability of the mean rainfall regime. When the SI/SIi ratio is higher, the month of maximum rainfall occurs in a small spread of months (see Table 17 and Figure 22), and then the replicability of the mean rainfall regime is higher.

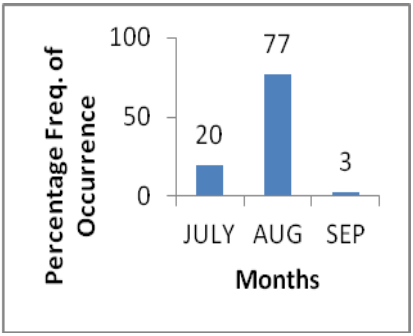
Table 17. Rainfall Seasonality Index for Sokoto

Station	Period of Record	Mean Annual Rainfall (mm)	SI	SIi	SI/SIi
Sokoto					
	1926-1955	719	0.95	0.99	0.96
Sokoto	1956-1985	648	0.97	1.0	0.97
Sokoto	1986-2015	663	0.97	1.0	0.97

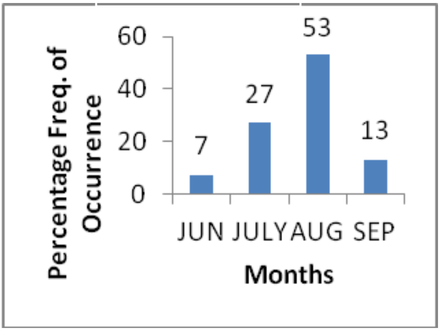
Source: Umar and Ismaila (2017)



(1926-1955)



(1956-1985)



(1986-2015)

Figure 22. Percentage frequency of occurrence of maximum monthly rainfall totals at Sokoto.
Source: Umar and Ismaila (2017).

Variations in the Onset and Cessation dates of the Rain, Length of the Rainy Season/Growing Period and Dry Spell Occurrences

Mr. Vice-Chancellor Sir, variations in the dates of onset and cessation of rain as well as length of the rainy season or growing period and dry spells are some of the major concerns of not only farmers but also agrometeorologists and agroclimatologists. Several cases of crop failure and replanting have been reported by farmers in different agro-ecological zones of Nigeria due to false onset of the rain and lack of information on the expected onset and cessation dates of the rain, expected rainfall amount, expected length of the rainy season and expected duration of the dry spells before the commencement of a rainy season (NiMet, 2010). Several definitions of the onset, cessation, growing period and dry spells and methods of their derivations have been suggested in the literature (see Oladipo, *et al*., 2000; Bello, 1996; Salack, *et al*., 2011).

Onset date of the rain refers to the actual date of the commencement of the effective rainfall for a particular rainy season. This is the period when the rain-producing systems become established in a given location and rainfall is expected to spread throughout the duration of the rainy season. Most farmers assumed that the first rain in a year signals the beginning of the rainy season, which is not the case. The cessation date of the rain refers to the actual date when no effective rainfall could be received again in a given location. The interval between the onset and cessation dates of the rain represents the length of the rainy season/growing period. The growing period *refers to the period during which rainfall distribution is sufficient to meet the crop water requirement throughout its phenological stages*. A dry spell is defined *as the sequence of days without rain to be followed and preceded by the sequence of days with a rain*. (Walter, 1967; Beniot, 1977; Omotosho, 2000; Odekunle, 2004; Salack, et la., 2011).

Mr. Vice-Chancellor Sir, a reliable prediction of rainfall onset and cessation times and thus the length of the growing season will greatly assist on-time preparation of farmlands, mobilization of seeds/crops, man power and equipment and will also reduce the risk involved in planting too early or too late (Benoit 1977; Fasheun 1983; Olaniran, 1983, 1984; Omotosho et al, 2000). The dates of onset and cessation of rain, length of rainy season and duration of dry spells can all be predicted through climatic prediction models or through statistical methods. Umar (2010) computed the onset and cessation dates of rain and length of the rainy season/growing period for each year and for all the nineteen selected synoptic weather stations in northern Nigeria over the period 1978-2007 using the Walter's technique. The first essential step of this method is to derive the accumulated monthly rainfall of a given magnitude, which is used to define the onset and cessation of the rains. Walter (1967) for instance, defined the onset of the rains in Nigeria in terms of time of receiving an accumulated amount of rainfall in excess of 51mm. The actual date of the onset of the rain according to Walter (1967) is as follows:

$$\text{Days in month} \left\{ x \, \frac{\text{1-Accumulated rainfall in the previous month}}{\text{Total rainfall for the month}} \right\}$$

Where the month under reference is that in which accumulated total of rainfall is in excess of 51mm of the rain. The end of the rain is the date after which no more than 51mm of the rain is expected. Thus, the above formula is applied in the reverse order by accumulating the total rainfall backward from December to obtain the actual date of the cessation of the rain. The interval between the onset and cessation of the rain represents the duration or length of the rainy season/growing season.

Mr. Vice-Chancellor Sir, Table 18 provides mean dates of onset and cessation of the rainy season for each station over the period 1978-2007, which were derived from the frequency distribution analysis of the dates of onset and cessation of the rainy season. It could be observed that the mean dates of onset and cessation of the rainy season tended to be concentrated in the months of April/May and September/October respectively, with about 70 percent of the stations having their mean onset dates concentrated in the month of April/May while about 69 percent of the stations had their mean cessation dates concentrated in the month of September. It has been stressed that an upward deviation from mean dates of onset implies a delayed onset of the rainy season, while a downward deviation from the mean date of cessation implies an abrupt end of the rainy season (Olaniran and Sumner, 2006). Frequent occurrence of such upward and downward deviations from the mean date of onset and cessation of the rainy season is another indication of the changing climate and could lead to shortened growing season and consequently reduced rainfall (Odekunle,2004) which invariably affects crop production since rainfall distribution characteristics within a shortened growing season may not be suitable for crop germination, establishment and full development.

Table 18: Mean Onset and Cessation dates of the rainy season in Northern Nigeria (1978-2007

Station	Onset	Cessation
Bauchi	8th May	3rd Spt
Bida	3rd Apr	13th Oct
Gusau	18th May	4th Spt
Ilorin	18th Mar	8th Oct
Jos	8th Apr	3rd Spt
Katsina	13th Jun	13th Spt
Kaduna	8th May	3rd Spt
Kano	3rd Jun	3rd Spt
Lokoja	8th Apr	7th oct
Maiduguri	3rd Jun	8th Spt
Makurdi	28th Apr	8th Oct
Minna	12th Apr	10th Oct
Sokoto	8th Jun	23rd Spt
Yelwa	3rd may	3rd Spt
Yola	22nd Apr	3rd Spt
Zaria	8th may	3rd Spt

Source: Umar (2010)

Mr.Vice-Chancellor Sir, the annual mean of the length of the growing season of each station was compared with the decadal means as shown in Table 19. It shows that, about 56 percent of the stations had their decadal means below their long-term mean in 1978-87 decade. There was however a change in the decade 1988-1997 with about 63% of the stations having their decadal means above their long-term mean. It was however followed by a failure in the decade 1998-2007, when about 50% of the stations had their decadal means below their long-term mean. The apparent variations in the length of the growing season among stations suggests a considerable northward incursion of the Inter Tropical Discontinuity (ITD) for most of the years in 1988-1997 decade with a restricted northward advance of the Inter Tropical Discontinuity (ITD) for most of the years in the decades 1978-1987 and 1998-2007, which might led to a considerable decrease in the length of the growing season in the affected stations between the period 1978-2007.

