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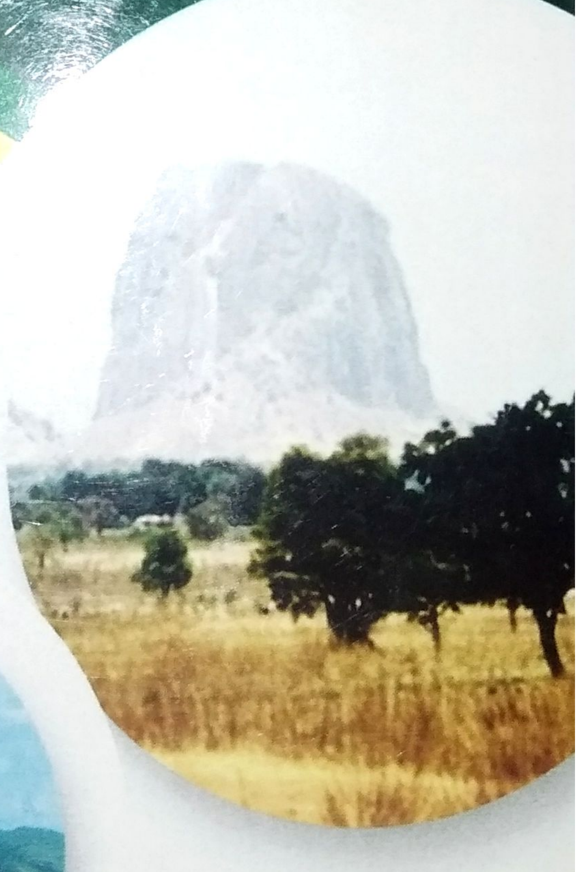

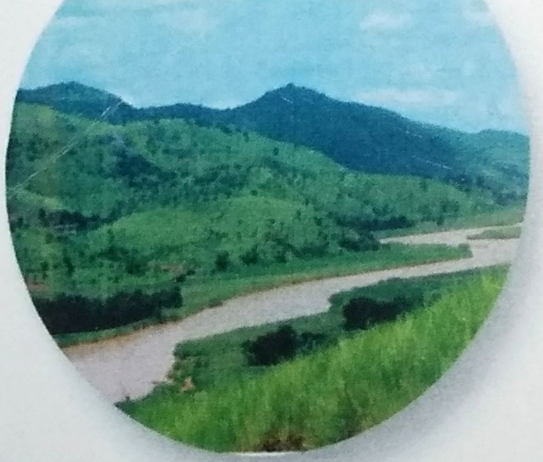

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RAINFALL VARIABILITY OVER GUSAU AND ENVIRONS, ZAMFARA STATE, NIGERIA

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ABSTRACT: This study aims to determine trends in long-term monthly rainfall using nonparametric methods (i.e. the Mann–Kendal and Sen's T tests) in Gusau North-Western Nigeria. Monthly rainfal records of Gusau synoptic stations for a period 60 years (1953-2012 were acquired from the Nigerian Meteorological Agency. The resu revealed that the monthly rainfall recorded downward trend in th months of April, June, July, August and September within 1953-201. While an upward trend in May, and October was recorded but they wer not significance at 95% confidence level. The s Sen's slope estimat revealed that of the seven (7) rainy months considered (April, Ma June, July, August, September and October) only two months May an October showed upward trends with rainfall of 0.028mm and 0.182m as obtained by Sen's slope estimator, while from of month of June, Jul August and September there were downward trends of -0.492mm, 0.580mm, -0.069mm and -0.716mm. The implication of the findings that the area experience some basic indices of climate change.

Keywords: *Rainfall, Trends, Climate, environment, variability*

1. Introduction

Yavuz and Erdoğan (2012) confirmed that global warming and climate change is significantly altering various environmental variables in many countries around the world. It has been documented severally that the Earth's climate has been changing notably at a fast pace since the last century and the changes are expected to continue (Huang, *et al.* 2014). Rainfall being one of the important climatic elements found to be changing on both t global (Dore, 2005) and t regional scales (Kayano a Sans´ıgolo, 2008). It is understo that projected global clima changes have the potential to al precipitation patterns. Changes precipitation patterns is believ to directly affect hydrolog agriculture, ecosystems and wa resources management. It argued that to meet the futu development and sustainable management of water resources of a given region especially within the context of global warming, water and energy cycles and the increasing demand of water for domestic, agricultural and industrial need, knowledge of trends and variations of hydro-climatological element is relevant (Shamsuddin, 2010).

Wang, *et al.* (2011) assed that temporal and spatial variability in precipitation around the world are receiving increasing attention as the information about changing patterns of precipitation is the starting point for accurate assessment of water resources, flood and drought control, understanding climate change and efficient water management. Rainfall trends studies in Nigeria have shown contrasting result. It is based on this Bigg, (1991) noted that a complete description of intraregional rainfall variability and changes is of great interest, especially in areas with strongly contrasting rainfall regimes and with associated environmental problems. Nigeria still remains largely an agriculture-based country where more than 65% of population are directly or indirectly engaged in a wide range of agricultural activities. Rainfall is the most important natural factor that determines the agricultural production in Nigeria. The variability in rainfall is therefore very important for the economy of the country. This study aimed to determine long-term rainfall trend in Gusau North-Western Nigeria with a view of identifying the impact of the rainfall variability in agricultural planning.

2. The Study Area

The study area is Gusau and its environs. It on Sudano ecological zones of Nigeria Longitudes 6.70° East and Latitudes 12.17° North.

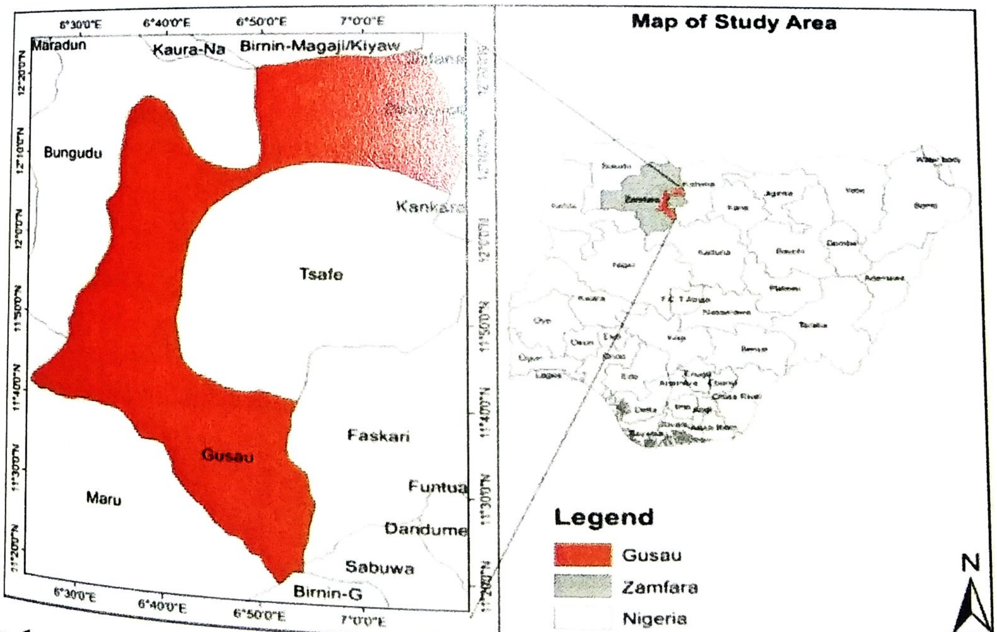

Figure 1: The Study Area (Gusau and Environs, Zamfara State Nigeria)

The climate is dominated by Tropical Maritime (mT) air mass, and the Tropical Continental (cT) air mass. The rainy season in this region is associated with late onset and earlier cessation. The onset and cessation are also characterized by destructive storms which destroy life and property (AbdulKadir, *et al.*, 2013). The seasonal and latitudinal variations are understood to affect diurnal and seasonal temperature ranges. The highest maximum air temperature is recorded in the northern part usually areas north of latitude 9° and occur in March /April and minimum temperatures are recorded in December/January North of latitude 9°N (AbdulKadir *et al*, 2013).

