CERTIFICATION

This is to certify that this study, carried out by **OGUNDELE MARY OLAOLUWA (WMA/13/1033)**, was submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Agriculture (B.Agr) in the Department Of Water Resources Management And Agrometeorology, Federal University Oye-Ekiti, during the academic year 2013-2018, is an original record of work carried out under my guidance and supervision.

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ABSTRACT

Drought is one of the a resultant effect of climate change and it is the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. Unlike many other natural hazards, drought develops slowly, making it difficult to pinpoint the onset and termination of an event.

The environmental impacts of hydrological drought are Reduced stream flow and loss of wetlands may cause changes in the levels of salinity. Increased groundwater depletion, land subsidence, and reduced recharge may damage aquifers and adversely affect the quality of water (e.g., salt concentration, increased water temperature, acidity, dissolved oxygen, turbidity). The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological throughput of the landscape.

The Standardized Precipitation Index is a powerful and flexible index used in this study to evaluate the extent of hydrological drought in the north east. Precipitation is the only required input parameter.

Key Words: Climate Change, Drought, Hydrological Drought, Standardized Precipitation Index

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Climate change is a phenomenon that cannot be overemphasized in this century, because it affects all phases of life including the biosphere, the lithosphere, the hydrosphereand the atmosphere both directly and indirectly. The variation in the series of processes taking place drives the study of these spheres in order to understand, the risk entailed, preparations to be made to either prevent, control or mitigate its effect andthe extent of the disaster including assessing its impact and the vulnerability of the affected, in order to manage it well if it goes out of control.

Climate change is a widely studied phenomenon. It is defined as a change in the statistical distribution of weather patterns when that change lasts for an extended period. Global warming, temperature variation, change in sea level, change in precipitation pattern etc., are pointing to climate change. Therefore, this study would focus on the hydrological droughtin the northern region of Nigeria using precipitation as an indicator.

Drought is one of the a resultant effect of climate change and it is the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.[1]

A drought is a sustained and regionally extensive occurrence of below normal, natural water availability due to climate variability. [2] It occurs everywhere and can develop over rather short periods of months, or much longer periods of several seasons. Droughts are regional in extent and each region has specific climatic characteristics. [3] The extent to which they affect vary with location and as we know, each region has its own climatic features. Droughts that will occur in Southwest Nigeria will be different from the drought in the North central Nigeria or the drought in North Africa, the severity or degree of extremities vary with location. Since drought is widely recognized as a complex, multifaceted phenomenon.

Unlike many other natural hazards, drought develops slowly, making it difficult to pinpoint the onset and termination of an event. [4]Drought is expected to get worsen with predicted climate change, and the aerial extent of drought-affected regions are projected to increase, which could have adverse effects on agriculture. Drought in the real sense cannot be quantified, because it is a qualitative term used to describe precipitation deficiency. The desire to quantitatively identify and analyze drought duration, severity, onset, and termination has led to the development of drought indicators. [4]

One of the primary uses of drought indicators is in monitoring and early warning, a crucial part of drought preparedness. [5] Little can be done to prevent a meteorological drought from occurring, but actions can be taken to prevent or mitigate the impact of a hydrological drought.

Drought affects all components of the hydrological cycle; resulting in, for example, low soil moisture, declines in groundwater levels and reductions in spring and river flows. Drought may refer to meteorological drought (precipitation), soil water drought, or hydrological drought (groundwater, stream flow, reservoir, and lakes). [6]

In Europe, international drought research became priority notearlier than about 2-3 decades ago. Drought definitions were further advanced building upon achievements in North America. Hydrological drought (groundwater, stream flow) was introduced to distinguish from meteorological drought. Understanding of hydrological drought is essential for water resources management. Propagation studies investigated differences between meteorological and hydrological droughts. Differences were connected to climate and catchment characteristics. Groundwater response appears to have a significant influence on drought characteristics

Currently, meteorological drought indices are used for the prediction of hydrological drought, but likely predictive skills for some sectors (e.g. public water supply) would improve if hydrological drought indices will be used. However, this requires that more groundwater and stream flow data become available.

1.2 Study Area

1.2.1 Geographic Locationand Areal Extent

The study area is in the Northeast region of Nigeria (Figure 1.1). The Republic of Niger, Cameroon, the Republic of Benin, and the Gulf of Guinea respectively border Nigeria in the northern, eastern, western, and southern parts. The total land area is about 923,300 km^2. The North East (NE) Geopolitical Zone of Nigeria covers close to one-third (280,419km2) of Nigeria's land area (909,890km2). It comprises 6 states: Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. According to projections for 2011 by the National Bureau of Statistics (NBS), these States have 13.5% (i.e. 23,558,674) of Nigeria's population. In Addition, the Zone shares international borders with three countries: Republic of Cameroon to the East, Republic of Chad to the North East and Niger Republic to the North.

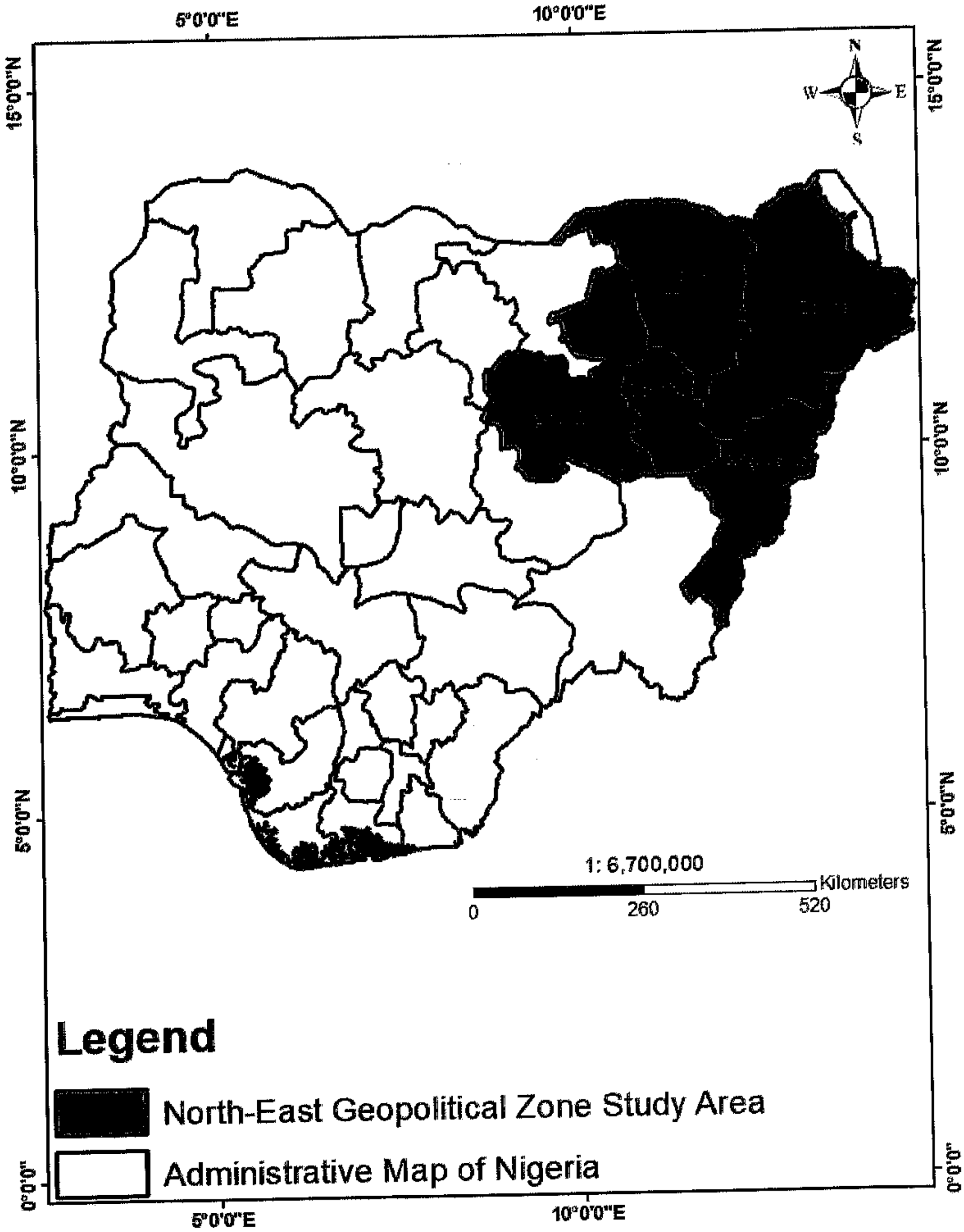

FIG.1 Administrative Map of Nigeria showing the Study Area

1.2.2 Geology

There are six major groups of rocks in the Northeast region, each of which contains several different rock types as shown in Table 1.

Table 1 Geological Rock Types in North East Nigeria

S/NO	Group	Rock Type	Formation Area	Age
1	I	Granites, gneiss Metasediments, and migmatite	Young granites, older granite	Jurassic and pre-cambrian
2	II	Sand stones, clays and shales with thin limestones, coarse fieldapathiclimestones	Gombe and gulani, fika, sekule, yolde, yola and bima.	Cretaceous
3	III	Continental sandstones with grits and clays	Kerri kerri	Rertiary
4	IV	Pyroplastic rocks and basalt rocks		Tertiary-recent
5	V	Ancient alluvian, lagoonal clays, beach sand and gravel, deltaic sands and clays	chad	Quaternary
6	VI	Recent alluvian		Recent

1.2.3 Ecology and Vegetation of Area

The vegetation zones in the north-east are sudan savannah, sahel savannah and the guinea savannah. The Sahel climate or tropical dry climate is found around Lake Chad region in Nigeria which is around Borno state, and is the predominant climate type in the northern part of Nigeria. Annual rainfall totals are lower compared to the southern and central part of Nigeria. The rainy season in the northern part of Nigeria last for only three to four months (June–September). The rest of the year is hot and dry with temperatures ascending as high as 40 °C (104.0 °F). Northern Guinea Savanna is characterized by grass species in general which only grow to 7 or 8ft in height.Sudan savannah is considerably dry with an average annual rainfall is 20-40 ins, dry seasonslasting for seven months or more in a year with relative humidity as low as 25% during the dry season. Tree species are mostly deciduous, with half of them being small leaved like the Acacia.The dry season is accompanied by a dust laden airmass from the Sahara Desert, locally known as harmattan, or by its main name, The Tropical Continental (CT) airmass, while the rainy season is heavily influenced by an airmass originating from the south atlantic ocean, locally known as the south western wind, or by its main name, The Tropical Maritime (MT) airmass. These two major wind systems in Nigeria are known as the trade winds.

1.2.4 Hydrology of Northeast

The North East project area includes parts of two major drainage basins: the internal basin of Lake Chad and the Benue river basin which flows to the Niger and then to the Atlantic Ocean.Lake Chad Basin area has Yobe river system, Damaturu river system, Kyauwo river system Yedseram river system E1 Beid river system and areas with only local surface flows and the benue river basin area has Gongola river and undifferentiated tributaries Hawal river system, Anumma river system, Benue river and undifferentiated tributaries, Tiel river system, Kilunga river system, Pai river system. The total area amounting to 106,300 km^2 and 69,700km^2 respectively.

1.3 Research Questions

What is the effect of precipitation deficit on the hydrological cycle?

What is the impact of hydrological drought on the environment, and how can it be mitigated?

1.4 Aim and Objectives

The aim of this project is to evaluate the extent of hydrological drought in the north-east region of Nigeria using the Standardised Precipitation Index.

The objectives of the study are to:

i. Process the precipitation data acquired between 1981 and 2010;

ii. Calculate average precipitation for each year;

iii. Compute the standardized precipitation index; and

iv. Characterize the impacts of hydrological drought in the region.

1.5 Justification of Study

The drought indicator used in this study to monitor the hydrological drought is the Standardized Precipitation Index (SPI).The Standardized Precipitation Index is a powerful and flexible index that is simple to calculate. Precipitation is the only required input parameter.The Standardized Precipitation Index was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow and reservoir storage reflect the longer-term precipitation anomalies.Originally, it was calculated SPI for 3-, 6-, 12-, 24- and 48-month timescale. [3] Therefore it is suffice to determine hydrological drought using longer-term precipitation anomalies like the 6-month, 9-month, 12-month, and 24-month.The

Nigerian meteorological Agency Nigeria, to monitor flood and drought, uses the standardized precipitation index: it is obtainable in the drought and flood monthly bulletin. The Standardized Precipitation Index indicates seasonal to medium-term trends in precipitation and is still consideredmore sensitive to conditions at this scale than the Palmer Index is.

The above explains the reason why standardized precipitation index was chosen as a drought indicator to study the tendencies and extent of drought in the northeast region of Nigeria.The Precipitation data applied in this study is a secondary source data, which was obtained from the Nigerian Meteorological Agency, Abuja. In addition, the data collected are from five (5) stations in the north-eastern region of Nigeria.

1.6 Significance of Project

The significance of this project is to assess the extent of hydrological in Northeast Nigeria, and use this assessment to determine the rate at which the northeast is being encroached into a desert using precipitation.

1.7 Project Outline

This project is organized into five (5) chapters thus:

A. Chapter One entails the introduction as highlighting the aim, objectives and significance of the project;

B. ChapterTwo gives a literature review on the concept of drought, its classifications, hydrological drought, its effect, and also further discussions on the topic.

C. Chapter Three presents the materials and method; it gives the data to be employed, and well as method for analysing the data in order to obtain results.

D. Chapter Four comprises of the result and discussion; it gives result on analysis of data and detailed discussion on the result.

E. Chapter Five draws conclusion, gives limitation and recommendation of the project.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

2.1 Introduction

The conceptual framework adopted in this study, is based on the main cause of drought which is precipitation, precipitation deficit is the most important causative agent of drought, although it is often accompanied by intense evapotranspiration, low relative humidity etc. in order to get a hold of the quantity of precipitation deficit over a region, a long-term average of the precipitation of that region would be obtained from a weather station in that region and standardized using a drought indicator. Drought indicators help quantify drought, some may involve statistical techniques, others empirical techniques: but they help in assessing the extent of the impact of drought on the environment and its elements.

2.2 Drought

Drought is a relative term used universally with reference to deficiency of rainfall of a given location. Drought has a shortcoming in its definition because it also involves defining it on the basis of rainfall and temperature, water demand, water consumption. Drought is an ecological hazard, which can in turn become a disaster if the vulnerability of the community it affects, cannot cope with its impact. Absence of water supply for plant growth directly as rainfall, indirectly through irrigation would affect food security.

Over the years, several regions of the world close to the desert have been encroached, while others are merely prone to drought because of the water supply in such locations. In Nigeria, the geopolitical zones prone to drought are the north-east, north-west and the north-central, this is because Nigeria's boundary to the north is the Sahara desert and also those regions have a vegetation that requires less water supply, or water demand than crops in other vegetation zones. The vegetation zone in the geopolitical listed above are: the Sudan savannah, Sahel savannah, and Guinea savannah. Other factors that can induce drought are anthropogenic sources caused by human activities in the environment such as urbanization, mining, agriculture, infrastructural development etc. these activities build up over time and result in climate change and global warming. Climate change which is variation in rainfall patterns amongst other things could cause a change in the distribution of rainfall over a geographical location over time and result in drought.