The result is inconsistent with the findings of Ati and Edwin, 2007, who studied the trends in the duration of the rainy season for nine stations north of latitude 9^0 N for the period of 50 years (1953-2002) and found out that the duration of rainy season was lower than the long-term mean for most of the stations in the decades 1963-1972 and 1983-1992, which also coincides with the worst Sudano-Sahelian droughts of 1972/73 and 1983/84.

Table 19 Mean of annual duration of the growing season and the decadal means for all the stations.

Station	Annual	(1978-1987)	(1988-1997)	(1998-2007)
Bauchi	125	117*	133	124*
Bida	175	171*	191	163*
Gusau	123	125	133	112*
Ilorin	199	206	208	185*
Jos	169	101*	173	168*
Katsina	94	93*	96	94
Kano	109	111	99*	117
Kaduna	156	154*	155*	159
Lokoja	193	197	196	186*
Maiduguri	91	82*	87*	104
Makurdi	173	164*	175	182
Minna	173	174	169*	176
Sokoto	104	99*	103*	109
Yelwa	147	149	155	139*
Yola	152	148*	149*	160
Zaria	145	146	146	143*

*Decades with mean below the long-term mean.

Source: Umar (2010)

Mr. Vice-Chancellor Sir, the frequency, duration and intensity of dry spells in recent days are some of the major concerns of farmers especially after the onset of the rain has been established. These dry spells pose great danger to crops particularly during the germination and ripening stage. Umar *et al* (2019) examined the rainfall characteristics in Sudano-Sahelian region of Nigeria over the period 1971-2006 using daily rainfall records of five selected synoptic weather stations. Four (4) dry spells categories namely: *very short* (DS1 = 1-3 days), *short* (DS2 = 4-7 days), *medium* (DS3= 8-14 days) and *long* (DS4= ≥ 15 days) were detected using multi-scale dry spells detection method adopted from Salack et al (2011). A dry spell is defined as a sequence of days without rain preceded and followed by a wet day (Salack et al. 2011). Stern *et al's* (1982) threshold of at least 0.83mm of rainfall to qualify as a rainy day was adopted in deriving sequence of dry days between the onset and cessation dates of a rainy season. This was generated for each year and for each selected station. The Salack's *et a*l (2011) scheme was then adopted to classify the dry spells into four categories. Figure 23 shows the total number of each dry spell category over the study period. It is obvious that the DS1 and DS2 categories have the highest frequency of occurrence at each of the selected stations. These dry spell categories do not however pose serious threat to crops because their effects could easily be reversed by a mere intervention of one good rain immediately after their occurrences.

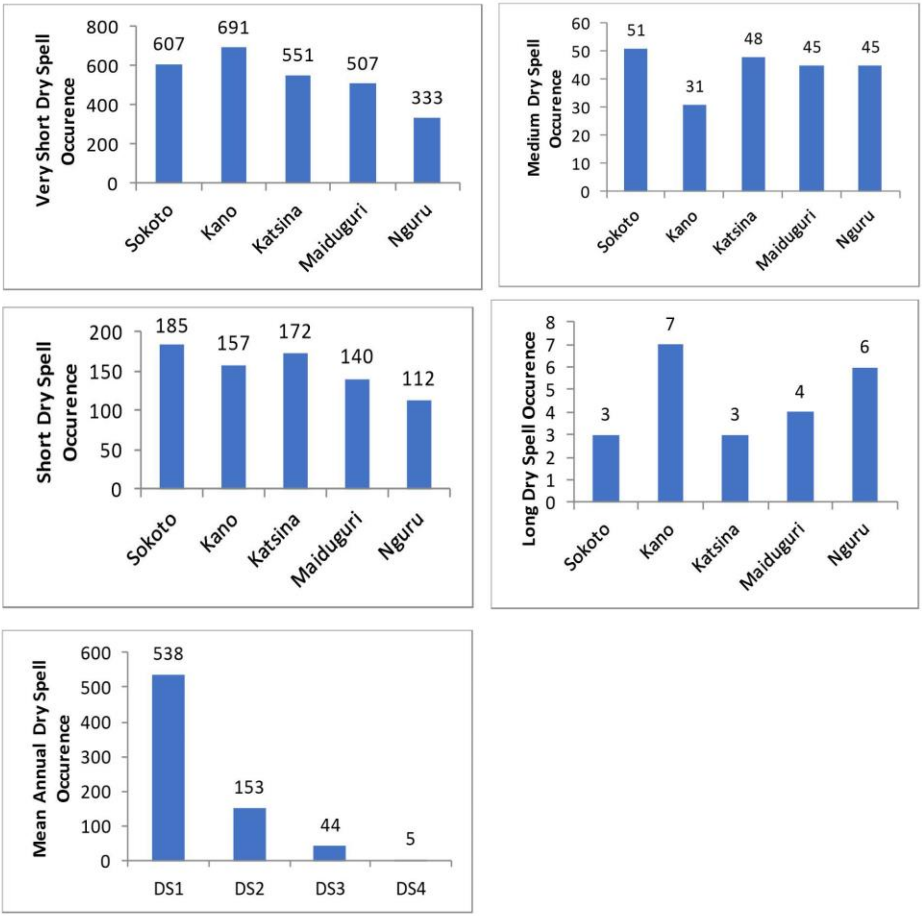
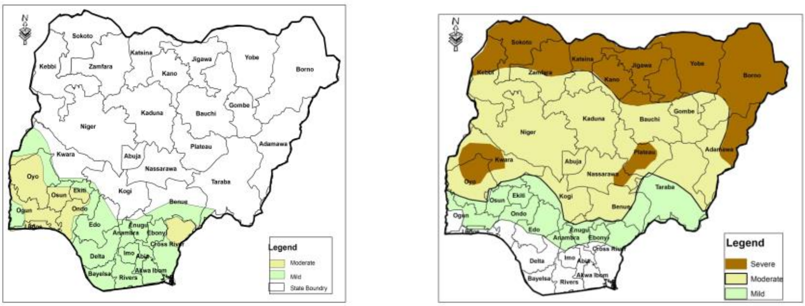


Figure. 23. Dry spell occurrence in the Sudano-Sahelian Region of Nigeria (1971-2006)

Source: Umar, *et al.* (2019)

A close observation of Figure 23 shows that DS3 and DS4 categories had low frequency of occurrence compared to DS1 and DS2 at all the selected stations. However, these dry spells categories could easily pose great danger to crops especially if occurred immediately after the onset date of the rain is established. It is pertinent to note that DS4 category is most dangerous of all the dry spells examined over the period 1971-2006. Kano recorded the highest of such dry spell incidences over the period of the study followed by Nguru. Some of the spectacular cases of DS4 category have been summarized in table 20. From Table 20, it is obvious that long dry spells are becoming a regular feature of Nigerian climate particularly in the Sudano-Sahelian region of Nigeria and are now on the increase. The Nigerian Meteorological Agency (NiMet) had since the beginning of its Seasonal Rainfall Prediction (SRP, now SCP) been reporting the likely occurrence of medium to long dry spells after the onset of the rain had been established. In the 2023 Seasonal Climatic Prediction (SCP), the NiMet had predicted the occurrence of a medium to long dry spells during the 2023 rainy season as we have witnessed it after the onset of the rain had been established within the first week of June, 2023 for most locations within the Sokoto basin and towards the end of the rainy season which had seriously affected crops especially during the germination, grain-filing and ripening stage (See Figure 24).