3 Materials and Methods

3.1 Data

Monthly rainfall records of Gusau synoptic stations for a perio[d of] years (1953-2012), is acqui[red]. The data were collected from Nigerian Meteorological Agen[cy].

3.2 Trend Analysis

In this research, trend detectio[n] carried out by the Mann-Ken[dall] test and Sen's slope estima[tor] analysis .The detail explanations of these methods a[re]

3.3 Mann-Kendall test

Mann-Kendall test (Mann, 194[5]; Kendall, 1975) is applied to dete[ct] the trend in rainfall time serie[s]. Confidence levels of 95% is take[n] as thresholds to classify th[e] significance of positive an[d] negative trends. Th[e] Mann–Kendall (MK) test is a non parametric test, commonly used t[o] detect significant trends i[n] hydrological and meteorologica[l] time series (example Tabari and Hosseinzadeh Talaee, 2011). The MK test is given as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sign}(x_j - x_k) \tag{1}$$

$$\text{Where: } \operatorname{sign}(x_j - x_k) = \begin{Bmatrix} 1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{Bmatrix} \tag{2}$$

$$\mathrm{VAR}(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18} \tag{3}$$

Where:

n = the number of data points t_i = the number of ties for the i value and m= the number of tied values (a tied group is a set of sample data having the same value)

Then Equation 2 and 3 is used to compute the test statistic Z from the following equation:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \tag{4}$$

A positive value of Z will indicates that there is an increasing trend and a negative value indicates a decreasing trend while zero value indicates no trends.

2.3.2 Magnitude of Rainfall Trend Changes

It is observed that some trends may not be evaluated to be statistically significant while they might be of practical interest (Basistha, *et al*, 2007). In the instance where climate change component is present, it may not be detected by statistical tests at a satisfactory significance level (Radziejewski and Kundzewicz, 2004). To overcome this challenge, linear trend analysis will be carried out and the magnitude (change per unit time) will be estimated by using a non-parametric procedure developed by Sen (1968). The Sen's slope approach is adjudge to gives a robust estimate of the magnitude of a trend (Yue, Pilon, Phinney, Cavadias 2002) and for this reason, it has been preferred above the regression slope approach in recent hydrologic studies (Huang et al. 2014; Zhang, Zheng, Wang, Yao 2015). The trend magnitude by this method is computed as follows:

$$Q = \frac{x_j - x_k}{j - k} \qquad (5)$$

$Q_{med} = \frac{Q(N+1)}{2}$ and if N is even, Sen's estimator is computed by $= \frac{[QN/_2 - Q(N+2/_2]}{2}$

Where:

Q = slope between data points x_j and x_k, x_j, x_k = data values at times j and k j>k respectively

N is the number of calculated slopes

4.0 Results and Discussion

The Mann Kendall trends test for monthly rainfall is shown in table 1. The result revealed that the monthly rainfall recorded downward trend in the months of April, June, July, August and September within the study period. The above months all showed a negative sign. While an upward trend in May and October was recorded. The month of May and October revealed a positive sign. The result however show no significance at 95% confidence level.

Table 1 Trends in Monthly Rainfall over Gusau and Environs

Time Series	First Year	Last Year	n	Test Z
April	1953	2012	60	-0.73
May	1953	2012	60	0.10
June	1953	2012	60	-1.38
July	1953	2012	60	-1.19
August	1953	2012	60	-0.11
September	1953	2012	60	-1.35
October	1953	2012	60	1.17

The trend slope, which is the reduction of rainfall is shown in table 2. The month of May and October recorded upward increase in rainfall of 0.028mm/month and 0.182mm/month. The above months showed a minimal increase in monthly rainfall. The month of June, July, August September recorded downwar -0.492mm/month 0.580mm/month 0.069mm/month an 0.716mm/month. The re revealed a minimal reductio monthly rainfall. The mont April however exhibit no chan

Table 2 Magnitude Change in Monthly Rainfall over Gusau and Env

Time Series	First Year	Last Year	n	Sen's Slope Estimate Q
April	1953	2012	60	0.000
May	1953	2012	60	0.028
June	1953	2012	60	-0.492
July	1953	2012	60	-0.580
August	1953	2012	60	-0.069
September	1953	2012	60	-0.716
October	1953	2012	60	0.182

The graphical distribution of the trends and the trend slope for the m under consideration are illustrated from Figure 2 to 8.

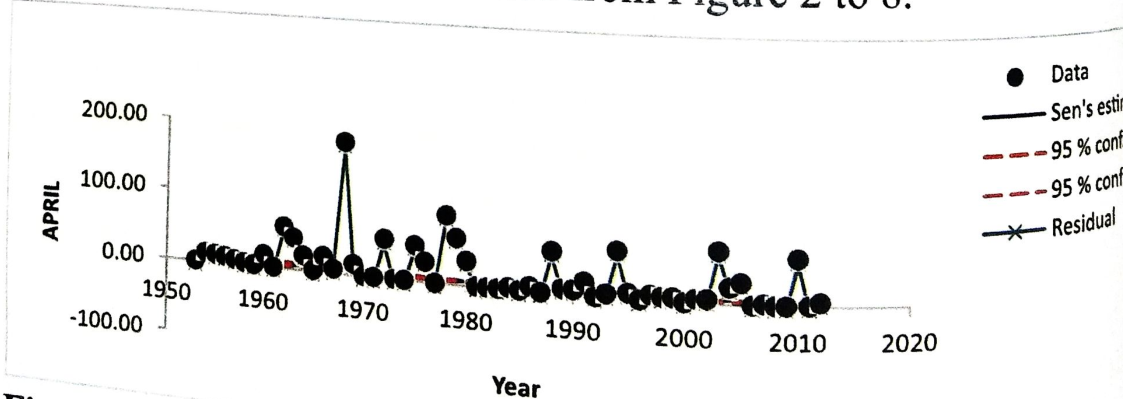

Figure 2. Trends and Magnitude Change in Monthly Rainfall of over Gusau and Environs (1953-2012)

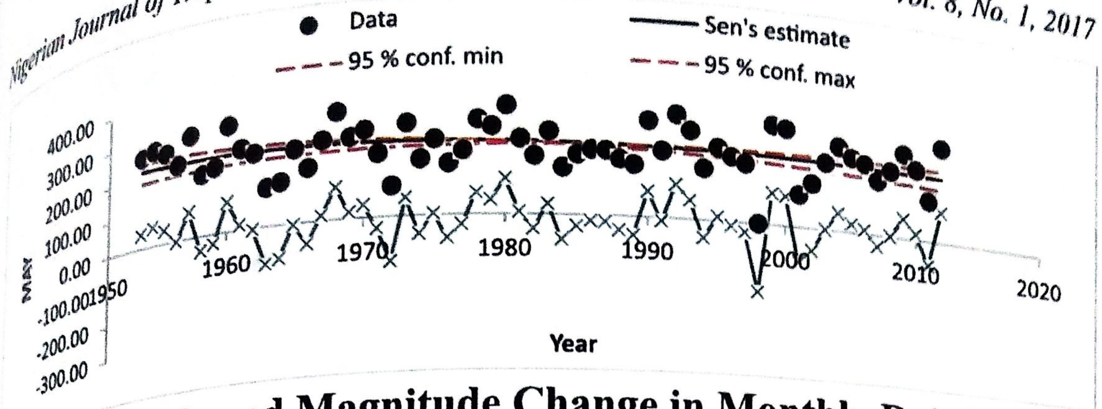

Figure 3. Trends and Magnitude Change in Monthly Rainfall of May over Gusau and Environs (1953-2012)