Droughts are one of the more costly natural hazards on a year-to-year basis; their impacts are significant and widespread, affecting many economic sectors and people at any one time. [3]

2.2.1 Types of Drought

i. Meteorological drought: Meteorological drought occurs when precipitation deficiency is more than 25% of the normal rainfall over an area; it is moderate when it is between 26% and 50% of normal rainfall and said to be severe when the rainfall deficiency is above 50%. It could possibly be combine with increased potential evapotranspiration, ranging over a large area and across an extensive period of time.
ii. Hydrological drought: When meteorological drought is prolonged, it results in hydrological drought with mark of depletion in surface water and consequent drying of reservoirs. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished. Like an agricultural drought, this can be triggered by more than just a loss of rainfall.
iii. Agricultural drought: It occurs when rainfall and soil moisture is insufficient to support growth of crops during growing season. There are three types of agricultural drought:

a. Permanent drought: it usually occur in arid areas where there is inadequate precipitation to satisfy the water need of plants. Such areas need agriculture is impossible without irrigation throughout growing season.

b. Seasonal drought: it occurs with well-defined wet and dry seasons, drought can be expected everywhere owing to seasonal changes in atmospheric circulations patterns. Some regions receive high rainfall during monsoon which is followed by dry spells for a long period of time.

c. Contingent drought: they are otherwise called dry spells or august breaks; they are hazardous to agriculture because of their unpredictability. The contingent drought can be divided into early-season, mid-season and late-season drought that is, the period it occurs during the rainy or monsoon season.

iv. Socio economic drought:Socioeconomic drought is associated with the impacts of the three above-mentioned types. It can refer to a failure of water resources systems to meet water demands and to ecological or health-related impacts of drought. It can be noted that more types of drought impacts are related to hydrological drought than to meteorological drought.

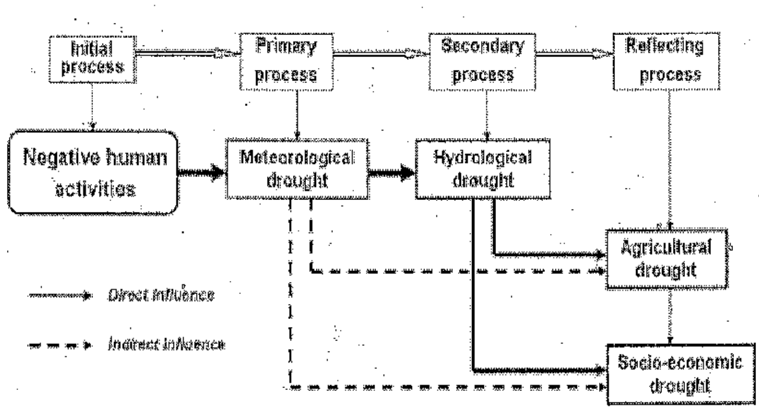

FIG.2 The Sequence of Drought Processes and its Major Types(**Source:© *Springer Science + Business Media B.V. 2008***)

2.2.2 Hydrological Cycle andHydrological Drought

Hydrology is the science of the properties, distribution and effects of water on a planet's surface, in the soil, and underlying rocks and in the atmosphere. Hydrological cycle is a system of cyclic movement of water through its various storage phases and the multitudes of paths along the manystorages, as it moves from the sea to the atmosphere and thence by precipitation to the earth, where it collects in streams and runs back to the sea or percolates into the ground to form groundwater reservoirs. In studying hydrological drought in an area, understanding hydrological cycle is important to know how the groundwater, streamflowis recharged, stored and discharged. In Figure 2, it is discovered that precipitation is the main source of groundwater recharge.

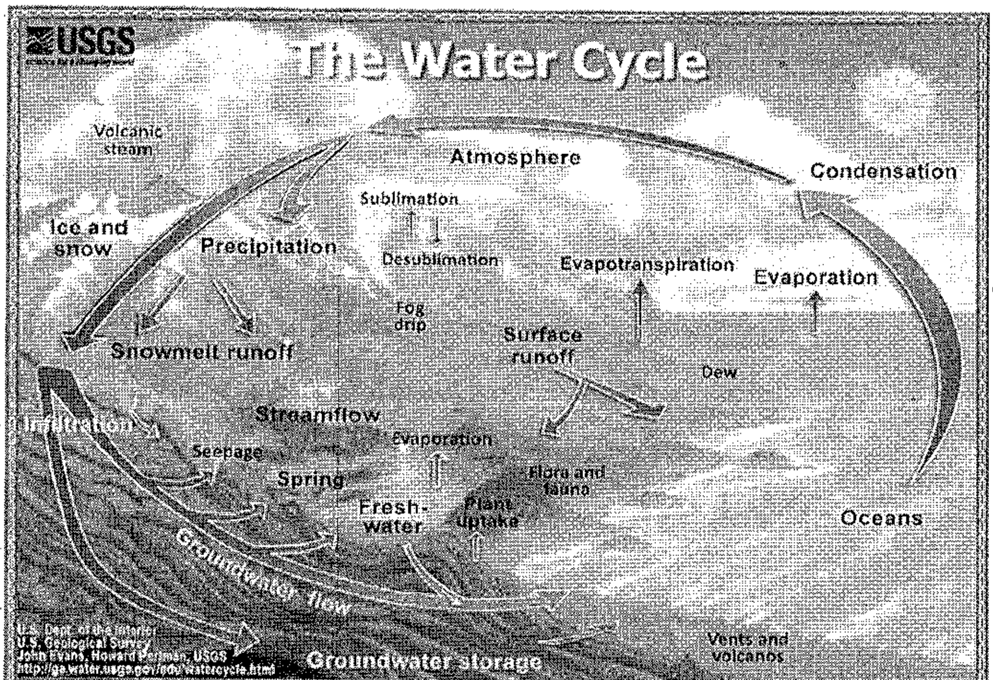

FIG.3 World Hydrologic Cycle (source: U.S. Dept. of Interior, U.S. geological survey)

Hydrological drought refers to a lack of water in the hydrological system; manifesting itself in abnormally low streamflow in rivers and abnormally low levels in lakes, reservoirs, and groundwater.To understand the concept of hydrological drought, certain terms would be considered.The consequences of groundwater droughts are diverse. The direct effects are lower groundwater heads and a decrease in groundwater flow to riparian areas, springs and streams. For shallow groundwater, capillary rise to the vegetation will decrease, which may affect wetlands and crop yield negatively. Also well yields may decrease and shallow wells may even dry up when the groundwater level is low.For this reason, precipitation data will be used to monitor the extent of hydrological drought in this study.

Precipitation is a weather phenomenon in which there is a release of various forms of water on the earth surface from the atmosphere (clouds). Forms of precipitation are rainfall, snow, frost, fogs, hail etc. rainfall is otherwise called precipitation and in Nigeria, rainfall is the form of precipitation common for recharge of both surface and subsurface water.Streamflow and surface water are water bodies on the surface of the land. Surface water range from ponds, streams, rivers, sea and the ocean. The streamflowis recharged by both precipitation and groundwater through seepage. Examples are effluent streams.

The groundwater is the water body below the surface of the land

Components of Hydrological Drought

i. Magnitude (amount of deficiency)

ii. Duration

iii. Severity (cumulative amount of deficiency)

iv. Frequency of occurrence

Hydrological Drought Techniques:

i. Surface water deficit

ii. Groundwater deficit

When groundwater systems are affected by droughts, the first thing affected is groundwater recharge which is precipitation as mentioned earlier, and later groundwater levels, then groundwater discharge decreases. Such droughts are called groundwater droughts and generally occur on a time scale of months to years. A lack of precipitation causes low soil moisture content which, in turn, causes low groundwater recharge. The resulting shortage in precipitation propagates through the hydrological system, causing a drought in different segments of the hydrological system (unsaturated zone, saturated groundwater, surface water). This means that the reaction of groundwater systems to droughts and their performance under drought conditions become increasingly important. [7, 8]

The occurrence of drought is a gradual process; it begins from both the anthropogenic and natural activities that causes climate change and subsequently global warming, which result in extremities, such as flood and drought. In Fig. 2.1, drought begins as from the meteorological drought, which is not prolong but causes deficit precipitation, it continues direct to hydrological drought, the hydrological drought causes either socio economic drought or agricultural drought, which leaves the area it affects vulnerable to its impact. The Hydrological cycle is a function of precipitation;therefore hydrological drought is also a function of precipitation deficit.

Recent studies and research of drought in relation to the aspect of hydrology and meteorology in Nigeria since the period of the Sahel drought which began in 1969 concentrated on the socio-economic aspects of environmental degradation. Such studies focused on drought, desertification, their causative mechanisms, factors and possible methods of abatement and control The Sahel drought that started in 1969 which lingered on till 1973 affected northern Nigeria and the calamity have had tremendous socio-economic impacts on the area where pressure on available resources is on the increase in the face of a fluctuating rainfall regime. The persistence of drought in parts of northern Nigeria during 1970s, 1980s and 1990s has been attributed to the prevalence of a stagnated anti-cyclonic circulation of the tropical atmosphere over areas that normally should be exposed to rising arm of tropical Hadley Cell Circulation by mid-summer.

Large areas of Northern Nigeria falling within the Sahel and Sudan ecological zones between latitude 9-14^{O}N are prone to recurrent droughts in one form or the other. The area is estimated to be about 38% of the total land area of Nigeria and it is the grain belt of the country populated by small scale subsistence farmers and nomadic livestock herders.Drought influences water availability, which is projected to be one of the greatest constraints to economic growth in the future. Reduced annual average rainfall and its run-off would increase desertification in Nigeria. Most of the rivers and streams in the drought prone areas flow into Lake Chad. Drought, therefore exacerbate the shrinking of the lake. The rivers in addition to contributing in recharging Lake Chad are catchments to several dams built for irrigation and domestic water supply.

2.3 Geographical Information System and Hydrological Drought

A Geographical Information System is a computerized system for input, storage, management, display and analysis of data that can be precisely linked to a geographic location. It allows mapping, Modelling, querying, analysing and displaying large quantities of diverse data, all held together within a single database. GIS has been applied to various field of science. Today's challenges require geographic approach in Climate Change, Urban Growth, Sustainable Agriculture, Water Quality and Availability, International and National Security, Energy, Epidemiology/Disease Tracking, Natural Hazards: Earthquakes, Weather Events etc. so it is also important that hydrological drought is approached geographically.

2.4 Environmentaland Social Implication of Hydrological Drought

Environmental impacts, such as lower water levels in reservoirs, lakes and ponds as well as reduced flows from springs, increased pollution of surface water and streams would reduce the availability of feed and drinking water and adversely affect fish and wildlife habitat. It may also cause loss of forest cover, migration of wildlife and their greater mortality due to increased contact with agricultural producers as animals seek food from farms and producers are less tolerant of the intrusion. A prolonged drought may also result in increased stress among endangered species and cause loss of biodiversity.

Reduced stream flow and loss of wetlands may cause changes in the levels of salinity. Increased groundwater depletion, land subsidence, and reduced recharge may damage aquifers and adversely affect the quality of water (e.g., salt concentration, increased water temperature, acidity, dissolved oxygen, turbidity). The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological throughput of the landscape. [11] leading to direct danger for amphibian life, the drying out of wetlands, more and larger fires, higher deflation intensity, worse health of trees and the appearance of pests and dendroid diseases

Social impact when hydrological drought occurs, there is a tendency of food insecurity whereby, there is scarcity in food available to feed the people per day and that causes malnutrition and starvation and consequently mortality. Also, hydrological drought which affects water quality can cause waterborne disease outbreak such as cholera etc. it is possible hydrological drought cause recession, that is, a collapse in a country's economy, recession brings poverty and poverty increases the risk of vulnerability to the affected persons or community.Economical losses includes; lower agricultural, forests, game and fishing output, higher food-production costs, lower energy-production levels in hydro plants, losses caused by depleted water tourism and transport revenue, problems with water supply for the energy sector and for technological processes in metallurgy, mining, the chemical, paper, wood, foodstuff industries etc., disruption of water supplies for municipal economies.

ThereforeSocial costs include the negative effect on the health of people directly exposed to this phenomenon, possible limitation of water supplies, increased pollution levels, high food-costs, pressure caused by failed harvests, etc. This explains why droughts and fresh water shortages operate as a factor which increases the gap between developed and developing countries.

The impact of hydrological drought vary in vulnerability. For example, subsistence farmers are more likely to migrate during hydrological drought because they do not have alternative food-sources. Areas with populations that depend on water sources as a major food-source are more vulnerable to famine.

2.5 Causes of Hydrological Drought

i. Precipitation deficiency

Hydrological Droughts take place whenever there is prolonged periods of rainfall deficiency for a season or more and usually when there is a lack of anticipated rainfall or precipitation. When a region goes for long periods without any rain, especially for more than a season, then the situation leads to dry conditions and water deficiency that qualifies as drought. Average prevalence of high-pressure systems, winds carrying continental, rather than oceanic air masses & ridges of high-pressure areas can trigger drought also.

ii. Global Warming

Human actions contribute more of emissions of greenhouse gases into the atmosphere thus resulting in the continued rise of the earth's average temperatures. Consequently, evaporation and evapotranspiration levels have risen, and the higher temperatures have led to wildfires and extended dry spell periods. The global warming situation tends to exacerbate the drought conditions. Some of the worst droughts witnessed in sub-Saharan Africa have been associated with global warming and climate change.

iii. Human Activities

Human activities play a relatively significant role in the management of the water cycle. Human acts such as deforestation, constructions, and agriculture negatively impact the water cycle. Trees and vegetation cover are essential for the water cycle as it helps to limit evaporation, stores water, and attracts rainfall.

In this sense, deforestation which is clearing vegetation cover and cutting down trees increases evaporation and lessens the ability of the soil to hold water leading to increased susceptibility of desertification. Deforestation can also influence the occurrence of dry conditions since it reduces forest's watershed potential. Construction and agricultural activities may as well reduce the overall supply quantity of water, resulting in dry spells. over farming, excessive irrigation, soil erosion, urbanization etc. trigger Drought, Greenhouse gas emission, climate change effects, Global warming.

iv. Dry season

Within the tropics, distinct, wet and dry seasons emerge due to the movement of the Inter-tropical Convergence Zone or Monsoon trough. The dry season greatly increases drought occurrence, and it is characterized by its low humidity, with watering holes and rivers drying up. Because of the lack of these watering holes, many grazing animals are forced to migrate due to the lack of water and feed to more fertile spots. Examples of such animals are zebras, elephants. Because of the lack of water in the plants, bushfires are common. Since water vapour becomes more energetic with increasing temperature, more water vapour is required to increase relative humidity values to 100% at higher temperatures (or to get the temperature to fall to the dew point). Periods of warmth quicken the pace of fruit and vegetable production, increase evaporation and transpiration from plants and worsen drought conditions.

v. Drying out of Surface Water Flow

Lakes, rivers, and streams are the primary suppliers of downstream surface waters in various geographical regions around the globe. In extremely hot seasons or because of certain human activities, these surface water flows may dry out downstream contributing to drought – meaning the demands for water supply become higher than the available water.Irrigation systems and hydro-electric dams are some of the human activities that can significantly diminish the amount of water flowing downstream to other areas.

2.6 Literature Review

Drought event also called the creeping disaster, affects a wide range of area and slowly develops unnoticed. Hydrological drought affects a wide range of sectors, most especially the ecological sector and economic sector. Examples of sectors affected are drinking water supply, crop production(irrigation), waterborne transportation, electricity production(hydropower or cooling water) and recreation (water quality). [14]

Currently, there is increasing awareness of drought and related hazards (heat waves and wildfires), resulting in more research on the topic in international projects like WATCH, DEWFORA and four projects started around 2014 in UK, That is, MarRIUS, IMPETUS, DRY, and Historic Droughts etc.

One of the most essential scientific progresses is the rising view that drought cannot simply be characterized by a lack of rainfall, and many recent papers show the increased complexity of drought including hydrological processes. However, there are still many reservations in our knowledge about hydrological drought. Many have argued also that hydrological drought deserves more attention due to its important link to drought impact. [14]

The determination of the extent of impact of hydrological drought has been determined through many factors rainfall, evapotranspiration, temperature, relative humidity, streamflow, catchment discharge, groundwater discharge: the following listed above are otherwise called hydrological drought indices. Overtime, they have been computed and evaluated to quantify drought.

Hydrological drought is an environmental hazard,that becomes a disaster when the community affected is vulnerable to it. In developing countries, it is almost always too late to discover a creeping disaster like hydrological drought, so it is eminent to understand disaster risk management and the processes involved so that the problem can either be controlled or mitigated. In preparation for risk management, it is important to constantly check or assess the possibility of an hazard or a disaster occurring in every region per time.