April.May 2023 June.July 2023

Figure 24. Predicted Dryspells in 2023 rainy season

Source NiMet (2023)

Table 20. Summary of some long dry spells in Sudano-Sahelian region of Nigeria (1978-2007)

Station	**Year of Occurrence**	**Onset Date**	**Cessation Date**	**Length of Rainy Season (days)**	**Annual Rainfall (mm)**	**Long-term Mean of Annual Rainfall (mm)**	**Dry Spell Category**	**Duration of Dry spell**
Sokoto	1981	19th May	10th Sept	115	560	625	DS 4	28th May – 22nd Jun (26 days)
	1984	7th Jun	18th Sept	102	467		DS4	18th Aug – 2nd Sept (16 days)
	1987	9th Jun	24th Sept	107	**371**		DS4	4th Aug – 18th Sept (15 days)
Kano	1981	28th May	14th Sept	110	575	912	DS4	29th May – 16th Jun (19 days)
	1987	2nd Jun	20th Sept	111	506		DS4	5th Jun – 23rd Jun (19 days)
	1990	6th Jun	17th Sept	104	560		DS4	7th Jun – 21st Jun (15 days)
	2002	11th Jun	29th Oct	141	**1034**		DS4	7th Oct – 29th Oct (23 days)
Maiduguri	1987	20th Jun	5th Aug	47	366	565	DS4	1st Aug – 16th

								Aug (16 days)
	2000	12th Jun	9th Sept	90	591		DS4	24th Jun – 8th Jul (15 days)
	2002	29th Jun	6th Sept	70	494		DS4	30th Jun – 15th Jul (16 days)
Kastsina	1971	28th May	21st Sept	117	489	535	DS4	29th May -14th Jun (17 days)
	1971	-	-	-	-		DS3	16th Jun – 27th Jun (12 days)
Nguru	1971	26th May	17th Sept	115	461	411	DS$	29th May – 25th Jun (28 days)
	1976	5th Jul	18th Oct	105	431		DS4	25th Sept – 14th Oct (20 days

Source: Umar, *et al.* (2019)

Mr. Vice-Chancellor Sir, the variability in the occurrence of the dates of onset and cessation of the rains as well dry spells could as well influence some rainfall characteristics such as annual and seasonal rainfall totals and length of the growing period/rainy season. Umar, *et al* (2019) further examined the influence of the onset and cessation dates of the rain and dry spells occurrences on the annual and seasonal rainfall amounts and length of the rainy season in Sudano-Sahelian region of Nigeria using step-wise multiple regression model.The results are summarized in table 21.

Table 21. Summary of the stepwise multiple regression model between the dependent and independent variables

Station	Annual rainfall Predictor(s)	R^2	p-value	Seasonal rainfall Predictor(s)	R^2	p-value	Length of rainy Season Predictor(s)	R^2	p-value
Sokoto	DS1`	.34	.000	DS1	.28	.001	Onset	.62	.000
	DS4	.43	.041				Cessation	.85	.000
Kano	Onset	.52	.001	Onset	.26	.002	DS1	.49	.000
							DS2	.69	.000
							DS3	.79	.001
							DS4	.85	.001
Katsina	Onset	.20	.006	DS1	.27	.001	Cessation	.45	.000
							Onset	.95	.000
Maiduguri	Cessation	.36	.000	DS1	.55	.000	Cessation	.61	.000
	DS1	.45	.028	Cessation	.67	.001	Onset	.87	.000
	Onset	.54	.016						
Nguru	DS1	.34	.000	DS1	.63	.000	Cessation	.59	.000
	DS3	.43	.034	DS3	.79	.000	Onset	.74	.000
							DS2	.78	.022
							DS3	.82	.008
							DS1	.91	.000
							DS4	.95	.000
SSRN	DS1	.31	.000	DS1	.46	.000	Onset	.49	.000
	Onset	.40	.000	Onset	.52	.000	Cessation	.88	.000
	DS4	.42	.034	Cessation	.53	.024	DS1	89	.000
							DS3	.90	.000
							DS2	.91	.000
							DS4	.91	.010

Source: Umar, *et al.* (2019).

Mr. Vice-Chancellor Sir, it is evidently clear that from the results presented in table 21, the most critical variables that influence annual and seasonal rainfall amounts and length of the rainy season in the Sudano-Sahelian region of Nigeria are the onset, cessation and long-dry spells while the length of the rainy season is influenced by a combination of factors such as variations in onset and cessation dates of the rain as well the occurrence of the various dry spell categories. The occurrence of dry spells may not directly reduce the length of the rainy season/growing period but could easily compromise the quality or potentials of the rainy season by distorting the normal distribution of rainfall within the growing period for crop requirements at various stages. These are further evidences of changing climate in Nigeria particularly in the northern fringes of the Sahel.

Changes in Water Balance Parameters

Mr. Vice-Chancellor Sir, a routine study of water balance is a veritable tool for monitoring the amount of water that will be available in the soil of any particular place at a particular time for optimal crop production and other uses. Water balance is the accounting of the inputs and outputs of water on the earth's surface. The water balance of any place, whether it is an agricultural field, watershed, or continent, can be determined by calculating the input, output and storage changes of water on the earth's surface and such changes in the input, output and storage can be considered as indicators of a changing climate. The major input is from precipitation and output is evapotranspiration (Ritter, 2012). Kehinde and Umar (2018) computed some water balance indices for Nigeria using mean monthly air temperature and precipitation for two years with contrasting moisture conditions (1983, a dry year and 2003, a wet year). The mean monthly air temperature data for each station were subjected to thornwaite's heat index formula given as:

$$ET_0 = 16 \times ({}^{10i}/_{I})^{a} ({}^{N}/_{12}) ({}^{1}/_{30}) \quad (1)$$

$$I = \sum_{i=1}^{12} (Ti/5)\, 1.514 \quad (2)$$

Where,

Ti = the mean monthly temperature in (°C).

N = the monthly Sunshine hours.

I = the heat index.

This formula has been packaged into a monograph. The monograph contains the values of mean monthly heat index (I); the duration of Sunshine hours and the correction factors based on the latitudinal and hemispherical location of a place. The estimated heat index (*I*) for each station was used to estimate the monthly and annual potential evapotranspiration (PE) for the twenty-seven selected weather stations for the selected wet and dry year in Nigeria.

Water Balance Computation

The estimated monthly PE values in conjunction with the monthly rainfall data were subjected to the climatic water budgeting procedure to calculate other water balance indices. These water balance indices include actual evapotranspiration (AE), water deficit (D), water surplus (S) and runoff (R). The calculation of these water balance indices was possible with the aid of Thornwaite Monograph. Thornwaite's water balance approach is simple, widely used most especially for regional water balance studies. The water balance sheet contains the following parameters and they are calculated thus:

Precipitation (P): This is the amount of precipitation in each month.

Potential evapotranspiration (PE): This is the maximum evapotranspiration, when water is not a limiting factor.