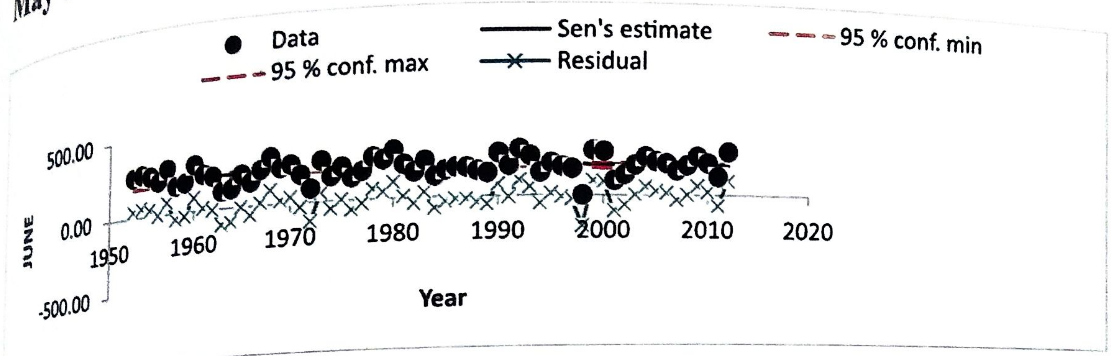

Figure 4. Trends and Magnitude Change in Monthly Rainfall of June over Gusau and Environs (1953-2012)

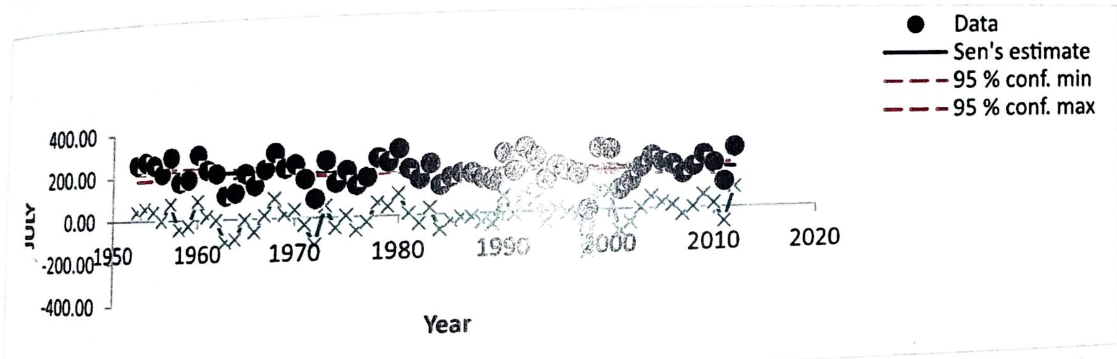

Figure 5. Trends and Magnitude Change in Monthly Rainfall of July over Gusau and Environs (1953-2012)

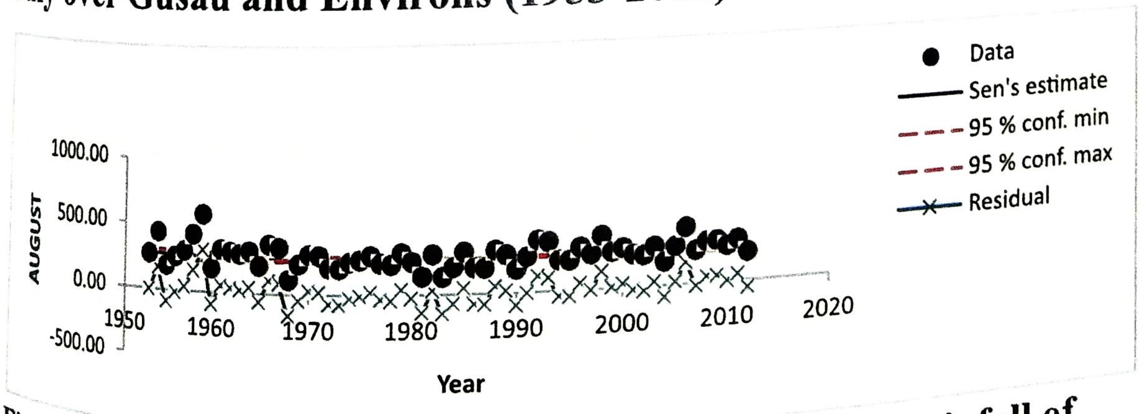

Figure 6. Trends and Magnitude Change in Monthly Rainfall of August over Gusau and Environs (1953-2012)

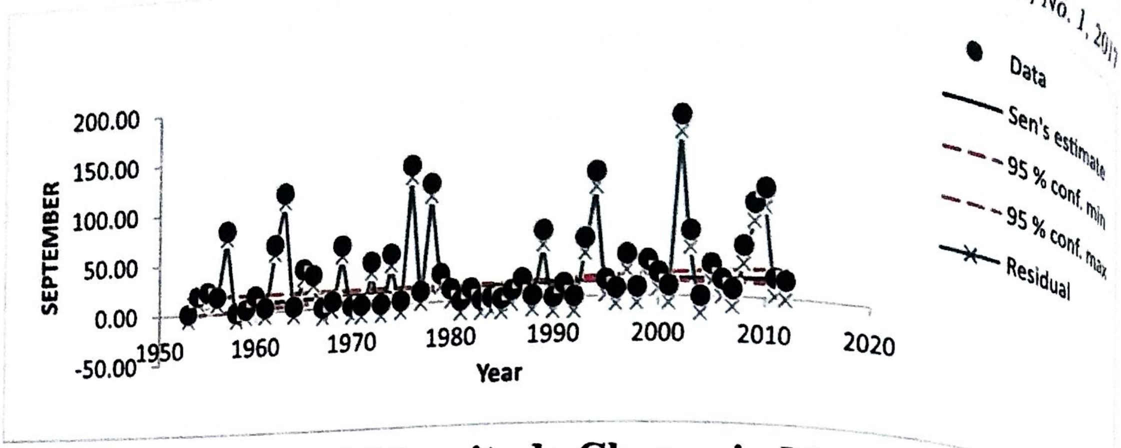

Figure 7. Trends and Magnitude Change in Monthly Rainfall of September over Gusau and Environs (1953-2012)

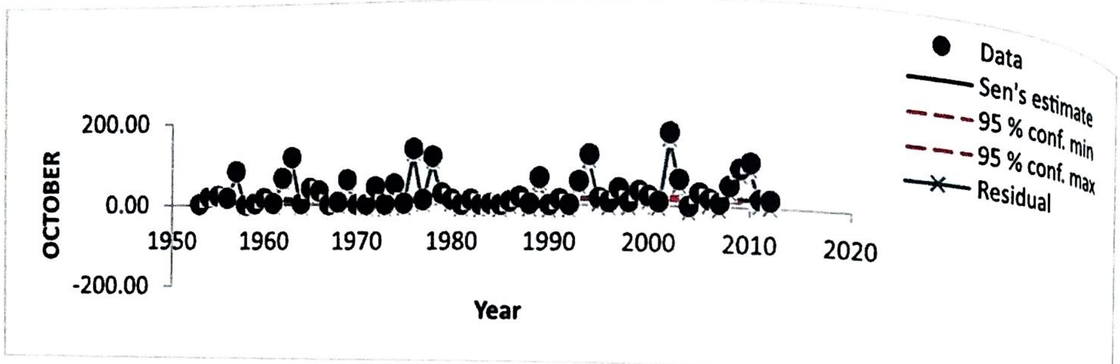

Figure 8. Trends and Magnitude Change in Monthly Rainfall of October over Gusau and Environs (1953-2012)

5 Conclusion and Recommendation

The study revealed that of the seven (7) rainy months considered in this study (April, May. June, July, August, September and October within 1953-2012) only two months May and October showed upward trends with the rainfall of 0.028mm and 0.182mm as obtained by Sen's slope estimator, while from of June, July, August and September there were downward trends of -0.492mm/month, -0.580mm mm/month, -0.069mm mm/month and -0.716mm mm/month. The month of April showed no changes. The implication of this is that the area experience some basic indices of climate change. There rain fed farmer are to take note of these fluctuation in order to take advantage of those months with increased rainfall.