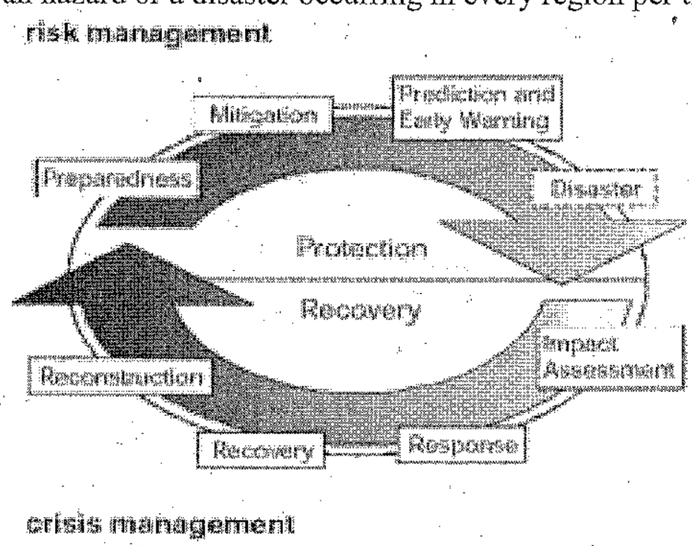

FIG.4 The cycle of disaster management (National Drought Mitigation Center, University of Nebraska-Lincoln; Wilhite and Svoboda, 2005)

In general, meteorological drought onset is first, followed by agricultural, then hydrological. The sequence is similar for recovery. Although, this study is aimed at the impact assessment aspect of the cycle in risk management, it will be focusing on the extent of the impact using precipitation data as the only indices.

There are several studies that have been carried out on hydrological drought, the Nigerian Meteorological Agency carry out monthly assessment on flood and drought using rainfall data only, and display in a bulletin, they display using a map, the meteorological drought, agricultural drought, hydrological drought, and annual drought. They also analyse the impacts, issue warning when a hazard risk is at the verge of rising to become a disaster. But this study is drawing conclusions from the accumulation 30 years daily rainfall.

2.6.1 Drought Control Measures

i. Agroforestry:

Planting trees in and around farms reduces soil erosion by providing a natural barrier against strong winds and rainfall. Tree roots also stabilise and nourish soils. Encourage farmers to grow trees as windbreaks or as part of combined forage and livestock production, among other uses.

ii. Soil management:

Alternating crop species leads to soil amendments, allows soil periods of rest, restoresnutrients, and also controls pests. Soil amendments help soils retain moisture near the surface by providing a direct source of water and nutrients to plant roots, even in times of drought.

iii. Increasing diversity:

Mono-cropping often exposes crops to pests and diseases associated with overcrowding, and can increase market dependence on a few varieties. Fruits and vegetables as intercrop is an ideal method improving food production:

Improved animal husbandry practices can increase milk and meat quantities without the need to increase herd sizes or associated environmental degradation.

iv. Agro-ecological and organic farming:

Organic and agro-ecological farming methods are designed to build soil quality and promote plant and animal health in harmony with local ecosystems. Research shows that they can increase sustainable yield goals by 50 per cent or more with relatively few external inputs. In contrast, genetic engineering occasionally increases output by 10 per cent, often with unanticipated impacts on crop physiology and resistance.

v. Supporting small-scale farmers:

Small-scale producers are affected more acutely by natural disasters and fluctuating commodity prices, even though they are more likely to be involved in food production. Government extension and support services should be adjusted to alleviate this deficit. Small and marginal farmers are to be extended subsidy in farming, seeds.

vi. Re-evaluating ethanol subsidies:

Reduce mechanised farming as much as possible to bring down cost. Encouraging cleanenergy alternatives to crop-based bio-fuels will increase the amount of food available for consumption, both at home and abroad.

vii. Agricultural Research and Development (R and D):

The research and development of farming has to take a determined step and help agriculture with innovative measures. The initiative has to be taken by the government as private companies, by virtue of their constitution are often legally bound to maximise economic returns for investors,raising concerns over scientific independence and integrity. Increased government funding and support for agricultural research, development, and training programs can help address issues such as hunger, malnutrition, and poverty without being compromised by corporate objectives.

2.7 Hydrological Drought in the North-East: Management and Control

According to an article "Drought Conditions and Management Strategies in Nigeria." .

Arid and semi-arid areas in Northern Nigeria are becoming drier and Sahara Desert characteristics are encroaching fast into the country. We already have an increasing incidence of diseases, declining agricultural productivity, scarcity of water supply and rising number of heat waves.Declining rainfall in already desert-prone areas in Northern Nigeria is causing increasingdesertification. The Northern part of Nigeria is endowed with a large expanse of arable land that has over the years provided a vital resource for agriculture and other economic activities, but the Sahara desert is advancing Southward at the rate of 0.6km every year [12].

Every part of Nigeria is faced with drought, but the part more susceptible to drought is the northern region, and more specifically the north-east. In 2004, Yobe state amongst all other northeast state was affected by drought and locust invasion, which caused heavy loss of crops, livestock, and fodder for livestock, drying up of rivers, ponds, and other water bodies and resulted in the increase of aridity in the area.

2.8Short Term Measures to Mitigate the Effects of Drought in the Northeast 2004

i. Emergency relief materials were dispatched to affected communities in form of food stuff, medication and tents.

ii. Provision of feed supplement for livestock.

iii. Provision of irrigation and water pumps.

iv. Rehabilitation of degraded Oases in some local government areas.

v. Establishment of rangeland of about 20 hectares in each of the local government areas.

vi. Survey and demarcation of 2 hectares drought rehabilitation centre in each of the local government areas to manage refugees.

2.8.1 Drought Alleviating Practices in the northeast

Responses embarked by government include the following:

i. Institutional Arrangements leading to the creation of Federal Ministry of Environment and the Drought and Desertification Amelioration Department.

ii. Management of Water Resources by the establishment of River Basin Development Authorities to promote sustainable utilization of water resources in the dry land.Use of Drought tolerant (hybrids) crop varieties in the drought prone regions by farmers.

iii. Production of National Action Plan(NAP) as part of the National Economic and Environmental Protection plan and making the NAP Coherent with other environmental strategy and planning framework

iv. Linking the NAP with National, intra-Regional and local approaches. Measures taken within the framework of NAP include adequate Diagnosis of past experience

v. New projects/strategies initiated as part of implementation process since the last NAP report in 2002 includes:

a) Sand dune fixation.

b) Rangeland establishment.

c) Oasis inventory and rehabilitation.

d) Drought forecasting.

e) Formulation of drought and desertification policies.

f) Development of National drought preparedness plan.

g) Development of Drought and Desertification policy.

h) Rainwater harvesting.

i) The Great Green Wall program to halt desert encroachment.

j) Preparation and implementation of the National Biodiversity Strategy and Action Plan (NBSAP) to halt the loss of biodiversity.

2.9 Methods of Measuring Drought

In order to quantify drought, drought indices and indicators are used, so as to obtain the magnitude of its impact on the environment, and its elements.Drought indices are variables or parameters used to describe drought situations. Examples include precipitation,temperature, streamflow, groundwater and reservoir levels and soil moisture.Drought indicators are typically computed numerical representations of drought severity, evaluated using climatic or hydro-meteorological inputs including the indicators listed above. They aim to measure the qualitative state of droughts on the landscape for a given time period. Indices are technically indicators as well. Monitoring the climate at various timescales allows identification of short-term wet periods within long-term droughts or short-term dry spells within long-term wet periods. Indices are used to provide quantitative assessment of the severity, location, timing and duration of drought events.

Severity refers to the departure from normal of an index. A threshold for severity may be set to determine when a drought has begun, when it ends and the geographic area affected. Location refers to the geographic area experiencing drought conditions. The timing and duration are determined by the approximate dates of onset and cessation. The interaction of the hazard event and the exposed elements (people, agricultural areas, reservoirs and water supplies), and the vulnerabilities of these elements to droughts, determines the impacts. The drought indicators are classified according to their efficiency for different types of drought.

Table 2 Major indices of hydrologic drought (SOURCE: © Springer Science + Business Media B.V. 2008)

Index	Elements	Criteria
Precipitation	Volume	Long-term decrease in rate
	Intensity	Intensive rainfall peaks
Rivers and stream	Stream course	Shallow water level
		High chlorophyll (and pollutants) content
		Low transported bed load
	Discharge	Decrease in discharge at outlets
		Low water velocity
	Length	Decrease in total tributaries length
		Intermittency in water flow in some courses
Spring	Discharge	Decrease in discharge
		Quality deterioration
	Permanency	Total disappearance of some springs
		Discharge intermittency
Lake and reservoirs	Water level and quality	Lowering in water level
		Surrounded by mud cracks and sediments
		Quality deterioration
Snow	Areal coverage	Decrease in areal coverage
		Low geographic distribution
		Lower snowfall frequency
	Thickness & density	Lowering in thickness
		Lowering in density
Groundwater	Pumping	Decrease in yield from wells
		Flow intermittency
		Quality deterioration
	Water table	High depletion in water level
	Water quality	Saltwater intrusion
Soil moisture	Water content	Decrease of water content below normal level

2.9.1 Classification of Drought Indicators

i. Meteorology indicators

ii. Soil moisture indicator

iii. Hydrology indicator

iv. Remotely sensing indicators

v. Composite and modelled indicators

2.9.2 Examples of Drought Indicators

i. Standardized Precipitation Index (SPI)

It is a powerful, flexible index that is simple to calculate. In fact, precipitation is the only required input parameter. In addition, it is just as effective in analysing wet periods/cycles as it is in analysing dry periods/cycles Precipitation is the only input parameter.

The strengths of Standardized Precipitation Index are that; it can be computed for different time scales, provide early warning of drought and help assess drought severity. Its weaknesses are that it can only quantify the precipitation deficit; values based on preliminary data may change, and values change as the period of record grows. [6]

ii. Palmer Drought Severity Index (PDSI)

It is less simple to calculate. Information on the water holding capacity of soils can be used, but defaults are also available. A serially complete record of temperature and precipitation is required. It was developed mainly as a way to identify droughts affecting agriculture, it has also been used for identifying and monitoring droughts associated with other types of impacts.The use of soil data and a total water balance methodology makes it quite robust for identifying drought. The weaknesses of the Palmer Drought Severity Index lie in the need for serially complete data which causes problems. It has a timescale of approximately nine months, which leads to a lag in identifying drought conditions based upon simplification of the soil moisture component within the calculations. Seasonal issues also exist, as it does not handle frozen precipitation or frozen soils well. [9]

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Materials

The material used in this study is valid because they are data observed and recorded by professionals in weather station owned and managed by the Nigerian meteorological agency, they record precipitation data with automatic rain gauges and back them up with weather radar to enable precision and accuracy of result and minimise error.

3.1.1 Data Used

The data to be used for this study are of secondary source, the daily precipitation data collected from archives of the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. Data for all the rainfall stations in this study are available between 1981 and 2010 (30 years).

The stations in each state is located as follows Yola station in Adamawa (12.47'N 9.23'E), Potiskum station in Yobe state (11.03'N 11.7'E), Gombe station in Gombe state (11.17'N 10.27'E), Maiduguri station in Borno state (13.08'N 11.85'E) and Bauchi station in Bauchi State (9.82'N 10.28'E).

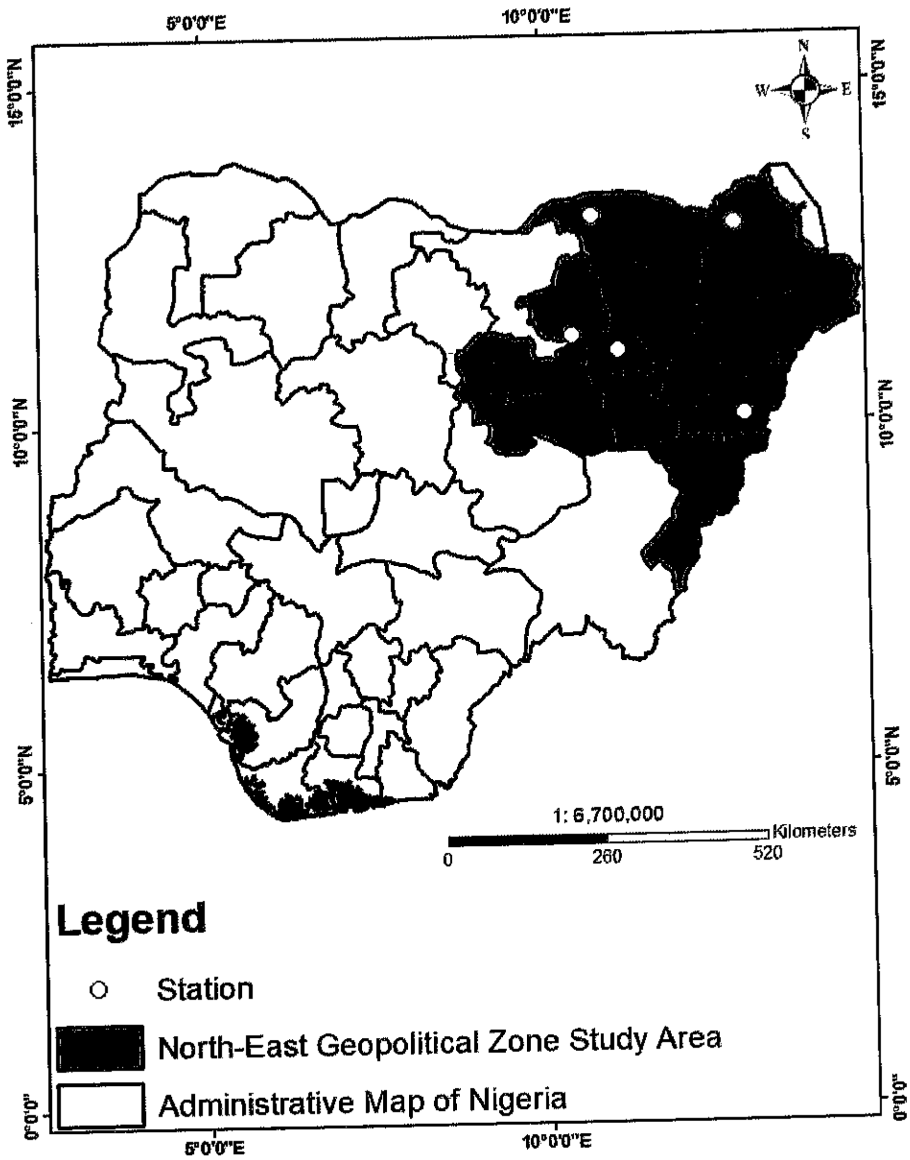

FIG.5 Administrative Map of Nigeria showing NIMET Locations

3.1.2 Software Used

The software used for this study are Microsoft excel and standardized precipitation index software.

3.1.3 Microsoft Excel

Microsoft Excel is a spreadsheet developed by Microsoft for Windows, macOS, Android and iOS. It features calculation, graphing tools, pivot tables, and a macro programming languagecalled Visual Basic for Applications. It has been a very widely applied spreadsheet for these platforms. Excel forms part of Microsoft Office.The Microsoft excel is used in this project to compute the sum of daily precipitation values into monthly rainfall values. It was also used to compare the SPI values derived from the SPI software, and the representation on charts.

3.1.4 The Standardized Precipitation Index software

The SPI quantifies the precipitation deficit for multiple timescales. These timescales, reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee and others (1993) originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales.A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The SPI software calculates the standardized precipitation index using the precipitation as the only index. The program used to compute the standardize precipitation index was obtained from the website below.

Table 3 Standardized Precipitation index values and interpretation

2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

3.2 Methodology

The soft wares used in this study are in different stages to carry out different procedures that will bring an end result which is to quantify hydrological drought by standardizing precipitation and representing it for visual analysis. First of all, the Microsoft excel is used to arrange and compute the data, then it is exported to the notepad, which enables the input file to be saved in text format, the standardized precipitation software runs the input file and output the standardized precipitation in different timescale, then it exported back to Microsoft excel. These soft wares form the basis of evaluation of hydrological drought in this study.