P-PE: This is the difference between the precipitation and the potential evapotranspiration.

APWL: This is the accumulated potential water loss. This only arises when $PE>P$.* If $PE>P$, then APWL is a cumulative values of (P-PE). * If $PE<P$, then no APWL.

ST: This is the soil water storage: the highest value is 300. This is obtained in the monograph but only in the months where the APWL occurs. Other months without APWL, ST = preceding ST + P-PE.

ΔST: This is the change in storage. That is, the different in storage value calculated by the difference in storage value of the current months and the preceding month.

AE: This is the actual potential evapotranspiration. That is, the actual amount of evapotranspiration that occurs. *If $P<PE$, then, $AE=P-\Delta ST$. *If $P>PE$ then $AE = P$

D: This is the water deficit in the soil that is calculated only when $P<PE$.*If $P<PE$, then $D=PE-AE$. *If $P>PE$, then no D.

S: This is the soil moisture surplus i.e. excess moisture gained in the soil, when capacity. This is only when $P>PE$ and ST is at full capacity. *If $P>PE$ and ST is at full capacity, then $S = (P-PE) - \Delta ST$.*If $P<PE$ or ST is not at full capacity or both, then no S.

R: This is the run-off. The runoff most be equal to the surplus i.e. R = S.

To check whether the table is correct, *$PE=P-S+D$.

Mr. Vice-Chancellor Sir, a paired sample test revealed that there is a significant difference between the water balance indices of a dry year and a wet year and across different locations in Nigeria [p=.000] indicating a further evidence of a change in the climatic condition between the 1980s and 2000s.

Variations in soil Moisture Storage

In a related study, Kehinde and Umar (2021) examined the spatial variations in the monthly soil moisture conditions obtained in the earlier study (Kehinde and Umar, 2018) and the result showed that most of the stations in the North recorded very low soil moisture storage below 10mm from the month of January to May especially in 1983. The soil moisture storage is high in virtually all the locations in January and February due to the low PE and APWL. Most Places in the Southern part of Nigeria recorded higher ST of between 20mm and above 100mm from January to May compared to their Northern counterparts in both 1983 and 2003. The soil moisture storage attained 250mm (100%) during the months of July, August, September and October across Nigeria. The study concludes that the soil moisture varies spatially and temporally in Nigeria and that the variations are function of the variations of PE, rainfall and APWL across Nigeria. A paired sample t test reveal a significant difference between the soil moisture storage of 2003 and 1983 in Nigeria (p= .000).

Variations in Air Temperature

The global climate report of October 2017 prepared and released by the National Center for Environmental Information (NCEI), USA showed that October 2017 was characterized by warmer-than-average conditions across much of the world's land and ocean surfaces. The largest positive anomalies were observed across north-central Russia, Alaska, northwestern and eastern Canada, and the northeastern contiguous U.S., where temperature departures from average were +3.0°C (+5.4°F) or higher. Near to cooler-than-average conditions were present across much of central Asia (stretching from western Russia to Kazakhstan, Mongolia, and eastern China), the western contiguous U.S., northern and southern Africa, as well as the eastern tropical and southeastern Pacific Ocean, northwestern Pacific Ocean (off the coast of Russia and Japan), eastern Indian Ocean, and areas across the Atlantic Ocean. No land or ocean areas had record cold October temperatures (Anuforum, 2017).

The combined average temperature over global land and ocean surfaces for October 2017 was 0.73°C (1.31°F) above the 20th century average of 14.0°C (57.1°F). This value tied with 2003 as the fourth highest October temperature on record since global records began in 1880, behind 2015 (+1.0°C / +1.8°F), 2014 (+0.79°C / +1.42°F), and 2016 (+0.74°C / +1.33°F). The 10 warmest Octobers on record have all occurred during the 21st century, specifically since 2003. October 2017 also marks the 41st consecutive October and the 394th consecutive month with temperatures at least nominally above the 20th century average. The global land surface temperature was the 11th highest for October at 0.99°C (1.78°F) above the 20th century average of 9.3°C (48.7°F).

The NCEI's 2007 report on global October temperature anomaly validates the Inter-governmental Panel on Climate Change (IPCC)'s claim of increasing average global temperature mainly due to man's anthropogenic activities particularly in the increased emissions of the Greenhouse Gases (GHGs) especially carbon dioxide (CO_2). The concern for the apparent rise in the earth's average temperature was as a result of the attendant consequences of such rising temperature of the global and regional climates.

Adebayo (1999) examined the spatial-temporal dynamics of rainfall and temperature fluctuations in Nigeria over the last century and showed that the mean annual temperature increased by about 0.04^{o} C. Using monthly temperature data for 27 selected synoptic weather station over the period 1941-2000, Umar (2012a) showed that Lagos, a nerve of industrial and commercial activities in the country, recorded the highest correlation coefficient of 0.78. The apparent rise in mean annual minimum temperature in Lagos could be attributed to the “Urban Heat Island” phenomenon as demonstrated by Oguntoyinbo (1981). It should however be noted that the general upward trend in the mean minimum temperature observed in the country may not be unconnected to the current global warming phenomenon as extensively discussed in the literature (see Adebayo, 1999; Ayoade, 2003) .

Mean annual maximum temperature also showed statistically significant upward trend in the mean annual maximum temperature in the country. It is noteworthy that Lokoja recorded the highest correlation coefficient of 0.61 followed by Ondo (0.49), Port-Harcourt (0.48), Enugu (0.46), Lagos (0.43) and Calabar (0.43). The highest correlation recorded by Lokoja could be ascribed to the influence of the Niger-Benue trough. The local changes in the maximum temperature particularly in urban areas such as Lagos, Port-Harcourt and Enugu could be ascribed to anthropogenic heat production, alteration of natural surfaces and canyon geometry as discussed in the literature (see Oguntoyinbo, 1981; Ayoade, 2004).

Bako and Umar (2023) also examined the trend and variability in mean annual maximum air temperature over the Sokoto basin using temperature records over the period 1970-2020. The Sokoto basin generally enjoys a tropical continental climate and temperatures are generally high (typically 36^{0}C) in most months of year except during the harmattan period (November – March). The lowest temperatures are recorded in December-January every year while the hottest months are

April-May. The 2023 Seasonal Climatic Predictions (SCP) of the Nigerian Meteorological Agency (NiMet) shows that in the month of April, both night and day temperatures are generally high within the Sokoto basin. Analysis of the long-term records of mean annual temperature and temperature anomaly patterns over the region (1970-2020) showed a general upward trend as shown in Figures 25-26. This temperature pattern has a number of implications especially in the area of health, agriculture and aviation. In the area of health for example, there will be a greater human discomfort especially in the months of April/May due to increased dehydration. In terms of agriculture, there will be high water loss due to increased potential evapotranspiration (PE) and raise demands for water for irrigation. During periods of high temperatures, the airline operators incur higher operational costs due to increased consumption of fuels by aircraft especially during take-off and landing amidst extreme temperatures, especially in April/May.