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PROSPECTS AND CHALLENGES OF WATER RESOURCES AND ENVIRONMENTAL MANAGEMENT IN NIGERIA: AN OVERVIEW

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ABSTRACT: *Nigeria; located between latitude 4^{0}N and 14^{0}N and longitude 3^{0}E and 15^{0}E is endowed with vast water resources both proven and potential. The country is well drained with a close network of rivers and streams. Some of these, particularly the smaller ones in the north, are seasonal. There are four principal surface water basins in Nigeria; the Niger River, the Lake Chad, the West Coast and the West Central Coast. There is a very large groundwater potential in Nigeria, far greater than the surface water resources, estimated to be 224 trillion l/year (Hanidu, 1990). This picture of availability leads to reckless use of water resources as if the flow will never cease. Both surface and groundwater sources are often polluted through anthropogenic activities. This overview examines the prospects of water resources in Nigeria, the challenges of availability, accessibility and affordability; and environmental management concerns of water resources. The conclusion is that Nigeria as a nation is endowed with huge water resources with the capacity to meet our burgeoning requirements across all facets of life given the requisite resources and a focused plan of action managed by competent and committed professionals within a well orchestrated institutional framework. To mitigate threats to our water resources, government must step up Integrated Water Resources management where all sectors must synergize to achieve results.*

Keywords: *Water resources, Groundwater, Environment, Prospects, Challenges*

1. Introduction

Water resources are sources of water that are useful or potentially useful. Uses of water include agricultural, industrial household, recreational and environmental activities; the majority of human uses require fresh water. 97% of the water on the Earth is salt water and only three percent is fresh water; slightly over two thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly as groundwater, with only a small fraction present above ground or in the air (Earth Water Distribution, 2009). Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia and North America, although it is still unclear how much natural renewal balances this usage, and whether ecosystems are threatened.

Surface water is water in a river, lake or fresh water wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and groundwater recharge. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates (Green facts, 2008). All of these factors also affect the proportions of water loss.

Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runo quantities and velocities by pavir areas and channelizing strea flow. The total quantity of wat available at any given time is a important consideration. Som human water users have a intermittent need for water. Fo example, many farms require larg quantities of water in the spring and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply such a power plant with water, a surface water system only needs enough storage capacity to fill in when average stream flow is below the power plant's need.

Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed. Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. Humans can also cause surface water to be "lost" (i.e. become unusable) through pollution.

2. Water Resources of

Nigeria: Spatial and Temporal Distribution

Nigeria is by far the most populous country in Africa, with its 127 million people accounting for about one-seventh of the total population of Africa's 53 countries (Spon, 1997)). Realizing that the single most important necessity for man is water, the Nigerian Government's priority and investment in water resource development, supply and distribution is borne out of the realization that water is not only a critical human need but also a major factor of socio-economic development. Also, it assists in the eradication of water borne diseases like guinea worm, which has plagued certain areas of the country.

2.1 Surface Water Resources

Nigeria has four large main surface water basins, providing opportunities for irrigated agriculture as well as fisheries. The two largest basins with their tributaries and distributaries are the Niger River Basin and Lake Chad Basin, covering about 83% of the country. Rivers and lakes make up approximately 16% of Nigeria's total surface area. Two surface water systems, the Chad and Niger-Benue complexes dominate the country's Hydrology/Hydrogeology. Nigeria has extensive fadama areas or flood plains found along the country's rivers, especially the Niger, Benue, Sokoto, Rima, Hadeija/Jamaare, Yobe in the North; and Anambra, Imo, Ebonyi, Cross River, Idemili, Benin, Ogun, Osun etc. rivers in the Southern parts. The fadama areas provide rich grazing and agricultural lands and are internationally important areas for all season farming and biodiversity.

Nigeria has annual internal renewable water resources of 221 cubic kilometers. Sixty-nine percent of water is used for agriculture, 21% for domestic uses and 10% for industries. Potable water supplies are scarce and irregular; in many areas water service is intermittent, sanitation facilities unavailable and water quality is substandard nationwide, suggesting that more than half the population is unable to access sufficient clean water on a regular basis. Nigeria's water resources have been degraded by floods, soil/gully erosion, siltation, salinization, saltwater incursion, pollution and contamination from industrial and agricultural sources, human and animal wastes. Nigeria's rapid population growth has not been accompanied by an increase in the delivery of water supply, sewerage and sanitation services.

The country of Nigeria is well drained with a close network of rivers and streams. Some of these, particularly the smaller ones in the north, are seasonal. There are four principal surface water basins in Nigeria; the Niger River, the Lake Chad, the West Coast (sometimes referred to as the southwestern littoral basins), and the West Central Coast (also known as the southeastern littoral basins).

The Niger Basin (See Figure 1) has an area of 584,193 km^2 within the country, which is 63 percent of the total area of the country, and covers a large area in central and north western Nigeria. The most important rivers in the basin are the Niger and its tributaries Benue, Sokoto and Kaduna.

Lake Chad Basin (depicted in Figure 2) located in the northeast with an area of 179,282 km^2, or 20 percent of the total area of the country, is the only internal drainage basin in Nigeria. Important rivers are the Komadougou Yobe and its tributaries Hadejia, Jama'are and Komadougou Gana.

The West Coast Basin (See Figure 3) has an area of 101,802 km^2, which is 11 percent of the total area of the country. The rivers originate in the hilly areas to the south and west of the Niger River.