3.2.1 Data Processing

Microsoft excel – the Microsoft excel arranges the precipitation data for each station and sums the daily data into monthly data, there by grouping each year's data into months. The arrangement of the data is shown in **Plate1.** It is saves as a text and opened in the in the notepad, the notepad serves as a platform for displaying the input and the output file.

Standardized precipitation index software – the software operates based on the formula o the standardized precipitation index, formulated by Mckee et al., in 1993 and 1997.

$$\mathrm{SPI} = \frac{(R_{ij} - \bar{r}_i)}{\sigma_i}$$

$$\sigma_i = \sqrt{\frac{\sum_1^n (R_{ij} - \bar{r}_i)}{N}}$$

where;

SPI = Standard Precipitation Index for station i and year j,

R_{ij}= annual rainfall for station i and year j,

r_i= mean annual rainfall at station i,

σ_i = standard deviation of the annual rainfall for station i,

N = number of specific years for sample station.

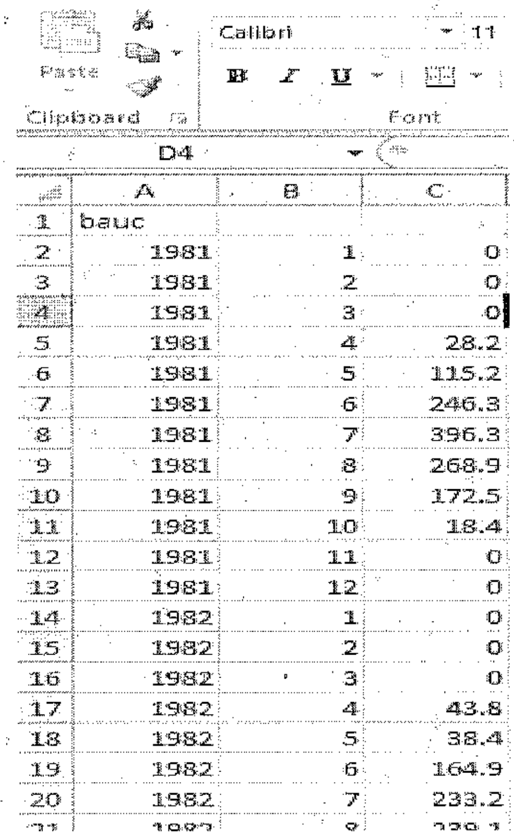

Plate 1 List of Daily Data in the Archives

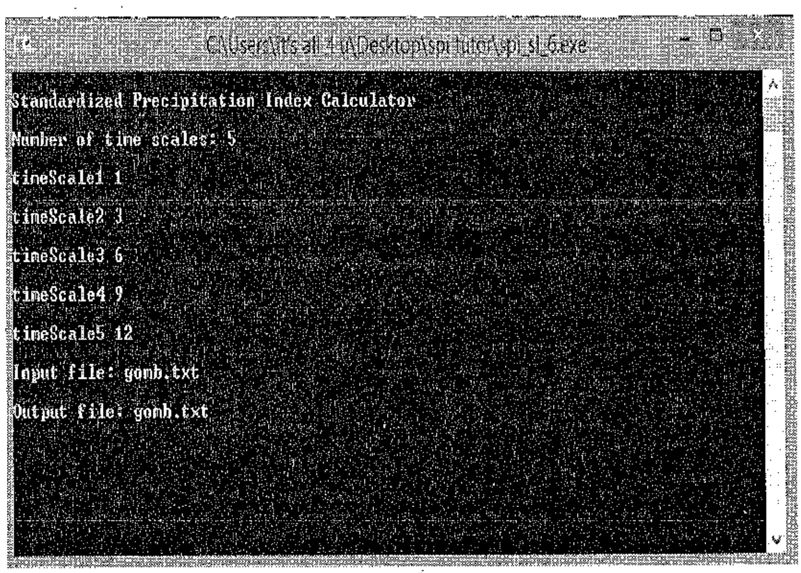

Plate 2 Standardized Precipitation Index Software

3.2.2 SPI Time Scale Interpretations

1-month SPI reflects relatively short time soil moisture during growing seasons; it is more accurate because the distribution has been normalized.1 month SPI addresses meteorological drought.

3-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. This time scale addresses both Meteorological and Agricultural droughts.

6-month SPI can be very effective in showing the precipitation over distinct seasons. 6-month SPI may also begin to be associated with anomalous stream flows and reservoir levels; this timescale is good for monitoring hydrological drought.

12-month SPI reflects long-term precipitation patterns. These timescales tied to stream flows, reservoir levels, and even groundwater levels at longer timescales.

3.2.3 Representation of Processed Data

The processed data are displayed on a chart, in the Microsoft excel to establish trends and mark areas of hydrological drought and its extent in each region over the years used as a case study in the study.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Standardized Precipitation Index

The average Standardized Precipitation Index of 6 months and12month time scale over the five (5) stations in the north east which depicts the anomalous changes in stream flow and reservoirs level, it also monitors hydrological drought and reflects the long term changes in precipitation patterns as shown in Table3.

The average standardized precipitation index over this region shows fluctuating disparities in both temporal and spatial scale. This helps in understanding that the hydrological drought extent differ in time and space. The SPI-6 timescale is for monitoring hydrological drought because it depicts the anomalous stream flow and reservoir levels, SPI-12 timescale are associated with long-term precipitation patterns such as stream flow patterns and reservoir level, and groundwater level etc.

4.2 Comparison of the Hydrological Drought in Various Stations

The comparison of the five (5) stations in the region clearly presents the differences in the hydrological drought extent as expressed in index in **Appendix 1**

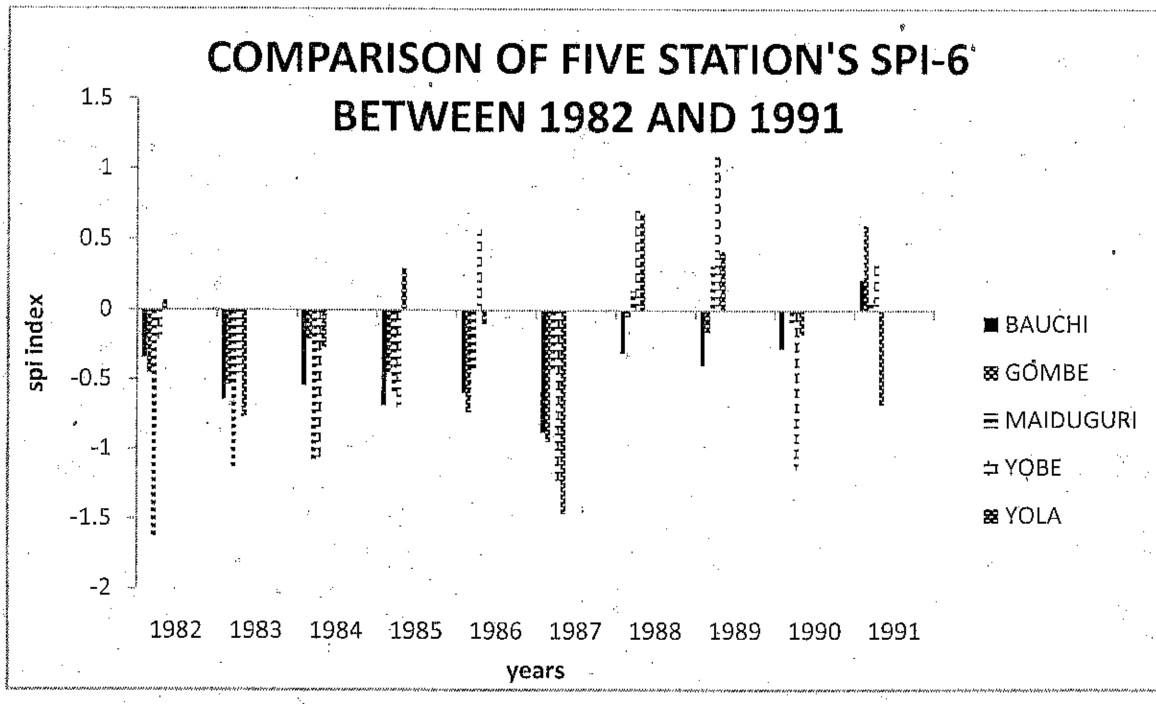

FIG.6 Chart showing the comparison of the average hydrological drought of the entire five stations between 1982 and 1991

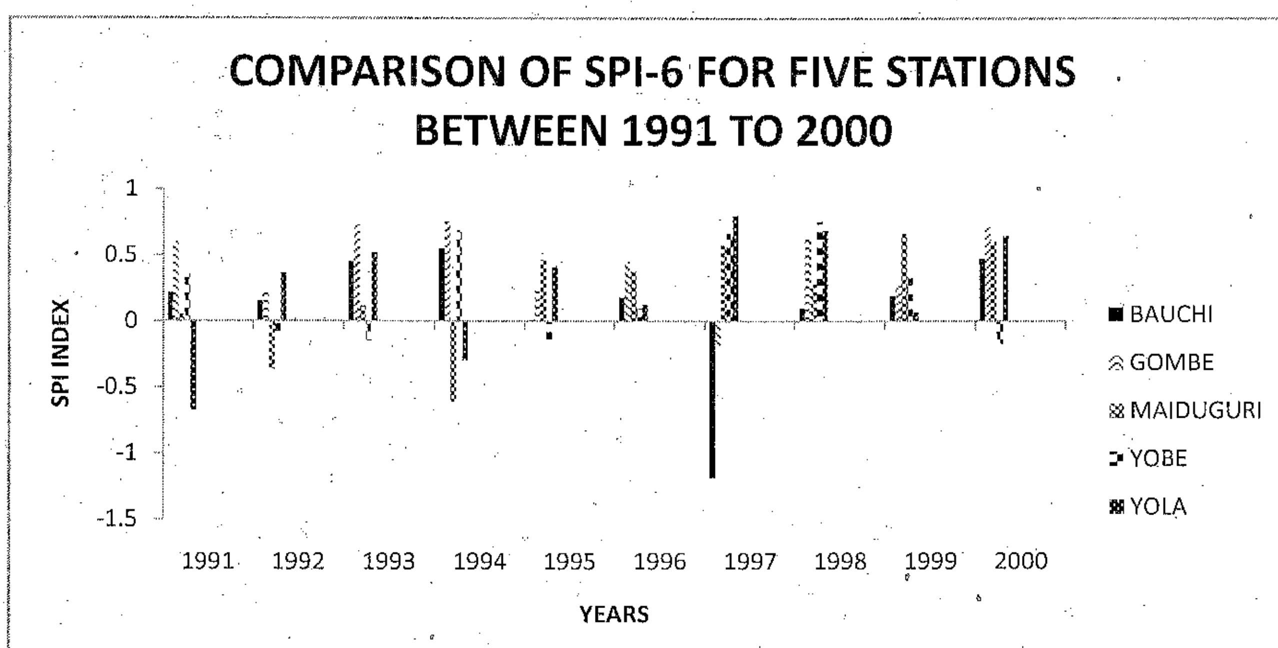

FIG.7 Chart showing the comparison of the average hydrological drought of the entire five stations between 1991 and 2000

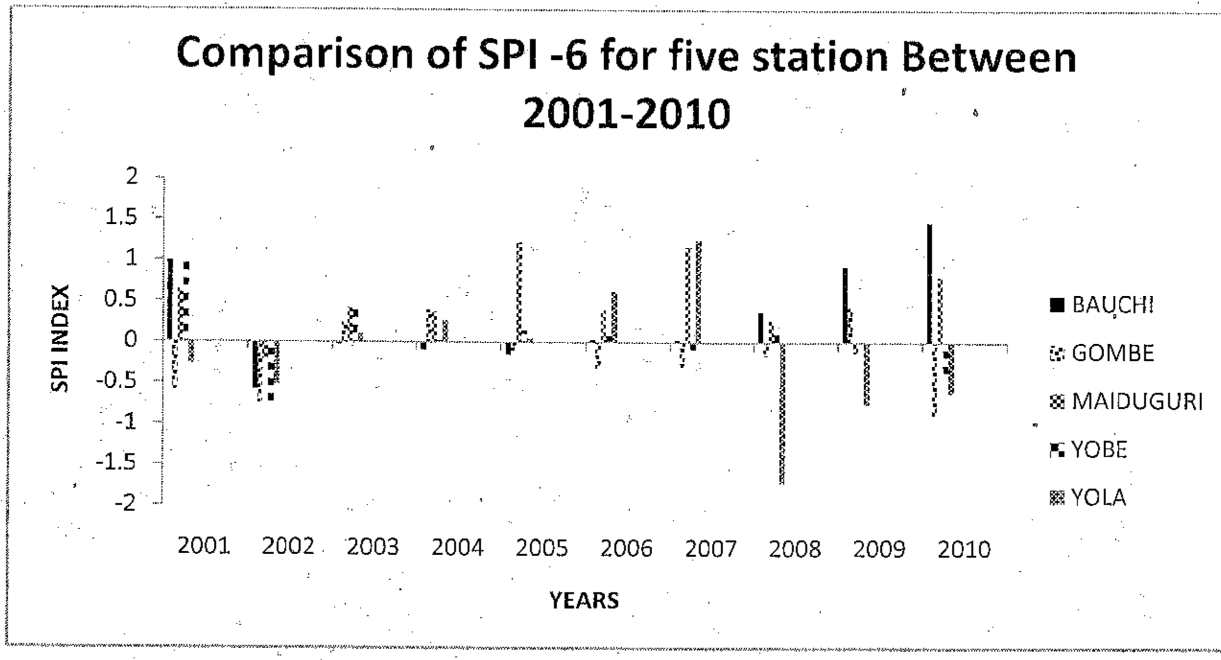

FIG.8 Chart showing the comparison of the average hydrological drought of the entire five stations between 2001 and 2010

4.3 Station Charts and Interpretation

4.3.1 BauchiStation Charts and Interpretation

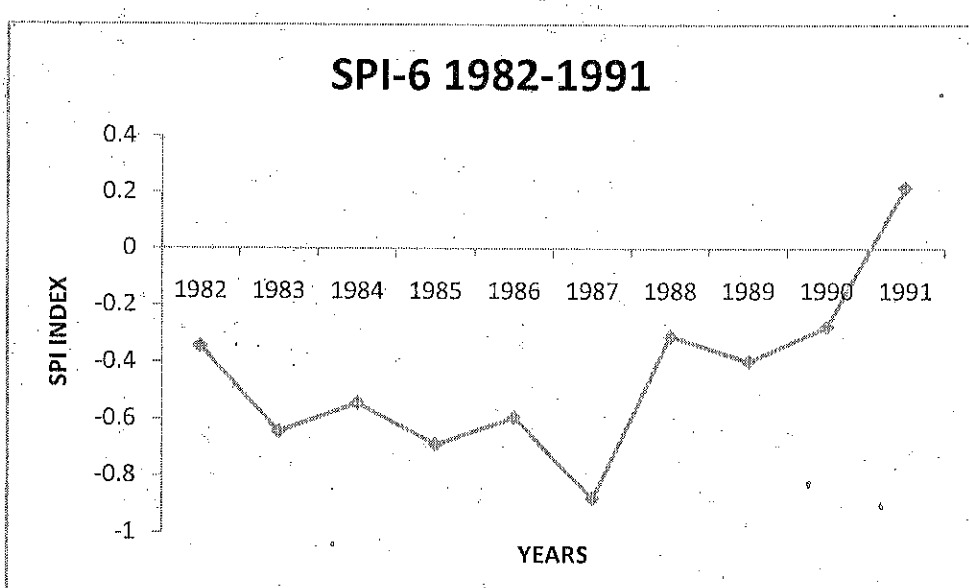

FIG.9 chart showing the average hydrological drought over bauchi between 1982 and 1991

The average hydrological drought between 1982 and 1991 was near normal, which does not pose any hazard to the environment. The extent of hydrological drought did not pose any threat to the Bauchi environment in the North east region of Nigeria.