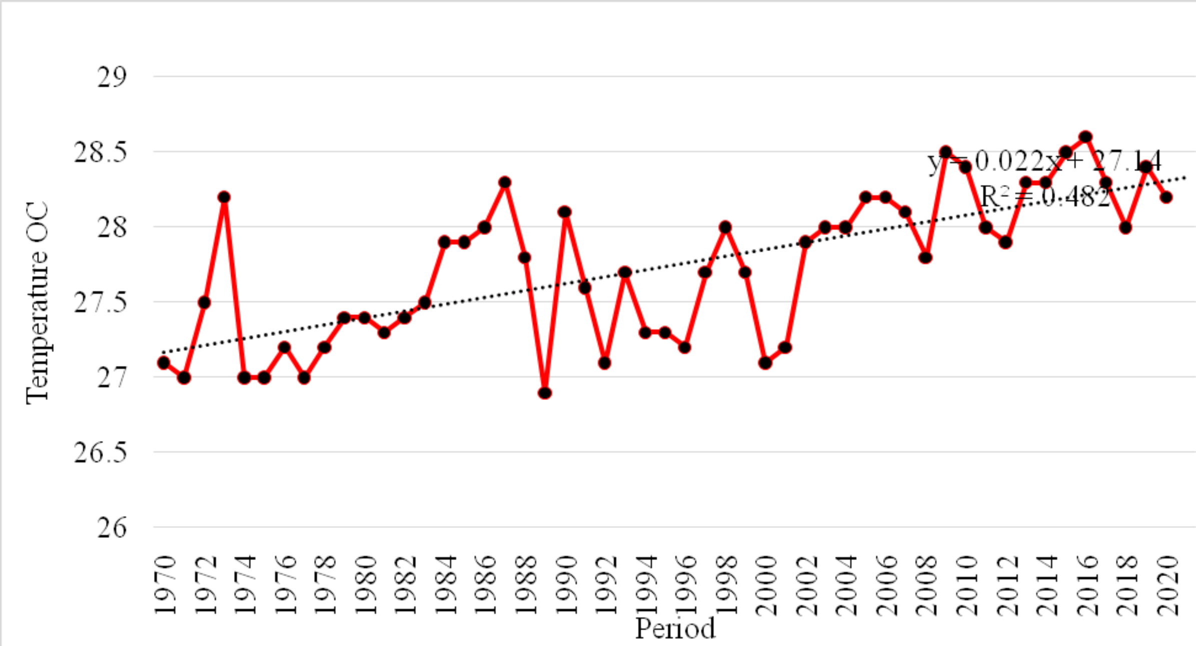


Figure 25. Mean Temperature of Sokoto Basin (1970-2020)

Source: Bako and Umar (2023)

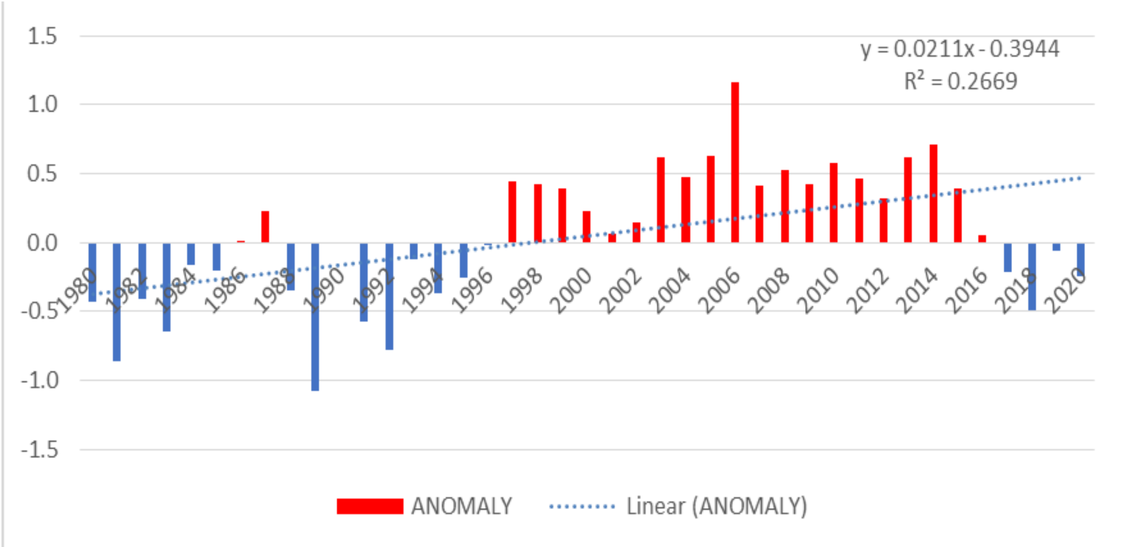


Figure 26. Mean temperature anomaly pattern for Sokoto basin (1970-2020)

Source: Bako and Umar (2023)

Variations in Ground Water Level

Mr. Vice-Chancellor Sir, population increase and demand for more water in the Sudano-Sahelian region of Nigeria is putting more pressure on the already stressed available water resources. The frequent failure of boreholes and dryness of hand dug wells reported by many researchers in the region (Oteze, 1979, JICA, 1990, Oduvie, 2006, Gada, 2016, and Offodile, 2002) is not only associated with decrease in rainfall but also due to over abstraction. Umar and Gada (2017) examined the pattern of rainfall anomalies and rural water supply in the Sudano-Sahelian region of Nigeria over the period 1951-2000, and showed most of the anomalies in rainfall over the region were caused by the air-sea interaction phenomenon of the El-Nino/Southern Oscillatiion (ENSO). These anomalies in rainfall have also affected the rate of gronundwater recharge as further demonstrated using the Water Simulation Model (WaSim). The Wasim model represents both the soil moisture zone and the aquifer with its storage as a single unit. Thus, the most notable indicator is the reduction in recharge as indicated in the response of water table to rainfall anomalies as input in the model as shown in figure 27.

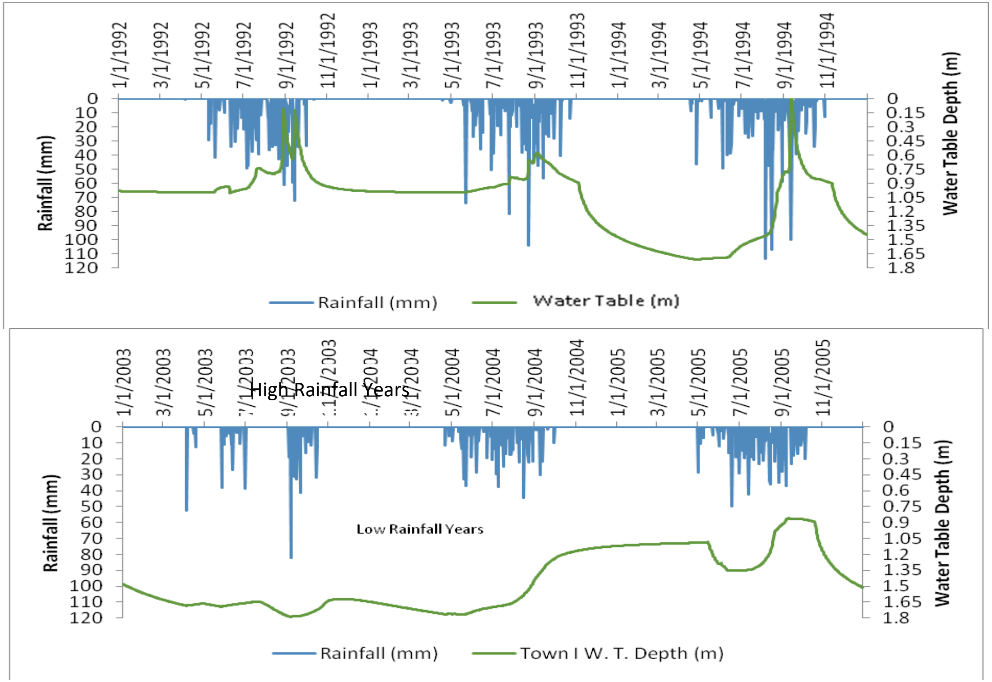


Figure 27: Daily Rainfall and Water Table Depth in the Wet (High) and Low (Dry) Rainfall Years for Sokoto Station

Source: Umar and Gada (2017)

Water Table (m)

Note that the three years selected each to represent the wet or high rainfall (1992-1994) and dry or low rainfall (2003-2005) years are in sequence. This is to allow for normalization of the model during the simulation process and to observe the effects of high or low rainfall year on the groundwater table.