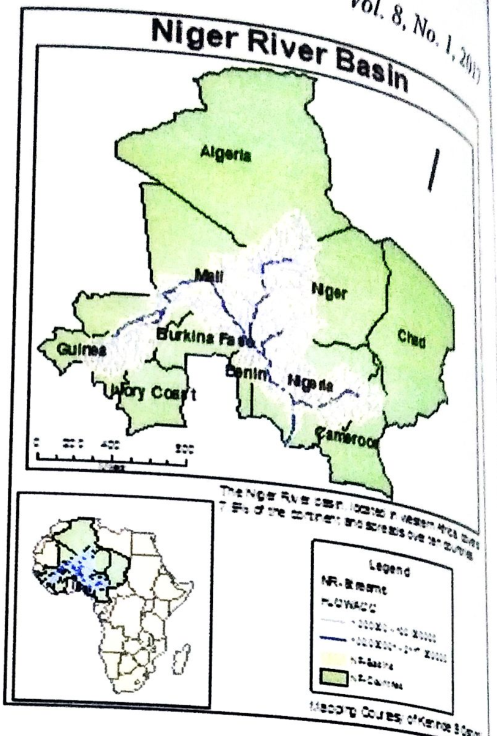

Figure 1: The Niger Basin

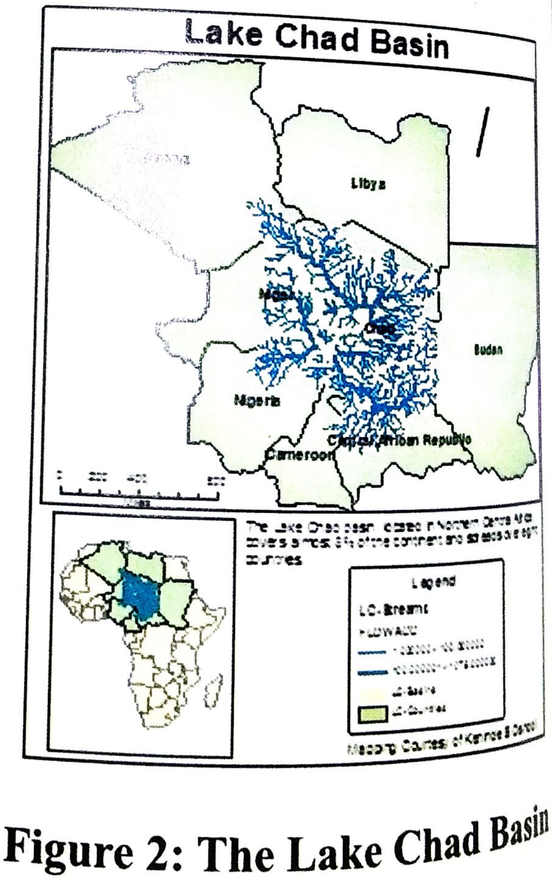

Figure 2: The Lake Chad Basin

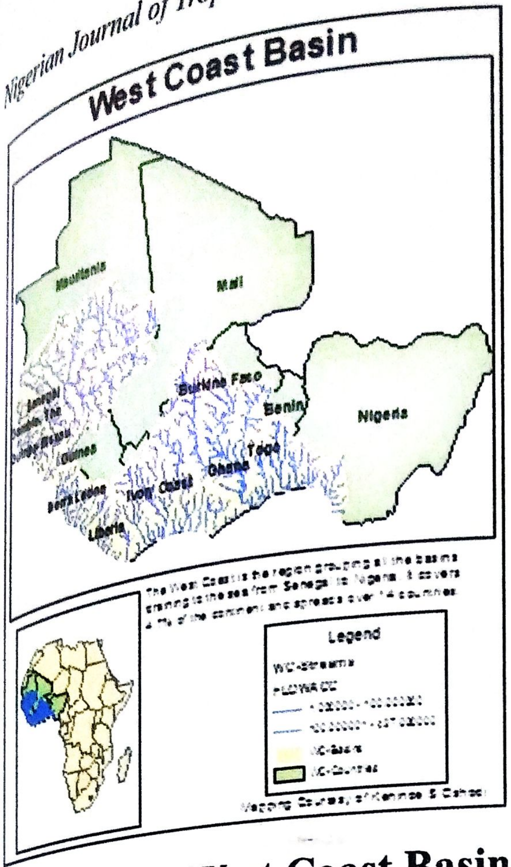

Figure 3: The West Coast Basin

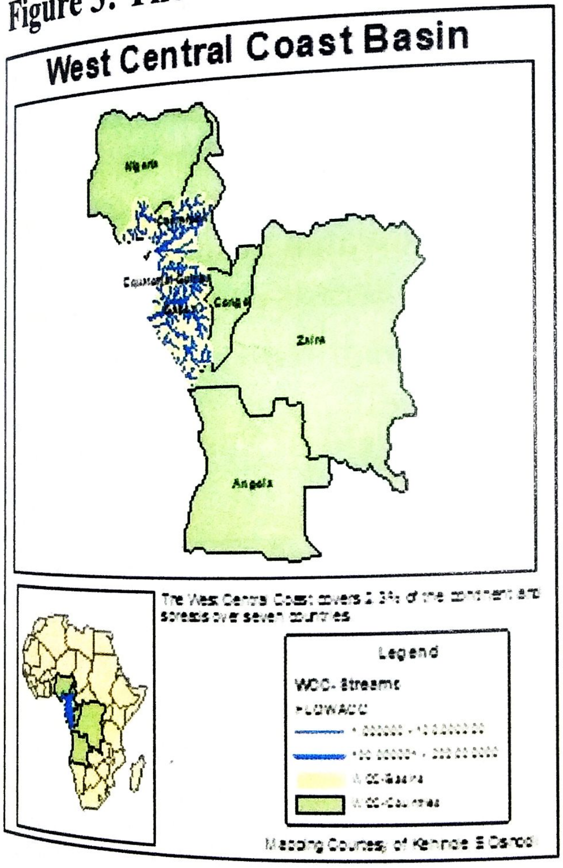

Figure 4: The Central West Coast Basin

The West Central Coast Basin (illustrated in Figure 4) with major water courses being the Cross and Imo Rivers, have an area of 58,493 km^2, which is 6 percent of the total land area of the country, and receive much of their runoff from the plateau and mountain areas along the Cameroon boarder.

2.2 Ground Water Resources

There is a very large groundwater potential in Nigeria, far greater than the surface water resources, estimated to be 224 trillion l/year (Hanidu, 1990). It is estimated that groundwater resources at 0 to 50 m depth in Nigeria is in the region of 6 × 10 km^3. However, from the eight aquifers in Nigeria the Ajali Sandstone aquifer yields 7 to 10 l/s, the Benin formation (Coastal Plain Sands) aquifer yields 6 to 9 l/s, the Upper aquifer 2.5 to 30 l/s, the Middle aquifer 24 to 32 l/s, the Lower aquifer with yields of 10 to 35 [/s (of the Chad formation), the Gwandu frmation aquifer with yields of 8 to 15 l/s, the Kerrikerri Sandstone aquifer with yields of 1.25 to 9.5 l/s and the crystalline fluvio-volcanic aquifer with a 15 l/s yield in the Jos Plateau region; groundwater occurrence is not limited to only 50 m b.g.l (below ground level). These eight mega regional aquifers have an effective average thickness range of 360 m, with a thickness range of 15 to 3,000 m at a depth range of 0 to 630 m b.g.l with an average depth of 220 m. Reserves of groundwater are considerable in large sedimentary basins, which cover some 50% of the country. The potential annual groundwater resources are estimated at 51.93 $\times 10^9$ m^3, out of which the sedimentary basins account for 67% (FMWRRD, 1995).

The occurrence of groundwater is greatly influenced by the local geological conditions which ultimately control yields. Recharge to aquifers, which influences the safe yields of wells, depends on rainfall over the area. Thus, rainfall ultimately controls the amount of groundwater recovered from wells in any given locality. The amount of groundwater storage is not yet known, but available records indicate that major aquifers in Nigeria are located in the sedimentary deposit basins which cover about 50% of the nation's land area. The remaining 50% is underlain by crystalline rocks of the basement complex. Aquifers within the basement are limited, their thickness ranges from 16 to 180 m, but depth of hand dug wells and boreholes are therefore seldom more than 60 m with a variable average of static water level between 1 to 45 m below the surface. This shallow depth coupled with the poor hydraulic conductivity, no doubt account for the general low yield of 1.0 m^3/h (Nwaogazie, 1995). On the sedimentary deposits, groundwater resources usually occur either as confined aquifers.