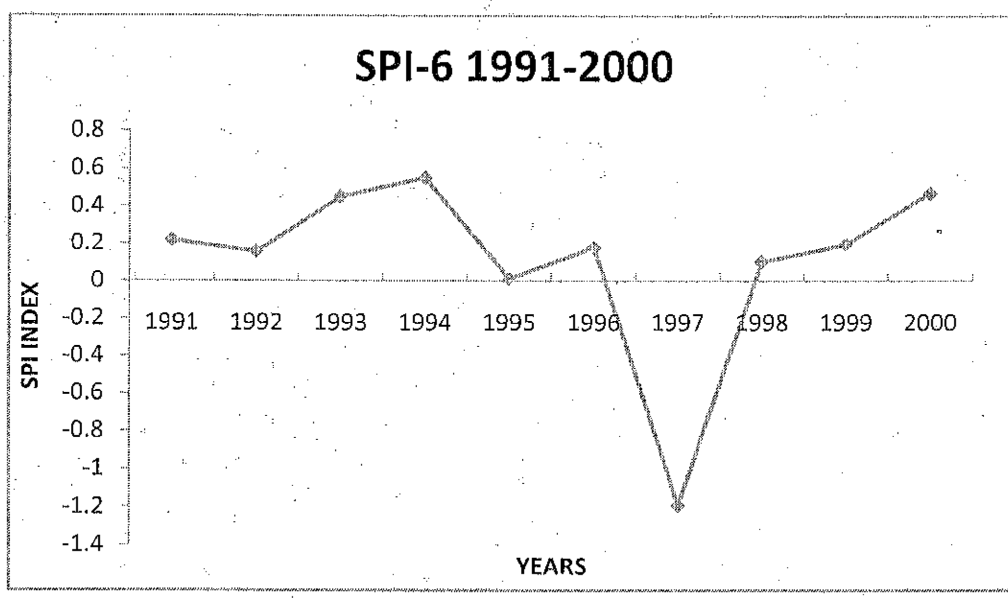

FIG.10 Chart showing the average hydrological drought over bauchi between 1991 and 2000

The average hydrological drought extent between 1991 and 1996 and between 1998 and 2000 was near normal, but in in 1997, there was a sudden increase in the extent of hydrological drought to a mild drought level or a moderate drought.

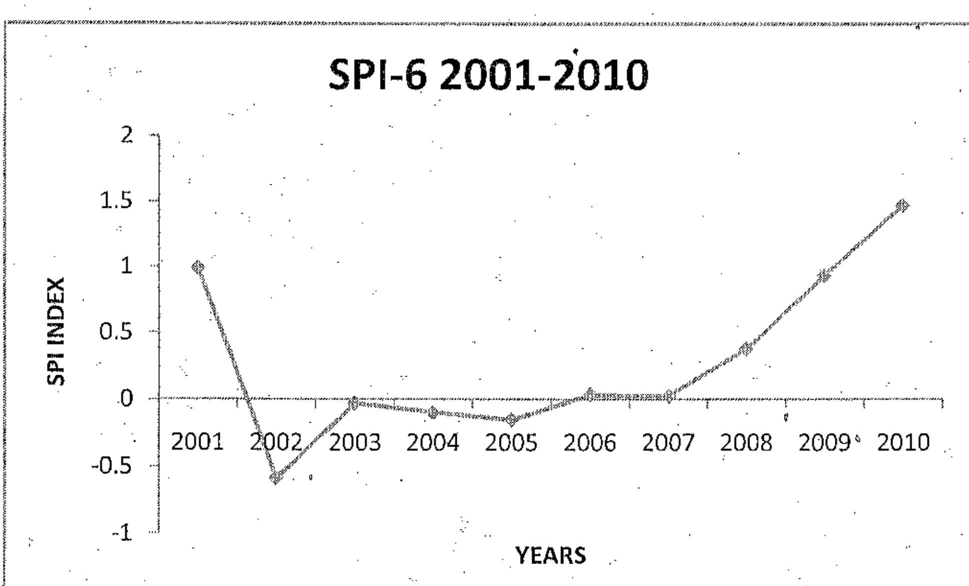

FIG.11 Chart Showing Average hydrological drought over Bauchi between 2001 and 2010

The extent of average hydrological drought in this region between 2001 and 2010 is **near normal** and the others are **moderately wet.**

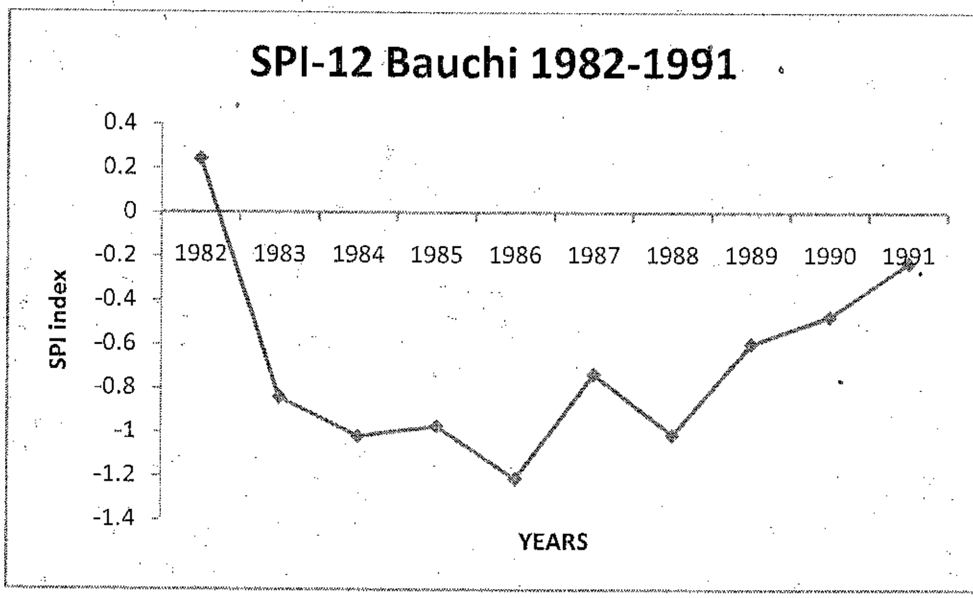

FIG.12 Chart Showing the Average Long Term Hydrological Drought over Bauchi between 1982 and 1991

The average long-term hydrological drought between 1982 and 1991 ranges between **near normal** and **moderately dry.**

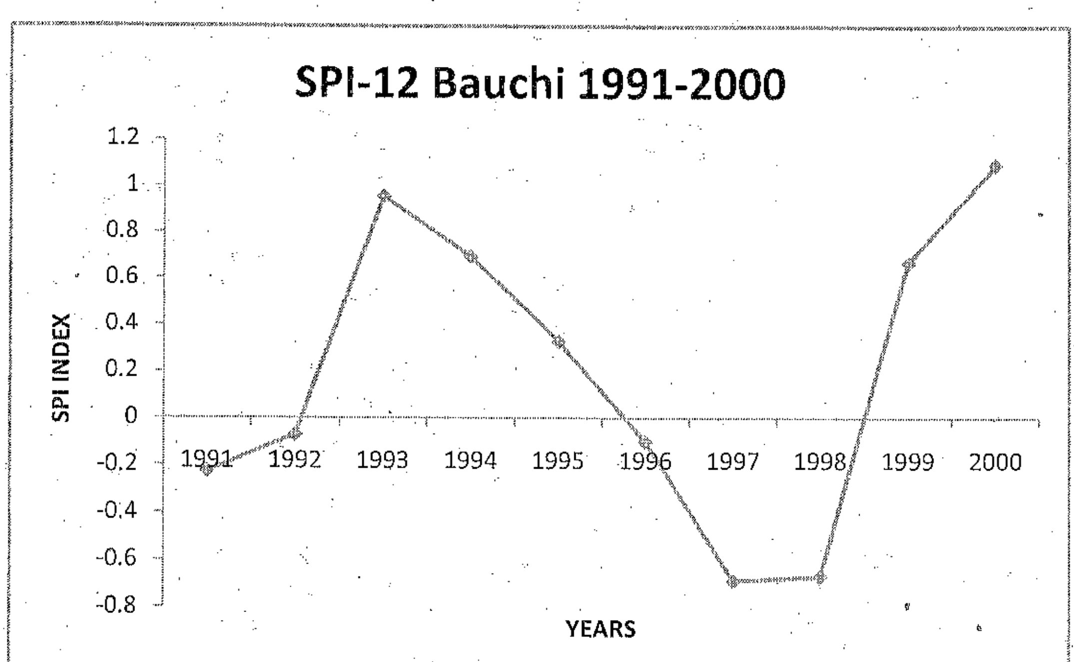

FIG.13 chart showing the average long term hydrological drought over between 1991 and 2000

The average long-term hydrological drought between 1991 and 2000 is **near normal.**

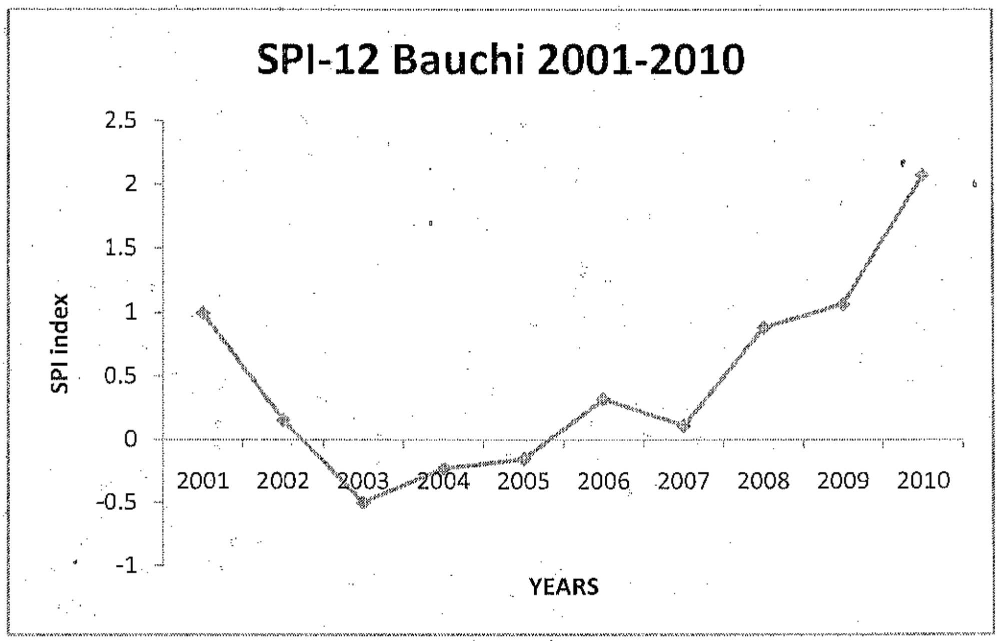

FIG.14 chart showing the long-term hydrological drought over bauchi between 2001 and 2010

The average long term hydrological drought range between **near normal and non-existent(moderately wet)** between 2001 and 2010

4.3.2 Gombe Station Area Charts and Interpretation

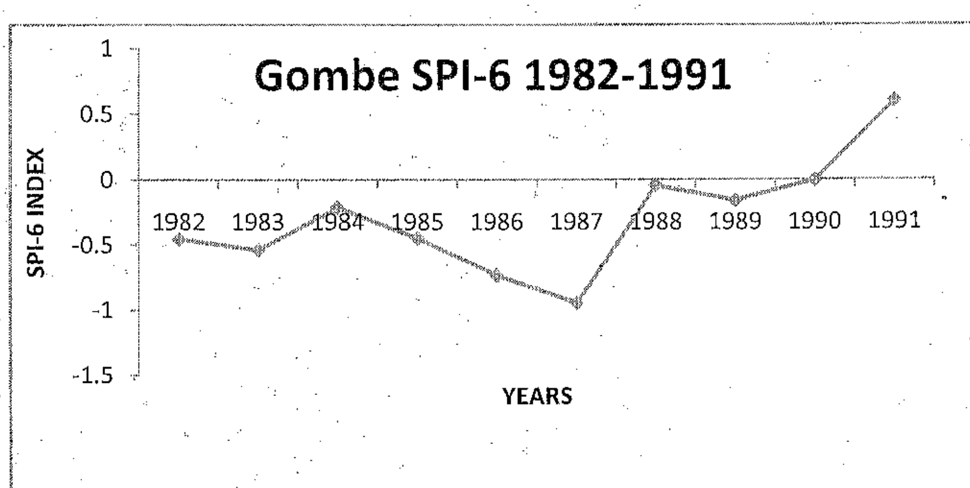

FIG.15 chart showing the average hydrological drought extent over Gombe between 1982 and 1991

The average hydrological drought extent was between theyear 1982 and 1991 ranged between **moderate drought** and **near normal condition.**

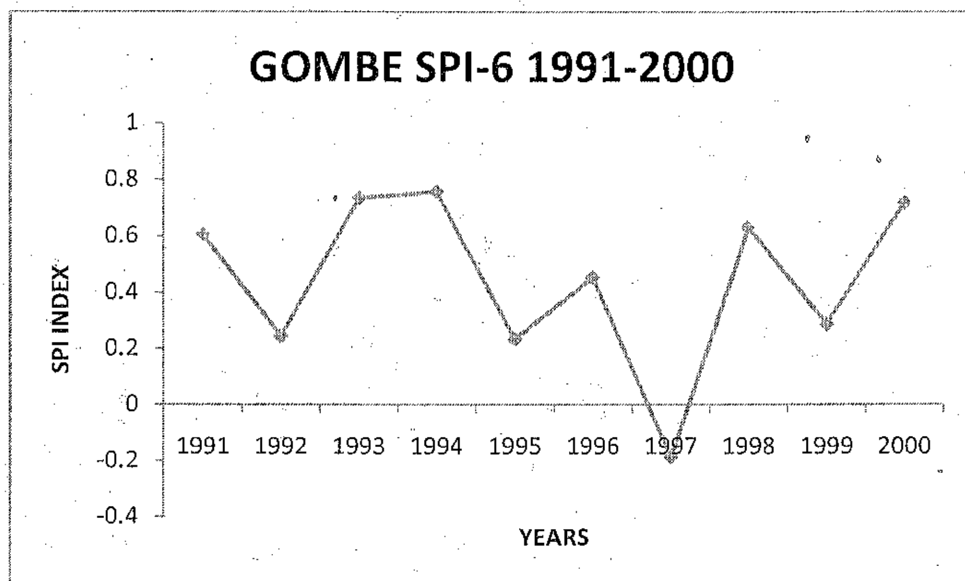

FIG.16 chart showing average hydrological drought over Gombe between 1991 and 2000

The average hydrological drought between 1991 and 2000 is **near normal.**

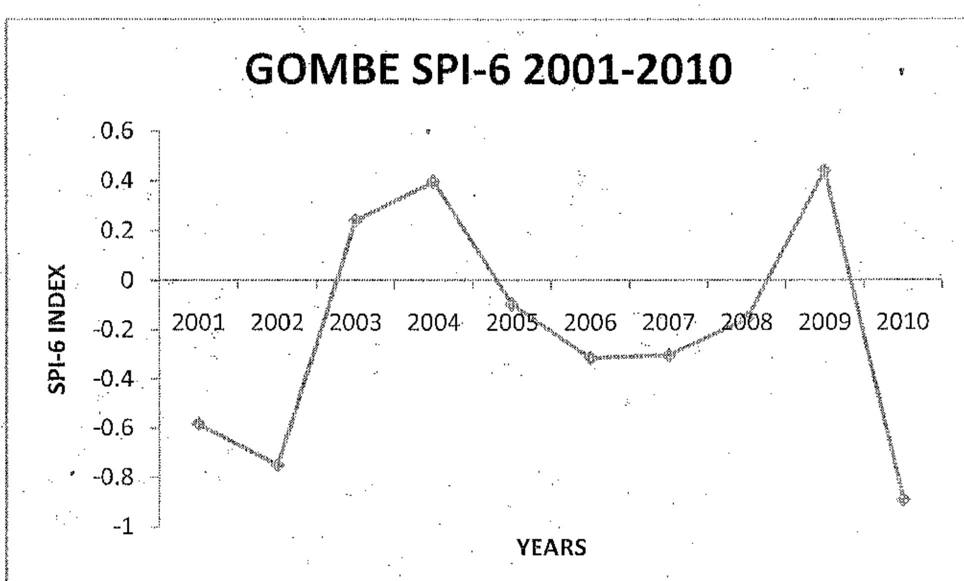

FIG.17 Chart showing the average hydrological drought over Gombe between 2001 and 2010