In Figure 27, the groundwater table usually responds to rainfall infiltration and subsequent recharge whenever there is heavy downpour or continuous rainfall for few days consecutively. During the high rainfall years, the water table rises higher close to the surface as shown in the first part of Figure 27 for the years 1992 and 1994. During the low rainfall years (2003 – 2005) however, the water table always remains at shallow level indicating low or complete absence of water table movement in response to rainfall. The response of groundwater table movement is not dependent on only rainfall occurrence, but also the density by which it occurs. This behavior generally controls the distribution and availability or otherwise of groundwater within the study area.

Mr. Vice-Chancellor Sir, since the major sources of rural water supply (e.g. hand-dug wells, hand-pumped boreholes, rain harvesting, ponds, streams, lakes, and rivers) are climate dependent as noted in the previous studies in the African Sahel, it is obvious that perturbations in climate as symbolized in the occurrence of rainfall anomalies, could have some implications on the availability and reliability of both the ground and surface water supplies in the rural communities in the Sudano-Sahelian region of Nigeria. These implications may include the following:

1. In the event of anomalously low rainfall in the region, the already poor yield aquifers will be badly affected in form of natural water recharge of which is mainly rain-fed, and consequently pose serious water stress in the region.

2. The contamination of the groundwater may occur due to excessive rainfall in the region in any given year. When rainfall is anomalously high, there will be huge run-off in the region, and this could lead to washing away of various industrial toxics and other pollutants that are not well-disposed off. These pollutants will eventually find their way to groundwater through natural water recharge. This may impair the groundwater quality and pose health threat to people when such water is extracted and used for domestic purposes.
3. Acute water scarcity in the event of anomalously low rainfall in region could trigger communal crises that may arise from stiff competition among population for limited water in the region. The cattle rearers for example, may clash with farmers under such conditions, since the former has to feed his animals and provide water for them even in the face of serious water scarcity in the region. He may want to continuously extract the limited water from the hand-dug wells around to give his animals while the farmer at the same time may want to extract this limited water for irrigating his crops. Hence, the clash is inevitable.
4. The rural population who rely on the flow of water in rivers and streams for fishing activities may suffer serious economic losses in the event of anomalously low rainfall in the region. The stream and river droughts may worsen if rainfall amounts continue to decline far below the long term mean in the region. The water vendors in the region are likely to suffer similar fate if rainfall anomalies in the region persist, especially in the case of anomalously low rainfall.

Conclusion

The sudden variations in the state of the climate system (climatic noise/climatic anomalies) especially in Africa since 1901 are characterized by the occurrence of either large-scale floods, droughts, or prolonged dry spells which exposed different nations within the continent to vagaries of weather and climate and their attendant consequences. In the West Africa sub-region, for example, rainfall was above the long-term mean for most countries within the region and that led to large-scale floods in the area. However, from the late 1960s, rainfall declined to far below average in most countries especially those located within the Sudano-Sahelian region of West Africa. This led to catastrophic droughts of 1972/73, 1982/83, and 1987 that ravaged most countries in the region. The analysis of rainfall records in the region in the last thirty years shows a gradual recovery in Sahelian rainfall from 1998 to date with periodic fluctuations. We have in the last fifteen years or so examined different aspects of these climatic anomalies with reference to Nigeria. Several other hypotheses put forward to account for the causal mechanisms of these climatic anomalies failed to explain the almost spatial coherence in the occurrence of these anomalies in the entire West African sub-region. We have demonstrated that though, the surface feedback mechanisms through albedo changes and displacement of ITD contributed to some of these anomalies, the inter-hemispheric teleconnections through the coupled ocean-atmosphere interaction as manifested through the El-Nino/Southern Oscillation are the dominant factors in rainfall variability in most countries within and outside Africa as reported by other studies conducted in different continents.

These El-Nino/Southern Oscillation (ENSO) events have impacted significantly on rainfall patterns in Nigeria causing changes in several rainfall attributes such as onset and cessation dates of the rainy season, length of the rainy season, rainfall seasonality, rainfall trends and variability, domestic waters supply, variations in some of the indices of water balance as well as changes in soil moisture storage.

Recommendations

Having examined different aspects of climatic noise in Nigeria and the dominant causal factors, we recommend that;

i. Inter-basin transfer of water by the Federal Ministry of Water Resources from those areas that are more humid to semi-arid environments should be explored to address the water demand problem in case of prolonged droughts.
ii. Since the Nigerian Meteorological Agency (NiMet) is saddled with the responsibility of advising the government and people of Nigeria on all aspects of meteorology and water related issues, the state governments should partner with NiMet for the downscaling of the Seasonal Climatic Prediction (SCP) for their respective states for effective planning and development.
iii. The inter-ministerial synergy should be improved to draw a comprehensive framework to deal with the effects of climatic noise in Nigeria.
iv. People should imbibe the culture of using NiMet's daily weather updates for planning their daily activities.
v. Water resources development projects should be enhanced to take advantage of excess water in the event of excessively wet periods.
vi. Enlightenment campaigns should be improved on the dangers of climate change and how to engage in climate-friendly activities.

Acknowledgments

Mr. Vice-Chancellor Sir, I celebrated my 48th birthday on the 20th May 2023, and over these 48 years of my life, several personalities within and outside this country have played critical roles in my academic, professional, and personal life and need to be appreciated at other time than during historic occasion. Let me first of all, thank the Almighty Allah (S.W.A) for the gift of life, for seeing me through several anomalies of life, and for making this day a reality. Since the charity begins at home, let me express my profound gratitude to my loving parents, Alh. Umar Abubakar Tambuwal (popularly called Malam Umaru MaiZane). He has been with me from the very beginning until the 1st day of Ramadan of 2023 when he answered the eternal call at over 100 years after a brief illness. May Allah forgive him and grant him Aljannat Firdausi, Amin. My aged mother, Hajiya ‘yar Gwaggo is still with us aging gracefully. May Allah continue to bless her with sound health, Amin. I am glad that my parents lived long and enjoyed the fruits of their labour.