Table 1: Distribution of Annual Average yield of Surface and Groundwater in Nigeria

Hydrological Area	**Average Surface water annual yield 10^9 (m^3)**	**Average Groundwater annual yield 10^9 (m^3)**
Chad Basin	8.2	5.6
North West	22.4	4.3
Upper/ Lower Benue	83.0	11.4
West Littoral	35.4	9.0
Niger	85.9	13.4
North Central	32.4	8.2
Total	**267.3**	**51.9**

Source: Martins (2001)

Groundwater resources are controlled by the hydrostratigraphy of the country and follow the pattern of occurrence of the aquifers, aquitards or aquicludes. More than half of the country is made up of igneous and metamorphic rocks which make up the basement complex. Even though these hard rocks are essentially non-water bearing (aquiclude) there are areas of weathered basement rocks which have acquired secondary porosity due to weathering over geologic time. These areas furnish moderate to marginal water yields at depths of 20-100 m. normally, weathering and compaction processes are followed by fracturing which is a major factor of incompetent rocks at depths.

These secondary aquifers are characterized by their non-extensive nature, susceptibility to anthropogenic pollution and climatic vagaries. As one proceeds towards the south, The prospects of good aquifers increase. Thus within the Anambra basins and Niger delta basins ground water yield becomes extensive to the extent that free flow conditions occur in confined areas.. Unlike surface water that cuts across geographical boundaries, the occurrence of groundwater in terms of quantity and quality displays spatial variability being driven by the geology and climate.

On this premise, we can chronicle the availability based on three hydro-meteorological areas:**The Sahel Region**: Although the Sahel region comprises areas above latitude 11°, there is gradual southward advancement of the Sahara to now cover areas down to 10° latitude. As a result, three River basins are considered to lie within the Sahel; the Sokoto basin, the Hadejia-Yobe basin and the South-east Chad basin. The main characteristics of the area are low annual precipitation of 500-750 mm. The region is also associated with greater extremes of temperature as high as 44°C before the onset of the rains or drop to as low as 6°C during the cool harmattan air around December to February. The Sokoto basin is drained by the River Sokoto with the Ka, Zamfara and Rima as tributaries. The groundwater resources are furnished by the fractured meta-sediments within the basement complex. Boreholes in these meta-sediments are shallow (30-40 m). Borehole yields are low (0.5-0.8 lit/sec), with steep drawdown. The Gundumi and Illo Formations are aquiferous but occasionally deeply confined.

Yields of 8 lit/sec and transmissivity of up to 978 m2/day have been reported at Gusau-Sokoto road by Anderson et al. (Anderson, 1973). Another borehole in the same town (Bakura Farm) was 85 m deep and gave 3 lit/sec. The Rima group comprising the Taloka (poor aquifer) and Dukamaje (aquiclude) Formations are not impressive hydrogeologically. The Wurno Formation is a moderate water yielding aquifer in the Sokoto basin. The thickness varies from 5-30 m and the recharge is restricted to only 330 km^2 (Ofofordile, 2002). The Sokoto Group consists of the Dange (aquitard), the kalambiana (perched aquifer, furnishing water seasonally) and the Gwandu Formation (best known aquifer in the Sokoto basin). The Gwandu consists of two main aquifers-an upper sandy aquifer and a lower confined sandy aquifer.

For the water table aquifer, water levels average 21 m, though in the uplands, near the Niger border, depths of 100 m can be recorded. Further west, and down dip, the aquifer is confined by 20 m of clay and lignite, giving rise to artesian conditions. The aquifer itself varies in thickness from 13-60 m. The Hadejia-Yobe basin is drained by the Hadjia-Yobe River. The tributaries rise from Kano, Katsina and the Jos Plateau, with relatively higher rainfall than the rest of the region. The rivers flow from the area of high rainfall in the Southwest to the area of lesser rainfall towards the Lake Chad. The geology of the basin comprises (from the oldest to the youngest); the basement complex, the younger granite complex, the Gundumi Formation, the Kerrikerri Formation and the Chad Formation.

Within the basement complex and younger granite complex areas, boreholes are shallow (20-35 m), Specific capacity of about 8-9 lit/m/min have been recorded (Offordile, 2002). In the overlying Gundumi Formation borehole depths average 45 m with maximum yield of 6.25 lit/sec and average of 3.2 lit/sec. The Kerrikerri Formation of thickness of up to 200 m is considered to be unpredictable and inadequately explored. It is however associated with deep water levels (165 m Southeast of Bauchi). It appears to belong to the same hydrostratigraphic unit with the Chad Formation which overlies it. The Chad basin sediments are reported to be 132 m at Gumel, 115 m at Nguru, and 132 m at Marguba. Yields of 3.3-5 lit/sec have been recorded. The separation of the Chad Formation

...) an upper, middle and lower ...uifer cannot be defined in this ...t of the basin. The upper 20-30 ... of the alluvial sands of the ...adejia-Yobe basin, holds a lot of ...ater as bank storage, directly ...echarged from river flows. ...he Chad basin is described as the ...argest area of inland drainage ...basin in Africa and occupies parts ...of Nigeria, Chad, Central Africa Republic and the Cameroon. Most of the rivers flowing into lake Chad rise from the watershed areas of the Jos plateau and the Adamawa highlands. The rivers include the Hadejia-Yobe, Alo and yedsaram from the southwest, and the Bambassa, Chari, Illi and lagone from the south east. The rivers Yedseram-Ngadda flow from the south to the northwest, and with all the minor tributaries and rivulets empty into Lake Chad. The Hadejia-Yobe, the Yedseram and all the other tributaries are seasonal. The yedseram with its smaller catchment area, starts to flow a little later, after the beginning of the rainy season, than the Hadejia-Yobe drainage system. There is practically no surface flow from the more arid regions of the north (Offordile, 2002).

Two Formations are important, hydraulically, in the Chad basin. These are the kerrikerri and the Chad Formations. While the kerrikerri is too deep to be of general hydrogeological interest, the Chad formation is well explored and demarcated into upper, middle and lower aquifers. In Maiduguri, the upper aquifer has a depth limit of 105 m. The aquifer consists of lenses of fine to very coarse, often, pebbly sands alternating with clays and sandy clays. The aquifer may be either water table or semi confined. The water levels vary from 10 m to 15 m in wells tapping the aquifer with yields ranging from 2.5 lit/sec to 30 lit/sec. The middle zone aquifer is separated from the upper by about 150 m of plastic clays. It has a thickness of 300 m and is underlain by another 120 m of clay and shale. It is thus highly confined. The recharge areas of the middle confined aquifer all fall outside the geographical boundaries of Nigeria, making it a trans-boundary aquifer.

The Guinea Savannah Zone: This zone covers the area with mean annual precipitation of 1000-1250 mm and about 80 to 60 days of rainy days northwards. About five River basins fall within this zone, namely; the Kaduna River basin, the Benue River basins(upper and lower), the Upper and lower Niger Basins. The Kaduna River basin is drained by the River Kaduna and its tributaries. The River has its headwaters at the Jos Plateau. The climate is typical of most northern areas of Nigeria, except areas bordering the Jos Plateau which feature the orographic influence of highland areas of the Plateau. The temperature shows a mean annual of 24 °C to 30 °C. Precipitation shows a mean of 1120 mm but attain 1500 mm around the plateau area. Over 80% of the Kaduna basin is underlain by basement complex rock with shallow well yields of 0.2-1 lit/sec. The rest of the basin is underlain by the Nupe sandstone and alluvial deposits [4]. The Nupe sandstone underlies most of the southeast including Kontagora,, Mokwa and Bida areas. It consists of slightly cemented fine to coarse sandstones and siltstones with interbedded thin beds of carbonaceous shale and clays. Yields of 1.8-4 lit/sec have been reported in the Nupe sandstone (Du Preeze, 1965).