The average hydrological drought extent between 2001 and 2010 is **near normal.**

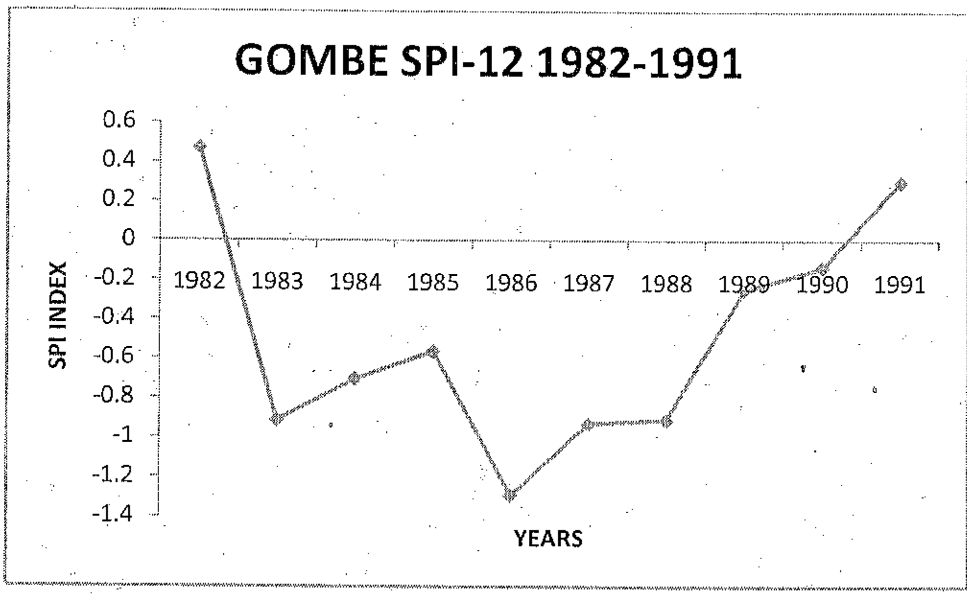

FIG.18 Chart showing the long-term hydrological drought in Gombe station between 1982 and 1991

The extent of the long-term hydrological drought ranges between **near normal** and **moderately dry** from 1982 to 1991.

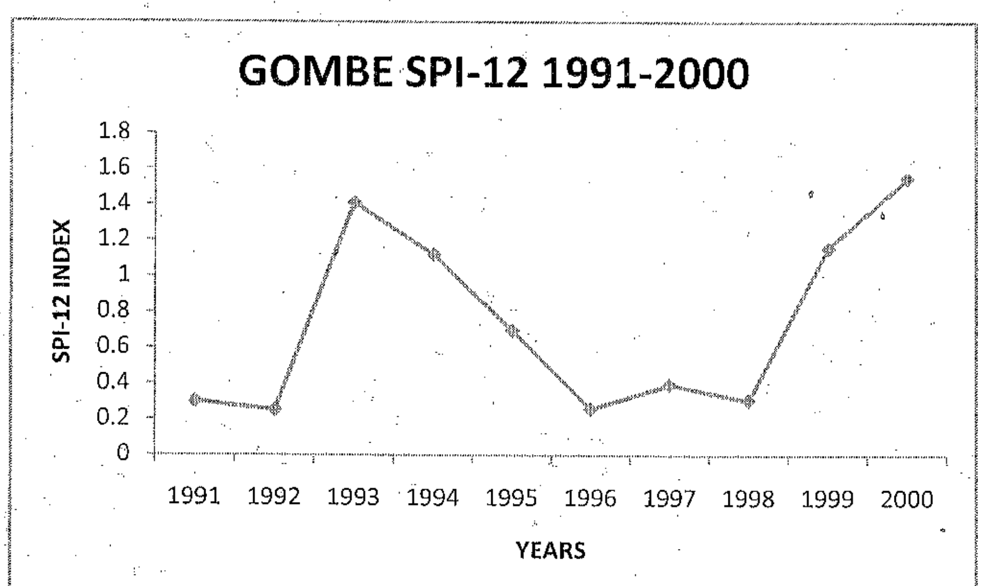

FIG.19 Chart showing the long-term hydrological drought over Gombe between 1991 and 2000

The average the long-term hydrological drought is non-existent between 1991 and 2000 in Gombe station area, the precipitation pattern is **moderately wet.**

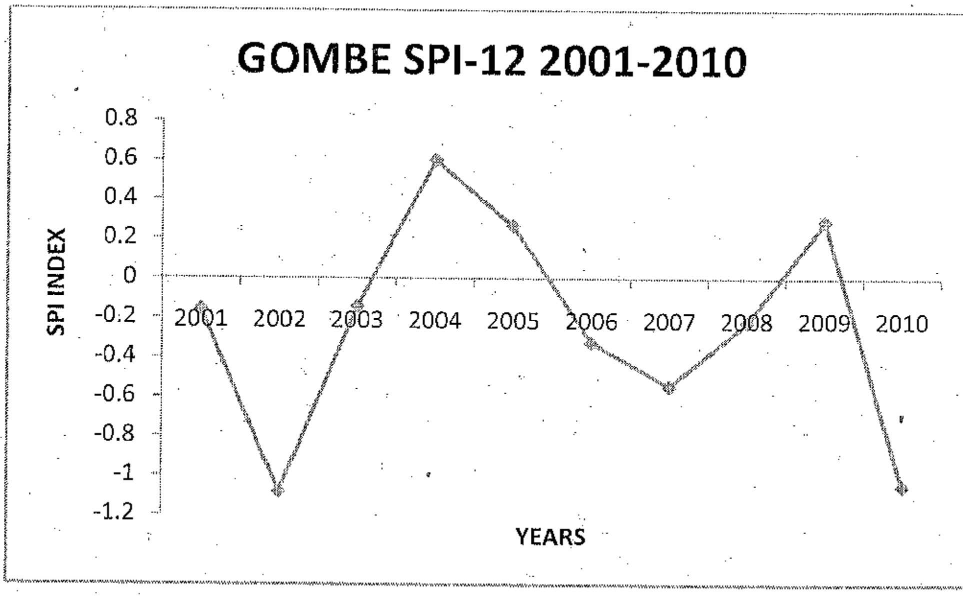

FIG.20 Chart showing the average long-term hydrological drought over Gombe between 2001 and 2010

The average the long-term hydrological drought ranges **near normal** and **moderately dry** between 2001 and 2010 in Gombe station area.

4.3.3 Maiduguri Station Area Charts and Interpretation

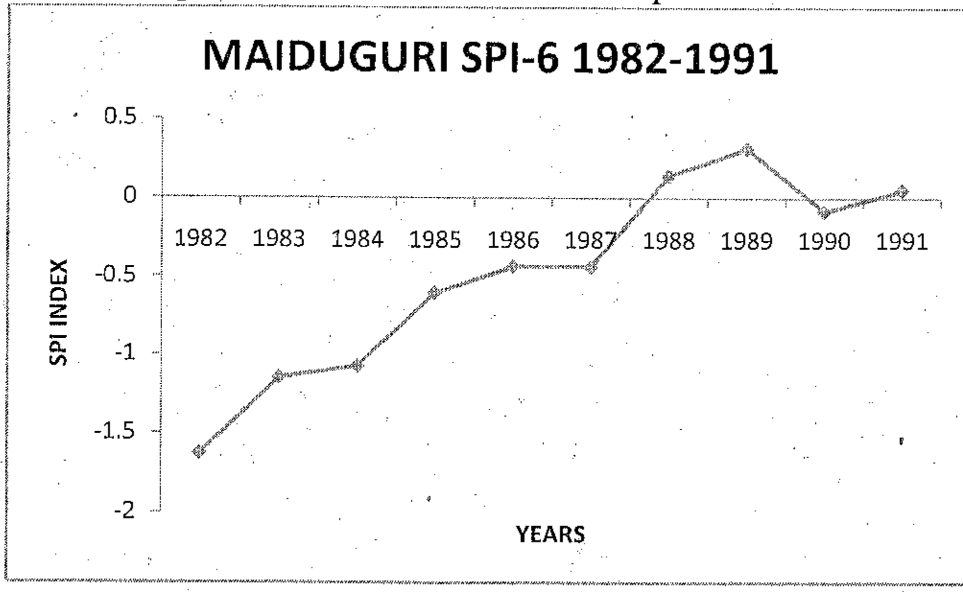

FIG.21 Chart Showing Average Hydrological Drought over Maiduguri between I982 And 1991

The extent of average hydrological drought over Maiduguri between 1982 and 1991 ranges between **severely dry, moderately dry and near normal.**

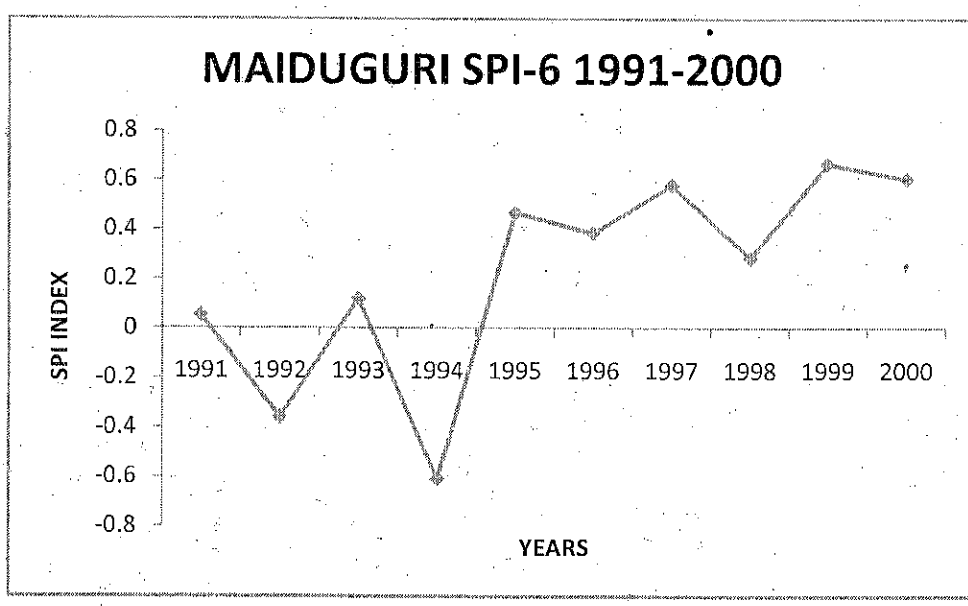

FIG.22 Chart Showing Average Hydrological Drought over Maiduguri between 1991 And 2000

The extent of hydrological drought over Maiduguri between 1991 and 2000 is **near normal.**

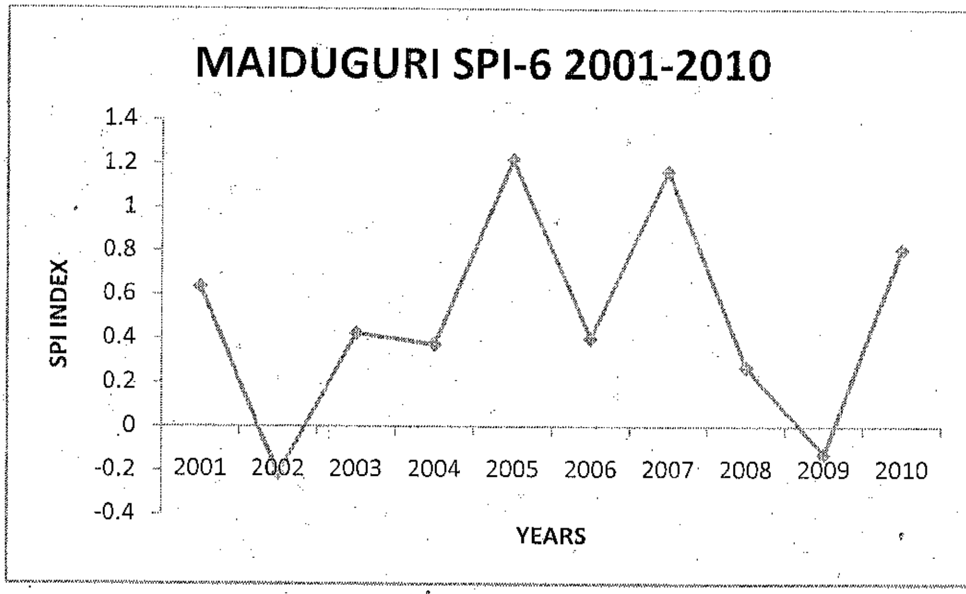

FIG.23 Chart Showing Average Hydrological Drought over Maiduguri between 2001 and 2010

The extent of the average hydrological drought over Maiduguri was near normal.

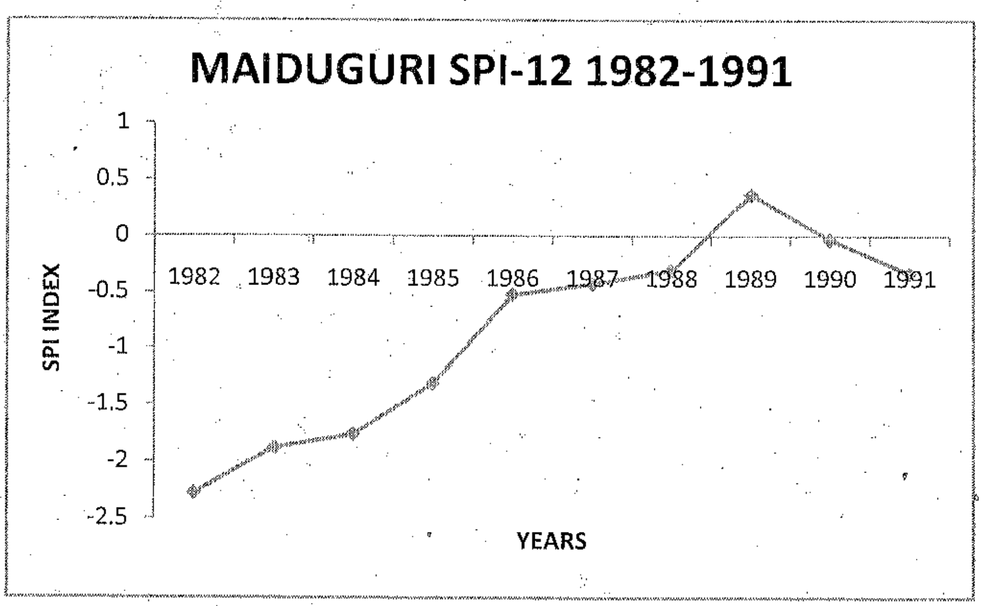

FIG.24 Chart Showing the long term Average Hydrological Drought over Maiduguri between 1982 and 1991

The extent of the long term average of hydrological drought over Maiduguri between 1982 and 1991 started at **extremely dry, to severely dry, moderately dry and then near normal.**