I want to sincerely thank all my family members who came out en masse to grace this occasion. I want to also thank my elder brother, Faruk Umar Tambuwal, who provided the needed financial and moral support when I was in secondary school and up to the time I graduated from the Shehu Shagari College of Education. After my NCE, he secured a teaching appointment for me at the Teachers Service Board to enable me earn a living. That singular gesture provided the needed capital to improve myself academically. I can recall vividly that despite the fact that I was working and taking salaries, it was my brother Faruk that paid registration fees for the first year of my Ph.D. programme. My brother, Faruk, and I also jointly supported the last born in our family, Dr. Abdullahi Umar Tambuwal, who equally acquired higher education from the

NCE up to the doctorate level. Dr. Abdullahi Umar Tambuwal successfully defended his Ph.D. thesis in May 2023 at the Department of Agricultural Extension and Rural Development, Ahmadu Bello University, Zaria. My elder brother Faruk also ensured that his biological children had the best education. His first daughter, Fatima Faruk Tambuwal was recently inducted into the pharmacy profession after she obtained a Bachelor of Pharmacy degree from the Usmanu Danfodiyo University, Sokoto in 2023. Her brother, Nazir Faruk Tambuwal also graduated with Second class Upper degree in Education Chemistry from the Usmanu Danfodiyo University, Sokoto, and is now in the NYSC programme at the Federal College of Education, Kano. The remaining children of Faruk Umar Tambuwal are currently pursuing various degree programs in Usmanu Danfodiyo University, Sokoto. One good thing about my elder brother Faruk is that, despite the support given to his younger brothers and his own biological children in terms of education, he did not rest on his oars as he equally improved himself academically. As of today, my elder brother, Faruk can boast of over ten different higher academic qualifications obtained from different higher institutions within and outside Sokoto. Among others are a certificate in storekeeping, a Certificate in Stores Administration, Diploma in Accounting and Auditing all from the then Sokoto State Polytechnic. Others are Higher Diploma in Management, B.Ed. (Business Studies) and Masters in Business Administration from the Usmanu Danfodiyo University, Sokoto, and Higher National Diploma in Purchasing and Supply from Kaduna Polytechnic. He is a certified member of the Chartered Institute of Purchasing and Supply (CIPS) and currently running a full-time Ph.D. degree programme in Business Administration at Usmaniu Danfodiyo University, Sokoto. My elder brother Faruk has indeed improved himself as he is currently the Chief Store Officer and Head of the

Department of Stores and Supplies, at Usmanu Danfodiyo University Teaching Hospital (UDUTH), Sokoto. I am glad that I didn't disappoint my elder brother, Faruk.

Mr. Vice-Chancellor Sir, I want to also thank the former Vice-Chancellors, Professors R. A. Shehu and A. A. Zuru. These erudite scholars and seasoned administrators have played critical roles in my academic, professional, and personal life. Professor R. A. Shehu graciously approved, through the Committee of Deans and Directors, my application for one year of study leave to enable me complete my Ph.D. programme at the University of Ibadan after tendering a satisfactory progress report on my Ph.D. duly signed by my Supervisor, J. O. Ayaode, a renowned Professor of Climatology. Professor A. A. Zuru also supported the Local Organizing Committee (LOC) of which I am a member and Secretary, for the 2015 Annual Conference of our professional body, the Nigerian Meteorological Society (NMetS) hosted by the Usmanu Danfodiyo University, Sokoto. In fact, it was very challenging at that material time because, not long after the University Management accepted to host the 2015 national conference of NMetS that, the popular and widely accepted Treasury Single Account (TSA) was implemented by the Federal Government of Nigeria. During one of the meetings with the LOC members, the then Vice-Chancellor, Prof. A. A. Zuru told the LOC that the conference should either be deferred or funds be sourced elsewhere for a future refund by the University because the TSA was just implemented at the time. The conference could not be deferred at that time since the LOC had already sent out letters of acceptance of abstracts and date had been fixed for the conference. The LOC went and sourced funds elsewhere and during the opening ceremony which was attended by all principal officers of the University at that time as well as the then Chairman and members of the

University Governing Council, Professor A, A. Zuru told the then Dean of Social sciences, Prof. Suleiman Khalid that the LOC should apply for the rerelease of funds promised to the LOC for that conference. Prof. A. A, Zuru immediately directed the Bursar to release funds to the Geography Department as promised by the University Management. Sir, we thank you for that kind gesture. I am also grateful to Professors S. M. Dangwaggo and M. U. Tambuwal for their words of encouragement whenever I paid them courtesy visits in their offices. While Prof. S. M. Dangwaggo was the immediate past Vice-Chancellor of the Sokoto State University, Prof. M. U. Tambuwal is the current Vice-Chancellor of the newly established Shehu Shagari University of Education, Sokoto.

Let me also express my profound gratitude to our Vice-Chancellor, Prof. L. S. Bilbis for reviving the culture of the bi-weekly inaugural lecture and for giving me the opportunity to deliver the 37th inaugural lecture on behalf of the Faculty of Social Sciences. I can recall vividly how our Vice-Chancellor also facilitated the partnership between the Usmanu Danfodiyo University, Sokoto, and the Nigerian Meteorological Agency (NiMet) which culminated in the signing of an MoU between the two federal institutions. This led to the upgrade of the weather station of the Department of Geography by NiMet and recently also led to the publication of a climate change book by the two institutions.

I am also grateful to all my teachers at all levels of my education. They are too numerous to mention but I want to specifically thank our DVC Academic, Prof. M. G. Mahuta, who not only taught me the sociology of education but also supervised my teaching practice at Government Girls Commercial Secondary School, Tambuwal during my NCE days. Sir, I am grateful. At the Department of Geography,

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I am also grateful to all my former students at Sani Dingyadi Unity Secondary School, Farfaru, Sokoto, and Usmanu Danfodiyo University, Sokoto for their loyalty. I want to recognize some of them that made me proud. These include Alh. Sanusi Kuchi, a Director in Kebbe Local Government, Dr. Aliyu Muhammed Achida, a Senior Lecturer at the Department of Biochemistry, Ahmadu Bello University, Zaria, and Dr. Garba Ibrahim, a lecturer at the Department of Modern European Languages, Usmanu Danfodiyo University, Sokoto. Drs. Aliyu Muhammed Achida and Garba Ibrahim obtained their Masters and Ph.D. degrees from the University of Ibadan. I taught three of them at Sani Dingyadi Unity Secondary School, Sokoto during their secondary school days. At the University level, I want to recognize some of my outstanding M.Sc. graduates including the likes of Kehinde Musa Oladejo, Lawan Bulama, Hadiza Jubril, and Gbenga Olanlere. Thank you all for your loyalty.

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Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, thank you for your rapt attention.

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PROFILE OF PROFESSOR ALIYU TAMBUWAL UMAR

Professor Aliyu Umar Tambuwal was born on the 20th of May, 1975 at Tambuwal town, Tambuwal Local Government, Sokoto State. He attended the Jama'atul Nasril Islam Model Primary School, Tambuwal between 1982 and 1987 and proceeded to the famous Government Science Secondary, Yabo, where he obtained the Senior School Leaving Certificate in 1993. Prof. Tambuwal also attended the then Haliru Binji College of Arts and Science (HABCAS), Sokoto for 'A' level studies in 1994 and later attended College of Education, Sokoto between 1995 and 1997 where he obtained a distinction in the National Certificate in Education (Geography/Social Studies).