The Benue River is a continuous elongated geological structure, conveniently subdivided into Upper, Middle and lower basins. The upper Benue River basin occupies the upper reaches of the Benue valley. Its main drainage network comprises numerous streams and rivers flowing into the River Benue from the north and South. The major river systems include the Gongola, Kilunga, and Pai to the north and the Faro and Taraba from the south of the River Benue. The temperature in the Benue valley is relatively high. It is typified by the recording from Yola where the mean daily maximum ranges from 29°C to 32°C in May to October, 32°C to 40°C in October to April. The highest mean maximum temperatures, of 38°C to 40°C, are recorded in February to April. The mean minimum ranges from 18°C to 21°C from November to February. Rainfall is limited, with a mean annual of 750 mm to 1000 mm. The Upper Benue basin is underlain by patches of the basement complex rocks, including a number of volcanic plugs, basaltic flows, and sedimentary rocks of cretaceous age. The geological sequence comprises the basement overlain by the thick sequence of shale of the Asu River group, continental sandstones of the Bima sandstone and shale, clays and limestone. The upper Benue is separated from the Chad basin by the Zambuk ridge. Of hydrogeological interest are the weathered basalts in Biu, Longuda and Sugu plateau areas.

Of more hydrogeological interest is the Bima sandstone outcropping in Yola, Jimeta,, Dabore areas. It is essentially feldspar sandstone with grit, pebbles and clay beds. It is highly cemented and behaves like crystalline rocks, hence its constraints hydrologically. Yields of 2 lit/sec to 8 lit/sec have been recorded. The Lower Benue River basin includes the lower reaches of the Benue valley, stretching from about river Wase down to the confluence of the Benue and Niger to the south. This part is drained by a number of River systems, including the River Wase, Shemankar, Dep and Mada, flowing northeast wards and the Donga, Bantaji and Katsina Ala drainage network flowing in the opposite direction, all the river systems emptying into the River Benue.

The climate is characterized by high temperature regimes, like in the upper Benue, ranging from between 27°C as mean annual. The altitude influences the situation in Jos. Rainfall is moderate with a range of 1120-1500 mm on the Plateau. The geology of the Lower Benue is related to the Upper Benue with close similarity in lithology of the geological formations. These include the Interbedded Sandstones of the Awe Formation, the Sandstones of the Makurdi and Ezeakku Formation, sandstones of the Awgu Formation and the basal sandstones of the Lafia Formation. A number of boreholes have been drilled into the Makurdi Formation with varying degree of success. Yields of 2.5 lit/sec 8.7 lit/sec have been reported. A borehole of about 150 m drilled into the Awgu formation furnished artesian flow at Assakio, north of Lafia. The Lafia formation has highly permeable sandstone of thickness 10-150 m and gives rise to various springs at the contact with underlying Awgu formation.

The Niger Basin consists of the broad valley of the River Niger, from the confluence of the Rivers Niger and Benue to the north western border with Benin Republic. The Basin is sub-divided into Upper and Lower Niger Basins. The Upper Basin represents the upper arm of the drainage area of the River Niger covering an area of about 116,300 km^2. The River Niger, in the upper Niger Basin of Nigeria, is charged with water, from mainly, the Sokoto-Rima and Kaduna River systems. Responsibility for potable water supply is entrusted to State Water Agencies (SWAs) or state water departments in the 36 Nigerian states. The SWAs are responsible to their state governments, generally through a State Ministry of Water Resources. SWAs are responsible for urban water supply, and in some states also for rural water supply. As of 2000, 22 States had separate State Rural Water and Sanitation Agencies (RUWASSA), mostly set up to implement a UNICEF programme. The Local Government Authorities (LGAs), of which there are 774, are responsible for the provision of rural water supplies and sanitation facilities in their areas although only a few have the resources and skills to address the problem. The most important external partners in the Nigerian water supply and sanitation sector are the African Development Bank, the European Union, Japanese JICA, UNICEF, USAID, the NGO WaterAid and the World Bank. The African Development Bank and the World Bank provide loans to the government; the European Union, JICA and USAID provide grants to the government; UNICEF and WaterAid receive grants from governments and donations from the public to implement their projects in cooperation with, but not through the government. Water policy

Nigeria's National Water Supply and Sanitation Policy, approved in 2000, encourage private-sector participation and envisages institutional and policy reforms at the state level. However, little has happened in both respects. As of 2007, only four of the 37 states - Lagos, Cross River, Kaduna and Ogun States - began to introduce public-private partnerships (PPP) in the form of service contracts, a form of PPP where the responsibility of the private sector is limited to operating infrastructure without performance incentives. While the government has a decentralization policy, little actual decentralization has happened. The capacity of local governments to plan and carry out investments, or to operate and maintain systems, remains low despite efforts at capacity development. Furthermore, the national policy focuses on water supply and neglects sanitation.

In 2003 a "Presidential Water Initiative (PWI): Water for People, Water for Life" was launched by then President Olusegun Obasanjo. The initiative had ambitious targets to increase access, including a 100 percent water access target in state capitals, 75 percent access in other urban areas, and 66 percent access in rural areas. Little has been done to implement the initiative and targets have not been met In 2011 the government voted in the United Nations in favour of a resolution making water and sanitation a human right. However, it has not passed legislation to enshrine the human right to water and sanitation in national law. With the above scenario, it is doubtful if the country will be able to attain the Millennium Development Goal for water and sanitation.

3. Water Resources and Environment: Challenges and Prospects Water resources development includes the Construction, harnessing, distribution and protection of both surface and groundwater infrastructures for the domestic, agricultural and industrial needs of the society. The exploitation of Nigeria's water resources has progressively increased with the return to civil rule. Despite the progress that has been made in water supply development since the first waterworks in Nigeria was commissioned in Lagos in 1915, many Nigerians still have inadequate access to modern water supply. Water shortages exist periodically in almost every major town and are present in many rural areas of the country. Areas that are provided with water more often than not revert to water distress due to the unsustainable nature of the infrastructures, making statistics of access unreliable. The turning point for water resources development and management in Nigeria occurred after the severe drought of the 1960s. The Government's response to the catastrophe was the initiation of strategies for co-ordinated and effective water resources development, culminating in the mid-1970s in the creation of the Federal Ministry of Water Resources and the River Basin Development Authorities. The activities of these institutions were further strengthened in 1981 by the establishment of the National Committee on Water Resources, and by the Water Boards at the state level. Later the National Water Resources Institute (NWRI), the Nigerian Hydrological Services Agency (NIHSA), the Rural Water Supply and Sanitation Agencies (RUWASSA) were added. These bodies were charged with taking an inventory, and ensuring rational and systematic planned management and conservation, of the country's water resources. This is further boosted by the various interventions by government, donor agencies and the setting up of many agencies at the national and sub-national levels. However, despite the robust structure in place for the development of Nigeria's Water Resources, there are numerous environmental threats militating against water resources development in Nigeria. Development is threatened when the quantity and quality of water available in an environment is insufficient to meet the various needs of the population and future expansion is hampered by the depletion and or quality deterioration of the resources resulting in water poverty or distress.

There are numerous environmental factors that affect water resources. These includes:

(a) Climate Change

Climate Change manifesting in increased evapo-transpiration and the attendant moisture deficit, decreasing precipitation with accompanying water level lowering in shallow aquifers and decreasing surface flows. These threats impact more on the sub-sahelian region. Climate change manifesting in increased coastal floods and saline water intrusion into upper coastal aquifers especially in the tropical rainforest zones.

Part of Northern Nigeria fa within the Sahel or sub-sahel region characterized by scar rainfall, vegetation and extrem temperatures. The groundwa systems in the area are such th the aquifers- basement sedimentary, shallow or deep a all under one form of threat or t other. The Sahel region populated by farmers who deper on water supply for the livelihood. They need water fo their crops and animals. Becaus of the scanty vegetation overgrazing has further deplete the soil cover exposing the soil to denudation and moisture deficit These farmers often resort to the digging of wells in the shallow basement aquifers to augment surface water resources furnished by various dams in the area.