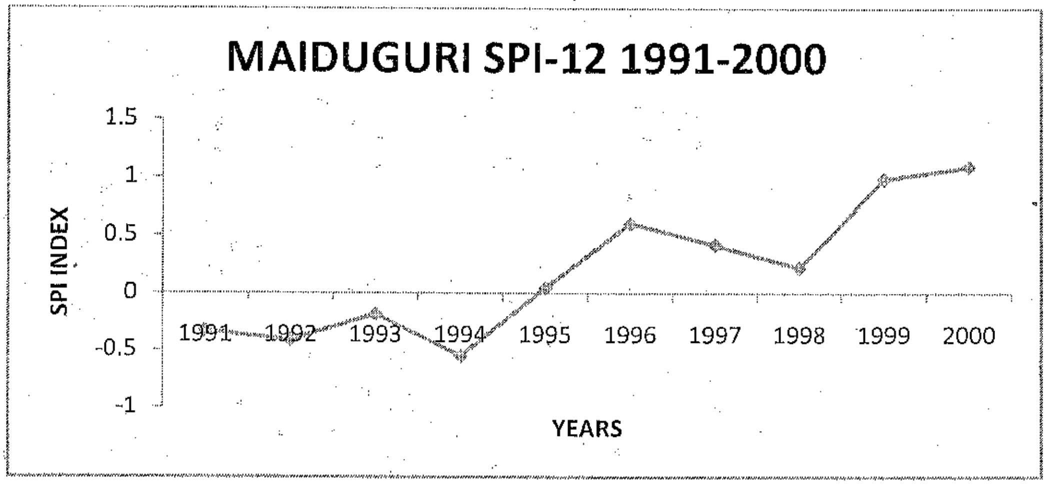

FIG.25 Chart Showing the long term Average Hydrological Drought over Maiduguri between 1991 and 2000

The extent of the long term hydrological drought over Maiduguri between 1991 and 2000 **is near normal.**

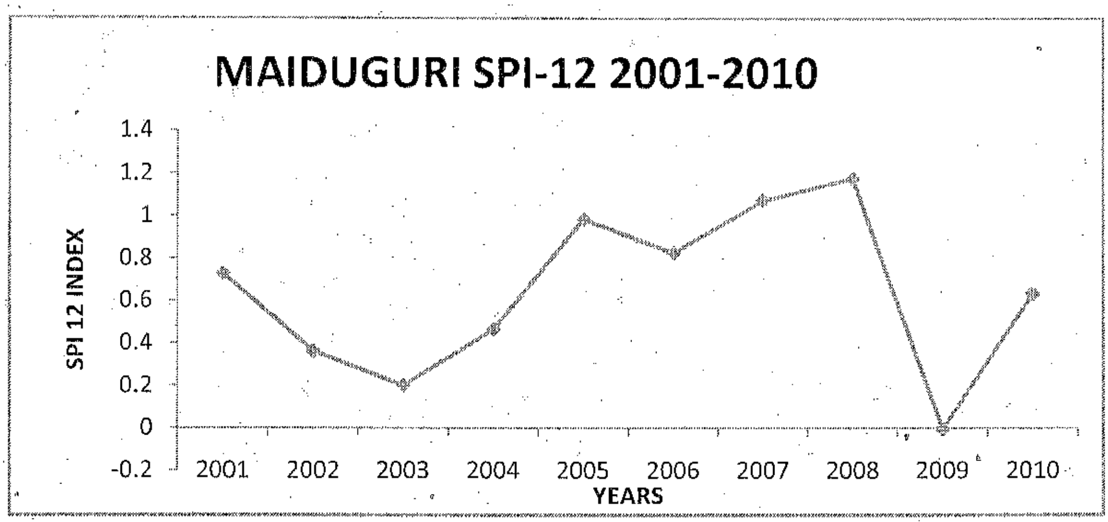

FIG.26 Chart showing the long term Average Hydrological Drought over Maiduguri between 2001 and 2010

The extent of the average hydrological drought over Maiduguri between 2001 and 2010 is

near normal.

4.3.4 Yola Station Area Charts and Interpretation

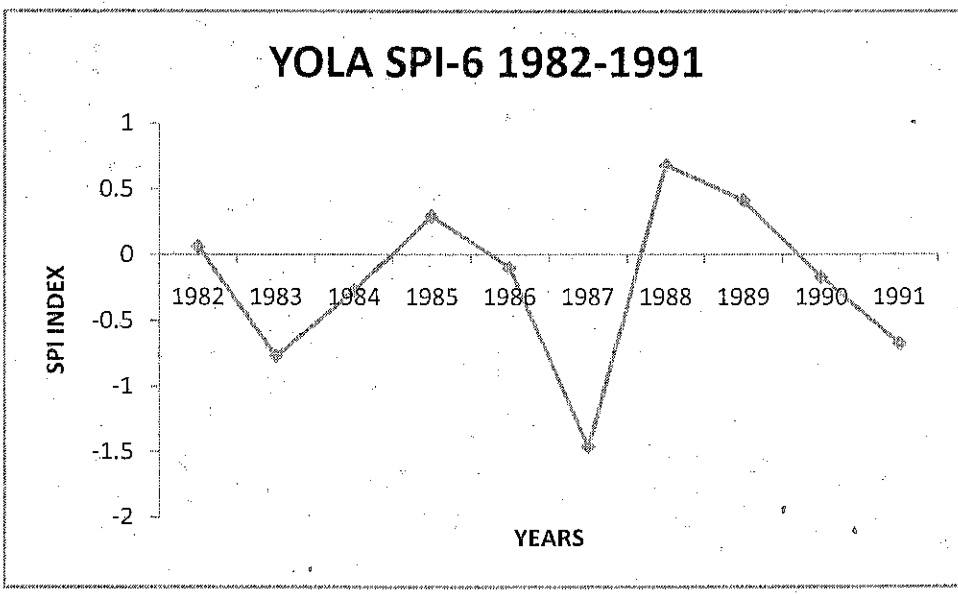

FIG.27 chart showing average hydrological drought over Yola between 1982 and 1991

The extent of the hydrological drought over yola between 1982 and 1991 is **moderately dry and near normal.**

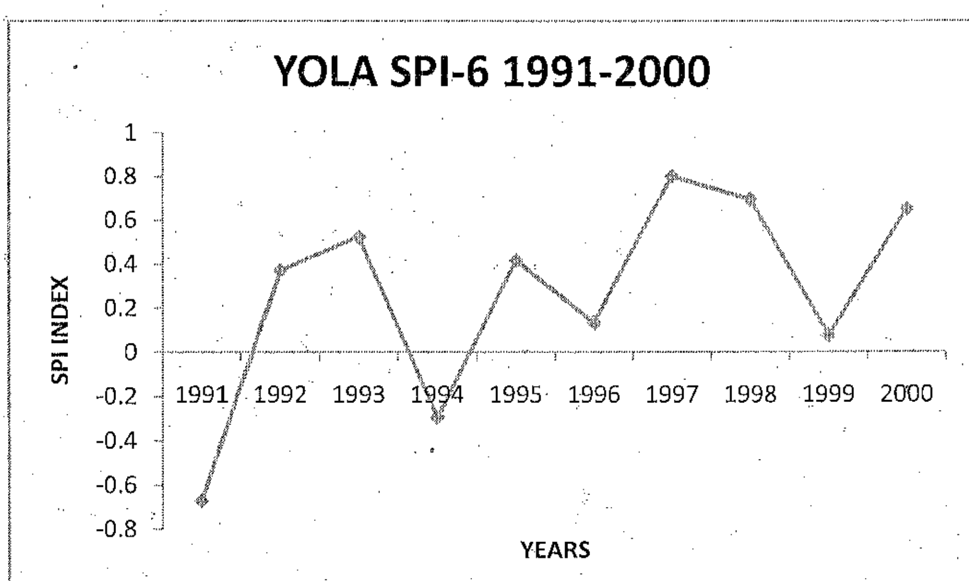

FIG.28 Chart showing average hydrological drought over Yola between 1991 and 2000

The extent of the average hydrological drought over yola between 1991 and 2000 is **near normal.**

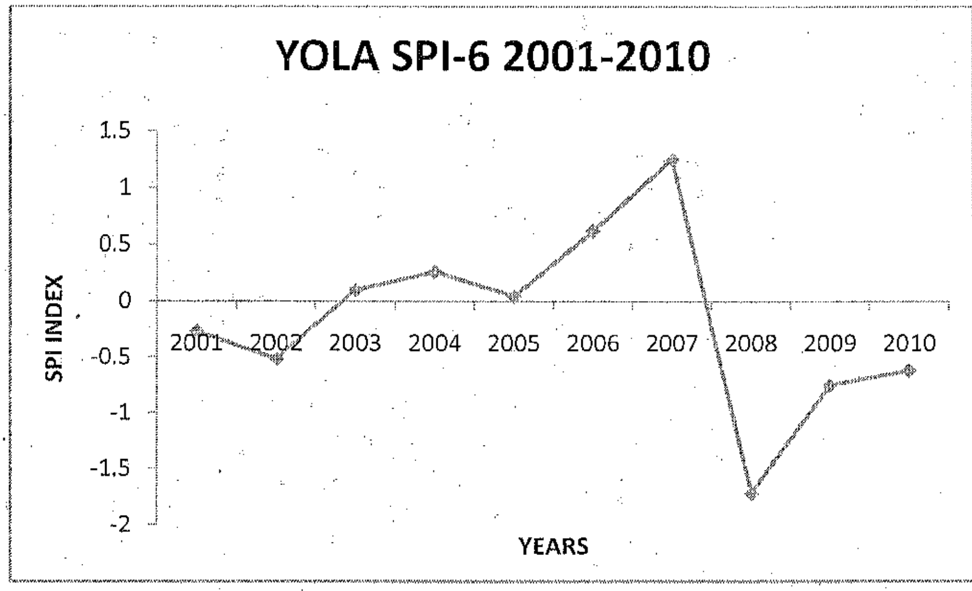

FIG.29 Chart showing average hydrological drought over Yola between 2001 and 2010

The extent of the average hydrological drought over yola between 2001 and 2010 is **near normal and moderately dry.**

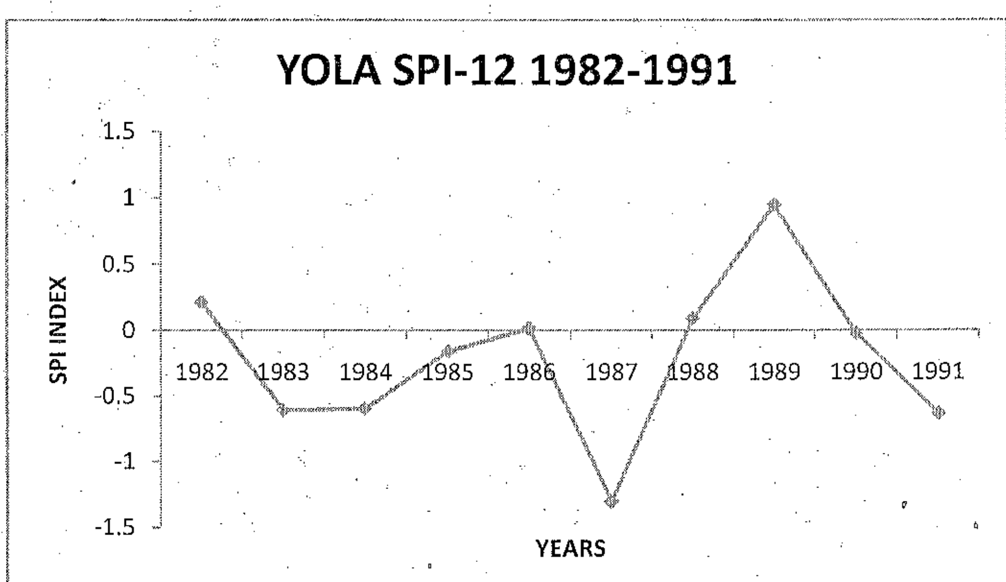

FIG.30 Chart showing average long term hydrological drought over Yola between 1982 and 1991

The extent of the average hydrological drought over Yola between 1982 and 1991 is between **moderately dry and near normal.**

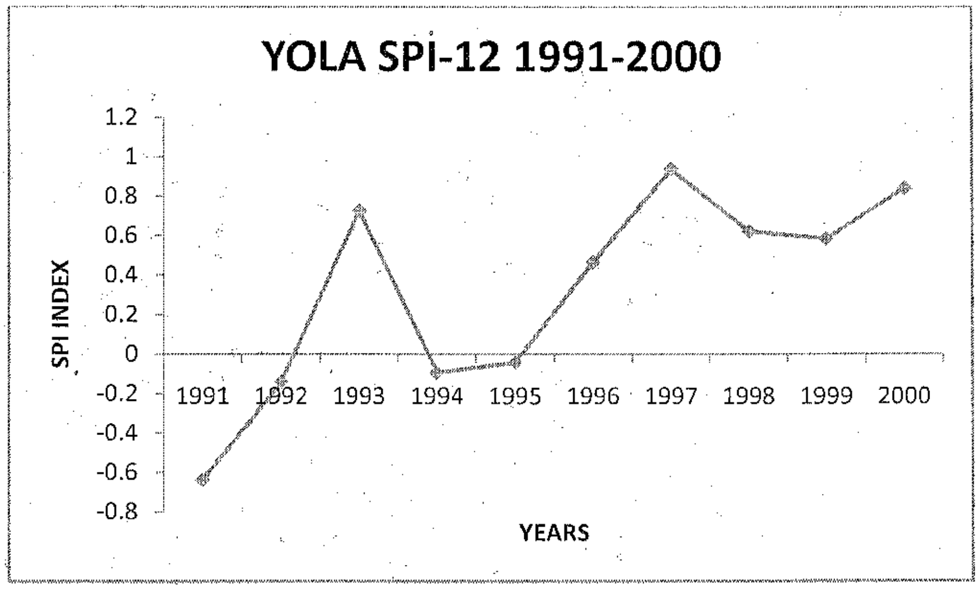

FIG.31 Chart showing average long term hydrological drought over Yola between 1991 and 2000

The extent of long-term hydrological drought over yola between 1991 and **2000 is near normal.**

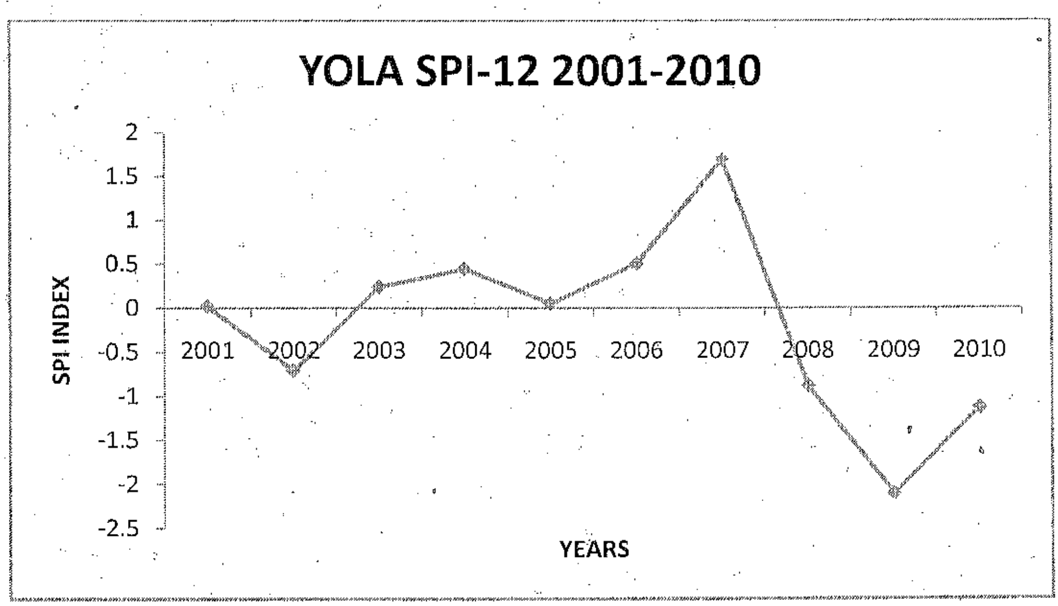

FIG.32 chart showing average Long Term hydrological drought over Yola between 2001 and 2010

The extent of average long term hydrological drought over Yola between 2001 and 2010 **is near normal and severely dry.**

4.3.5 Yobe Station Area Charts and Interpretation

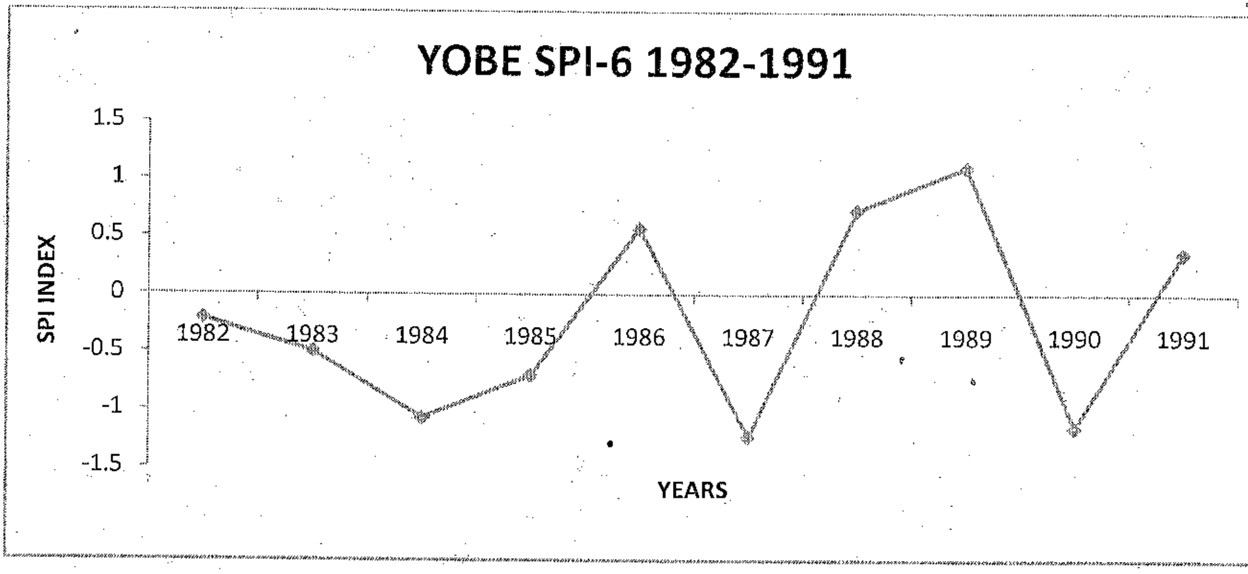

FIG.33 chart showing average hydrological drought over Yobe between 1982 and 1991

The extent of the hydrological drought in the chart above ranges between **near normal** and **moderately dry**.