After the three years professional teacher training, Prof. Tambuwal gained admission into the Department of Geography, Usmanu Danfodiyo University, Sokoto through direct entry in the 2000/2001 academic session and graduated with a second class, upper division in 2003. While waiting for mobilization into the National Youth Service, Prof. Tambuwal registered for a Diploma in Computer Studies with the Usmanu Danfodiyo University Consultancy Services (UDUCONS) which he obtained in August 2004. He was later deployed to Oyo State in September 2004 for the National Youth Service Corps (NYSC) and successfully completed it in September 2005. During the national service, he taught Geography at Fiditi Grammar School, Afijio Local Government, Oyo State.

Professor Aliyu Tambuwal started his teaching career in 1998 at Sani Dingyadi Unity Secondary School, Farfaru, Sokoto as Master III and later as senior Master II at Government Girls Commercial Secondary School (GGCSS), Tambuwal but resigned from this appointment in 2008 when he secured another appointment as Lecturer II in the Department of Geography Usmanu Danfodiyo University, Sokoto.

Between 2005 and 2014, Professor Tambuwal attended the prestigious University of Ibadan and obtained his M. Sc. and Ph.D. Degrees in 2007 and 2014 respectively. Prof. Aliyu Tambuwal had to combine his full-time teaching appointment with the full-time Ph.D. degree programme at the University of Ibadan (under the supervision of Prof. J. O. Ayaode) and that period, was the most hectic period in his life. After about three years in service and after presenting a satisfactory progress report of his PhD, the Committee of Deans and Directors, approved his application for one-year study leave (2010/2011 session). This gave him the opportunity to completely relocate to University of Ibadan up till the tail end of 2011 when he had submitted a draft of his Ph.D. thesis, preparatory to the final viva voce. This waiting took about two years due to the unfortunate ASUU strike of 2013 and other academic bottlenecks. God's time is the best, Prof. Tambuwal finally defended his PhD thesis in February, 2014 and had his convocation in November, 2014.

Upon completion of the Ph.D. program, he resumed work and continued with teaching, research, and community service. He rose through the academic ranks in the university to Senior Lecturer in 2015, Reader in 2018 and finally to Professor of Climatology with effect from 1st January 2021.

Professor Tambuwal attended and presented papers at various conferences in many Universities within and outside Nigeria including University of Calabar (2008), University of Maiduguri (2008), Kogi State University, Ayingba (2009), Osun State University (2009), University of Ilorin (2010), Ahmadu Bello University, Zaria (2011), University of Benin (2012), Usmanu Danfodiyo University, Sokoto (2015), Nassarawa State

University, Keffi (2017), Kwame Nkrumah University of Science and Technology, Kumasi, Ghana (2017), University of Ibadan (2018) and Federal University of Technology, Akure, Ondo State (2019). Prof. Tambuwal had about forty publications to his credit including chapters in books, peer-reviewed journal articles, referred conference proceedings, and technical reports. He had successfully supervised nine (9) M.Sc. students on various aspects of theoretical and applied climatology and co-supervised one Ph.D. student from the Faculty of Agriculture. He has also granted several interviews with the Nigerian Television Authority (NTA) on various aspects of climate change,

Professor Tambuwal represented Usmanu Danfodiyo University in the Sokoto State Committee on Flood Control (2016) and was a member of the Task Force on Land Matters (2020) and UDUS-Sokoto State Government Joint Committee on Land Matters (2020-Date). He also served at various times as a member of different strategic committees of university such as representative of the Faculty of Social Sciences in Senate Standing Committee on Examinations (SSCE) between 2020 and 2023, member of the Reconstituted Editorial Board of the Studies in Humanities Journal (2020-Date), Ad-hoc Committee on Housing (2020), Council Ad-hoc Committee on Housing (2022-2023), University Projects Monitoring Committee (PMC) (2021-Date), University Ranking Committee (2022-Date), among others. He has also served as the Departmental Examinations Officer, Department of Geography (2015-2019) and Faculty Examinations Officer, Faculty of Social Sciences (2020-2023).

Prof. Tambuwal was also a visiting lecturer in the Department of Geography and Regional Planning, Federal University Dutsin Ma, Katsina State (2017/2018 session), a sabbatical staff at the Department of Geography, Federal University, Gusau, Zamfara State (2018-2019 session) and an Adjunct Lecturer at the Departments of Meteorology and Climate Change, WMO Regional Training Centre, Muhammadu Buhari Meteorological Institute of Science and Technology (MBMIST), Katsina State, Nigeria since 2021. He has also served as the External Examiner (M. Sc.) Oral Defense at the Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria (3rd March 2021), Department of Geography, Bayero University, Kano (20th December 2021) and Ph.D. Oral Defense at the Department of Geography, University of Ibadan under the PAN African University programme on 'Life and Earth Sciences', University of Ibadan (4th November 2022).

Outside the University, Prof. Tambuwal is a registered member of several professional bodies within and outside Nigeria such as Nigerian Meteorological Society (NMetS), Association of Nigerian Geographers (ANG), Nigerian Association of Hydrological Sciences (NAHS) and Meteorological Society of Japan. He has been a regular attendee of the public presentation of NiMet's Seasonal Rainfall Prediction (SRP) now Seasonal Climatic Prediction (SCP) since 2015. Until 16th June, 2023, Prof. Tambuwal was also a member of the Board of Nigerian Meteorological Agency (NiMet), Abuja, Nigeria. Similarly, Prof. Tambuwal has a community fellowship of the Nigerian Meteorological Agency (NiMet) at the World Meteorological Organization (WMO) and was a delegate to the virtual session of the Technical Commission (TC) for Weather, Climate, Water and related Environmental Services and Applications (SERCOM) otherwise known as Services Commission held between 22nd – 26th February, 2021.

In the same direction, he participated in a 2-day workshop on 'Climate and Weather Information Services in Nigeria' organized by the Nigerian Meteorological Agency (NiMet) in collaboration with the Federal University of Technology (FUTA), Akure, Ondo State and the University of Leeds, United Kingdom, as part of the 'Science for Weather Information and Forecasting Techniques (SWIFT)' project on 'How to Support Users' Understanding and Use of Weather Forecasting and Services in Nigeria' held on 26th – 27th March, 2019. He was also invited to the National Dialogue on WASCAL Climate Change Agenda for Africa organized by the West African Science Service Center on Climate Change and Adapted Land-Use (WASCAL), Nigeria Regional Centre held on 21st January 2016.

In the area of consultancy services, he served as member, Ad-hoc Committee for the conduct of Land Validation for Sugarcane Biofuel Project in Kebbi State, Nigeria (January – December, 2020) and member, Ad-hoc Committee for the conduct of Environmental Impact Assessment (EIA) and Environmental Baseline Studies (EBS) of Sokoto and Bida Basins, (2021-Date).

Professor Tambuwal had received several academic and professional merit awards amongst which included Academic Merit Award of being the Best School Overall in the School of Arts and Social Sciences (1996-97 session) and best final year student in the Departments of Curriculum Studies and Geography (1996-97 session). In December, 2019, Professor Tambuwal was unanimously elected as the 2nd Vice- President of the Nigerian Meteorological Society (NMetS) at the 32nd Annual Conference and Annual General Meeting (AGM) of Nigerian Meteorological Society (NMetS) held at the Federal University of Technology (FUTA), Akure, Ondo State.

Professor Aliyu Tambuwal is married and blessed with one daughter, named Hauwa'u Aliyu Tambuwal.