Due to dwindling precipitation, the water levels of these shallow wells are being lowered. The surface water quality is often impaired by excessive use of sulphate fertilizers and the authorities are not immediately sensitized to the present and future implication of the leachate into surface and ground water systems. The implication of the state of affairs is that both surface and ground water systems in the north are under threat of impairment and or depletion. A well-articulated

Integrated Water Resources Management involving the Ministry of Agriculture, Ministry of Water Resources and the Ministry of Environment must be vigorously pursued to adapt to the natural threats and prevent the human threats.

(b) Groundwater degradation

Excessive exploitation, for example where groundwater levels fall too fast or to unacceptable levels. This not only reduces available water resources and borehole yields but can result in other serious and potentially costly side effects including saline intrusion and subsidence. Inappropriate or uncontrolled activities at the land surface, including disposal of waste and spillage of chemicals, which contaminate the underlying aquifer. This can arise from diffuse sources, which results in widespread but generally less intense contamination, or from a point source, which causes more intense but localized problems. Major change of land use, for example in Sahel, the removal of natural vegetation through overgrazing led to water logging and salinization problems. The nature of the aquifer will also influence the scale of the contamination problem. Thus, in a highly fractured aquifer where groundwater flow is easy and relatively rapid, contamination may become more widely dispersed in a given time than where flow is inter granular, especially if the strata have only a modest permeability. Salinization: Salinity is the major threat to aquifer sustainability because it does not reduce naturally, and salinized groundwater can only be made fit for purpose by energy-intensive desalination or by dilution. Salinization can occur as a result of poor irrigation practice in agricultural areas, and as a result of over-abstraction inducing saline intrusion. The latter occurs usually, but not exclusively, in coastal aquifers. Mixing with just 3 to 4 per cent sea water (or groundwater of equivalent salinity) will render fresh groundwater unfit for many uses, and once this rises to 6 per cent the water is unfit for any purpose other than cooling and flushing. Once salinized, aquifers are slow to recover. In inter granular-flow aquifers, the enormous volumes of water in storage have to be displaced, and in some fracture-flow systems where the matrix is also porous, it is difficult to drain relatively immobile water that has entered by diffusion from the fracture network.

(c) Indiscriminate disposal of industrial effluents into Surface water bodies

Studies carried out in most cities in Nigeria had shown that industrial effluent is one of the main sources of surface water pollution in Nigeria (Ekiye, 2010). Industrial effluents when discharged directly into the rivers without prior treatment have capacity of Increasing water quality parameters. Dada (1997) indicated that less than 10 % of industries in Nigeria treat their effluents before being discharged into the rivers. This has led to high load of inorganic metals such as Pb, Cr and Fe in most of water bodies (Ahmed, 2000; Wakawa, 2008).

The poorly managed drainage system in the country had caused the surface water impairment due to erosions during rainfall. Rainfall runoff carries all sorts of pollutants from houses, industries, farmland and dumping sites. Industries are the major sources of pollution in all environments. Based on the type of industry, various levels of pollutants can be discharged into the environment directly or indirectly through public sewer lines.

Wastewater from industries includes employees' sanitary waste, process wastes from manufacturing, wash waters and relatively uncontaminated water from heating and cooling operations. High levels of pollutants in river water systems causes an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), toxic metals such as Cd, Cr, Ni and Pb and faecal coliform and hence make such water unsuitable for drinking, irrigation and aquatic life. Industrial wastewaters range from high biochemical oxygen demand (BOD) from biodegradable wastes such as those from human sewage, pulp and paper industries, slaughter houses, tanneries and chemical industry.

Others include those from plating shops and textiles, which may be toxic and require on-site physiochemical pre-treatment before discharge into municipal sewage system. Research has shown that some of the water quality parameters of both ground and surface water often rise up during rainfall with high values of turbidity, solids and anionic species often been recorded (Taiwo, 2011; Jaji, 2007; Taiwo, 2010; Mustapha, 2008 & Izonfuo, 2001). Agricultural runoff of pesticides, plant and animals wastes is also a major contributing source of organic pollution to water bodies in Nigeria. Agricultural run-off of pesticides, plant and animals wastes is also a major contributing source of organic pollution to water bodies in Nigeria. The work of Mustapha (2008) had Linked the periodic eutrophication of Oyun Reservoir in Offa, Kwara state to run-off of phosphate fertilizers from nearby farms in addition to cow dung washing from the watershed into the Reservoir. Water pollution through surface run-off has been reported in Literatures with subsequent effects on nutrient enrichment, water quality mpairment, marine lives pawning ground destruction and ish kill (Izonfuo, 2001 & Martins, 998).

) Threats to existing water frastructures from erosion d contamination of water pelines

e to regulation lapses and ing is a common business in tern Nigeria. These activities n lead to severe erosion of the lines leading to excavation collapse of the pipelines gure 8). Effluents from strial and domestic activities lly enter the network through the joints of the collapsed pipes. The situation is further aggravated by the activities of cattle men who take advantage of the leakages from the pipes to provide water for their herds. Unfortunately these activities take place in areas far from residential areas such that detection may take months to occur.

4 Conclusion and Recommendations

The Nigeria Water Sector has significant potentials to contribute to the development of the economy. The provision of potable water for cooking and drinking; and the construction of dams for hydro-electricity are all relevant for economic development while irrigation facilities across the country have helped the nation to support its growing population without solely depending on rain-fed agriculture. Additionally, the existence of dams and irrigation schemes has contributed to suburban development of several communities and induced socio-economic improvement of the residents. Clearly, the Water Sector has a major role to play in the sustenance and further development of the nation's industrial sector especially in food and beverages, textile, pharmaceutical among others.

The supply of potable water holds the key to the elimination of water-related diseases such as cholera, typhoid, dysentery, river blindness and malnutrition.

Fortunately, Nigeria as a nation is endowed with huge water resources with the capacity to meet our burgeoning requirements across all facets of life given the requisite resources and a focused plan of action managed by competent and committed professionals within a well orchestrated institutional framework. This will require significant capital to transform the stated objectives and requirements into available water resources for domestic and industrial consumption. The amount of resources required to maintain the dams and irrigation facilities as well as keep the taps running would require the private sector participation.

In view of these considerations, Government needs to take the first step of articulating a holistic roadmap for the development and management of the nation's water resources towards the actualization of the sector's potentials. We believe that with the support of private sector investors and other key stakeholders, focused implementation of the roadmap will facilitate the achievement of water target objectives and cre[ate] the enabling environment [to] attract private investments in th[e] sector. To mitigate threats to o[ur] water resources, governme[nt] must step up Integrated Wat[er] Resources management where a[ll] sectors must synergize to achieve results.

The Federal Ministry o[f] Environment must strengthen the present environmental laws such that the polluters of water bodies could be prosecuted. Industrial and agricultural sectors should also be compelled to treat their wastes before being discharged into the water bodies. Drastic measures must be taken by all authorities concerned to minimize children morbidity and mortality due to poor sanitation and water quality problems. The threats to water resources are variable and many. The variation in water quality experienced in Nigeria reflects differences in land management and the physical environment. These differences occur both as a result of natural variability, societal development and pollutant inputs. In addition, water quality in the vicinity of urban areas is influenced by industrial and urban development. Understanding the condition of rivers and streams and their relation to ground water is critical to effective mitigation of threats to water development.

The River basins and Research Institutes must evolve custom mitigation measures suitable for the hydro meteorological environment. Education of the benefitting masses is also likely to help in reducing anthropogenic threats to our water bodies. The Ministry of Environment should take up the challenge by stepping up regulations.

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