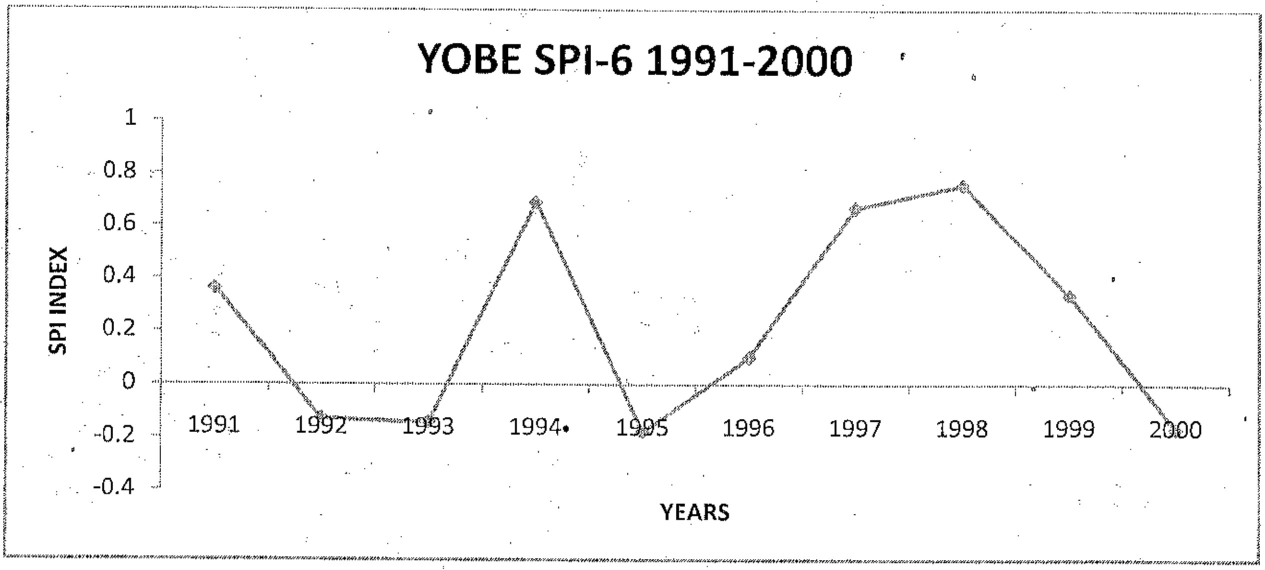

FIG.34 Chart showing average hydrological drought over Yobe between 1991 and 2000

The extent of average hydrological drought in the chart above is **near normal.**

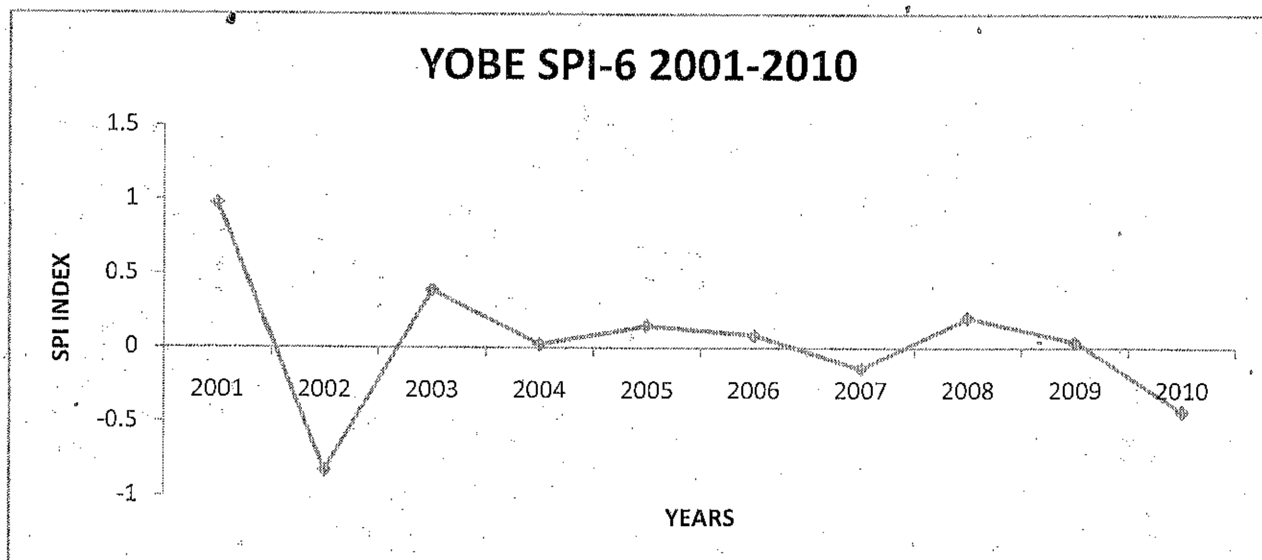

FIG.35 chart showing average hydrological drought over Yola between 2001 and 2010

The extent of average hydrological drought in the chart above is **near normal.**

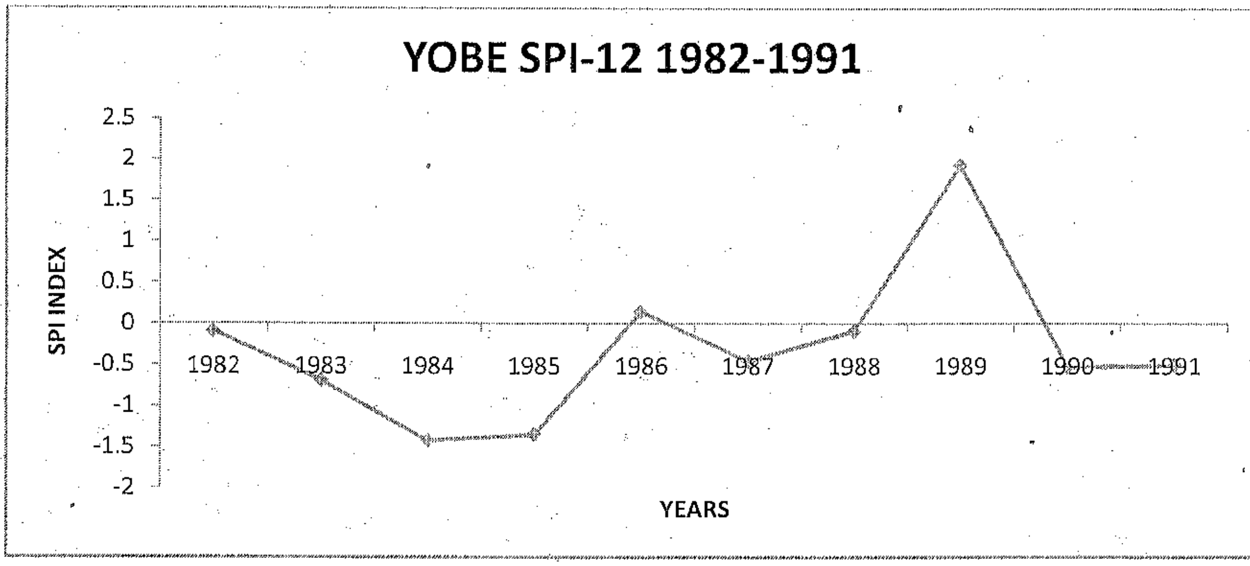

FIG.36 Chart showing average long-term hydrological drought over Yobe between 1982 and 1991

The extent of hydrological drought in the chart above rangesbetween **near normal** and **moderately dry.**

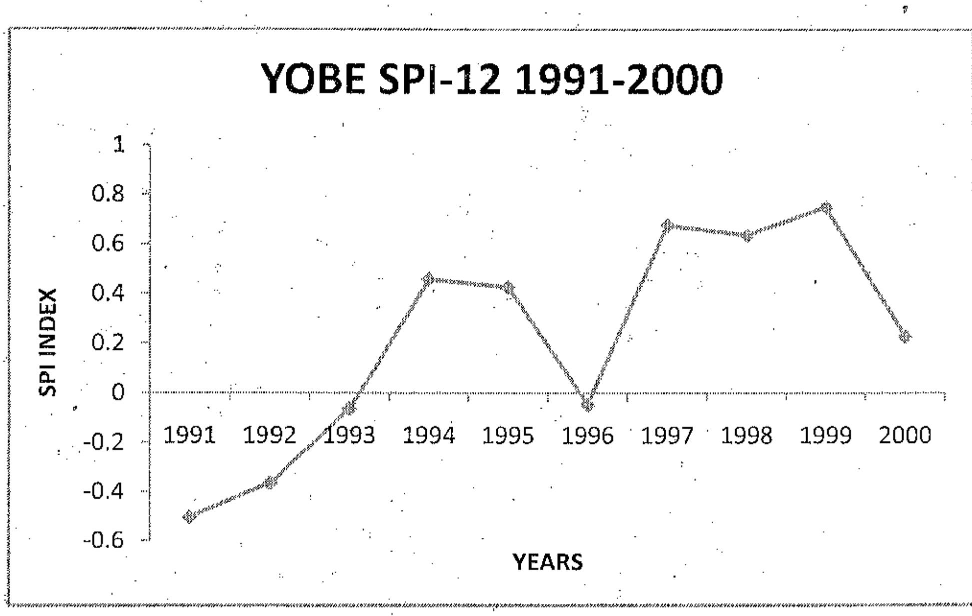

FIG.37 chart showing average long-term hydrological drought over Yobe between 1991 and 2000

The extent of the average long-term hydrological drought in the chart above is near **normal.**

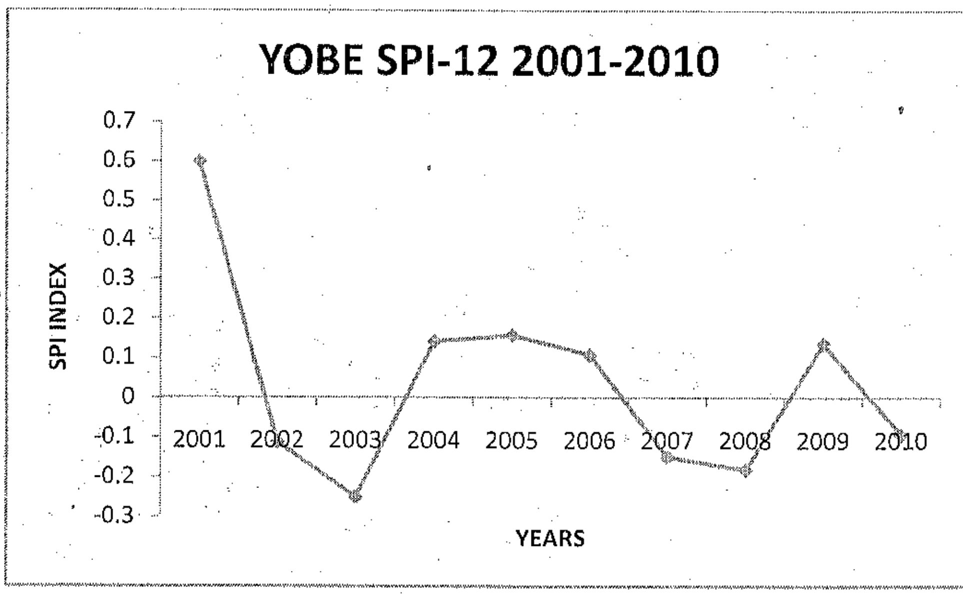

FIG.38 Chart showing average long-term hydrological drought over Yobe between 2001 and 2010

The extent of the average long-term hydrological drought in the chart above is **near normal.**

4.4 Discussion

Hydrological drought in the northeast was mostly near normal for the period of 30yrs used in this study due to several factors. One which is the presence of river bodies in the region as listed in chapter one. Although the average extent of the hydrological drought over the years was **near normal** (-0.99 to 0.99) which still exposes the region to risks especially in food production and water supply.

Using the charts that compare the five stations considered in this study, Maiduguri had the highest index, which was 1.5 and it depicts moderately dry from 1985 to 1987, Yobe and Yola closely followed it around that same time. Bauchi and yola also had a moderate hydrological drought in1997 and 2008 respectively.

Comparing the charts and results in this with Nigerian Meteorological Agency's Seasonal Rainfall Prediction report between the time frame used in this study, the hydrological drought is said to be normal. Northeast was identified as a region that has less rainfall due to its proximity to the Sahara desert, but it still shows positive results and with efficient coping system applied, hydrological drought hazard can be controlled.

CHAPTER FIVE

CONCLUSION

5.1 Introduction

This shows the extent of hydrological drought between 1981 and 2010, it uses the standardized precipitation index to classify and characterize the various stages of hydrological drought. The result shows that the average extent of hydrological drought for northeast between 1981 and 2010 is near normal, and it is quite efficient because it corresponds with the various studies related to it with only little disparities.

The SPI timescale used is the 6- and 12-month timescale, which reveals the presence of hydrological drought in the area considered.

The application of the results derived from this study is in monitoring prospective weather predictions and assessing drought risks.

Although, the drought situation in the northeast during this time is on the better side, drought as a natural occurrence cannot be overlooked, as a reoccurrence can be disastrous without any preemptive measures in place to reduce the impact, as climate change is no more unreal but very factual.

The importance of measures to reduce the effects of drought cannot be overemphasized. Measures such as irrigation, development of drought tolerant early maturing and high yielding crop varieties, reduction in post-harvest crop losses, efficient weather forecast, storage of excess production and development of fishery and livestock industries assist greatly in reducing the risk of drought.

5.2 Recommendation

The government should establish the necessary agencies and organization whose responsibility would be to attend to issues arising from drought occurrences in other to lessen its impact on the population.

Studies of this calibre are invaluable for water resources management and other sectors such as agriculture, economy etc. therefore it must be improved and evaluated per time.

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