UNDER PEER REVIEW

Original Research Article

IMPLICATION OF CLIMATE CHANGE ON GROUNDWATER RESOURCES

ABSTRACT

This study focuses on establishing whether climate change has been occurring in Nigeria. Four States in the South Western part of the country was considered in the study. Climatic data like the rainfall, raindays, surface air temperature for a period of 32 years were collected and analysed. Also, the yield, the static water level and some other data of the boreholes sunk in the region were collected to examine the effect of climate change on groundwater. The climatic data were collected from the Nigerian Meteorological Agency Lagos, while the hydrogeological data for the boreholes were collected from Rural Water Sanitation Agency (RUWATSAN) in each State. The results show that the percent change in the average cumulative rainfall for Osogbo, Osun State, Ibadan, Oyo State, Ikeja, Lagos State and Abeokuta, Ogun State range from 1.2-4.4, 3.1-15.4, 7-16.3 and (-)14-18, respectively. Also, the percent change in the average surface air temperature for Osogbo, Osun State, Ibadan, Oyo State, Ikeja, Lagos State and Abeokuta, Ogun State range from 0.64-1.61, -0.94-1.27, -1.92-0.97 and -2.74- (-0.27), respectively. The percent change in the rainfall indicates there has been increase in the amount of precipitation over the decades considered which implies that climate change effect may be setting in. Most of the data for the yield of the boreholes for the period (1980-2012) considered in this study were not available. However, the data available indicates that yield has not changed significantly.

Keywords: Climate Change, Rainfall, Temperature, Yield, Static Water Level

1. INTRODUCTION

Climate change is one of the challenges that have a global dimension. The consequence of climate change on agriculture, flooding, water resources and environment has brought negative impacts that have attracted global attention. The United Nations Framework Convention on climate change refers to climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods [1] The Intergovernmental Panel on Climate Change (IPCC) defines climate as the average weather in terms of the mean and its variability over a certain time-span and a certain area and a statistically significant variation of the mean state of the climate or of its variability lasting for decades or longer, is referred to as climate change [2]. Climate change is a long-term shift in the statistics of the weather (including its averages). For example, it could show up as a change in climate normal (expected average values for temperature and precipitation) for a given place and time of year, from one decade to the next [3].

Global change encompasses changes in the characteristics of interrelated climate variables in space and time, and derived changes in terrestrial processes, including human activities that affect the environment. Climate is changing because of the natural variability. Climate change is a normal part of the earth's natural variability, which is related to interactions among the atmosphere, ocean, and land, as well as changes in the amount of solar radiation reaching the earth. Also, climate change is caused by human activities. Naturally occurring gases, such as carbon dioxide (CO_2) and water vapor (H_2O), trap heat in the atmosphere

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causing a greenhouse effect. Burning of fossil fuels, like oil, coal, and natural gas is adding CO_2 to the atmosphere. The current level is the highest in the past 650,000 years [3]. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change concluded that most of the observed increase in the globally averaged temperature since the mid-20th century was very likely due to the observed increase in anthropogenic greenhouse gas concentrations [3]). Recent estimates of the increase in global average temperature since the end of the last ice age are 4 to 5 ℃ (7 to 9 ℉). That change occurred over a period of about 7,000 years, starting 18,000 years ago. CO_2 has risen by 40% in just the past 200 years, contributing to human alteration of the planet's energy budget that has so far warmed earth by about 0.8 ℃ (1.4 ℉). Even though an increase of a few degrees in global average temperature does not sound like much, global average temperature during the last ice age was only about 4 to 5 ℃ (7 to 9 ℉) colder than now [4]. Global warming of just a few degrees will be associated with widespread changes in regional and local temperature and precipitation as well as with increases in some types of extreme weather events. These and other changes (such as sea level rise and storm surge) will have serious impacts on human societies and the natural world. Decades of slow warming as well as decades of accelerated warming occur naturally in the climate system. Decades that are cold or warm compared to the long-term trend are seen in the observations of the past 150 years and also captured by climate models [4].

Groundwater is a key resource for human development. The total volume of water on the earth is approximately 1.4 billion km^3. Of this, freshwater content is only 2.5% estimated at 34 million km^3. Groundwater makes up 10 million km^3 of the freshwater in the world. On a global scale, one third of the population depends on groundwater for their drinking water in urban as well as rural areas. Groundwater also plays a pivotal role in agriculture, and an increasing portion of groundwater extracted is used for irrigated agriculture. It is estimated that at least 40% of the world's food is produced by groundwater-irrigated farming, both in low income as well as high-income countries. The effects of global warming on water resources, and especially on groundwater, will depend on the groundwater system, its geographical location and changes in hydrological variables. Knowing how climate change will affect groundwater resources is thus important as it will allow water resources managers to make more rational decisions on water allocation and management [5] and enable the formulation of mitigation and adaptation measures. Groundwater, as with surface water, is increasingly stressed due to human development, population growth, increased reliance on groundwater, and climate change. Changes in global climate are expected to affect the hydrological cycle, altering surface water levels and groundwater recharge to aquifers with various other associated impacts on natural ecosystems and human activities. Groundwater discharge, storage, saltwater intrusion, biogeochemical reactions, and chemical fate and transport may be modified by climate change.

Therefore, this study evaluates the existing relationship between the elements of changing climate and groundwater resources in the four States in the South Western part of Nigeria. The increase of concentration of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere will certainly affect hydrological regimes. Global warming is thus expected to have major implications on water resources management. Kumar [6] explained that climate change poses uncertainties to the supply and management of water resources. Temperature increases also affect the hydrologic cycle by directly increasing evaporation of available surface water and vegetation transpiration. Consequently, these changes can influence precipitation amounts, timings and intensity rates, and indirectly impact the flux and storage of water in surface and subsurface reservoirs (i.e., lakes, soil moisture, and groundwater). The greater variability in rainfall could mean more frequent and prolonged periods of high or low groundwater levels, and saline intrusion in coastal aquifers due to sea level rise and resource reduction. This study examines if climate change has been taking place in four States in the South Western part of Nigeria and the impact it may have on groundwater resources.

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2. THE STUDY AREA

The South West region of Nigeria comprises Lagos, Ogun, Oyo, Ondo, Osun and Ekiti States. Four of the states namely Lagos, Ogun, Oyo and Osun States were considered in the study. One local government area (LGA) was considered in each of the States: Ikeja LGA in Lagos State, Abeokuta LGA in Ogun State, Ibadan LGA in Oyo State and Osogbo LGA in Osun State.

The wind currents that dominate the South West Region of Nigeria are the tropical maritime (mT) air mass and the tropical continent (cT) air mass. The third air mass, that is, the equatorial easterlies, is not as pronounced as the mT and the cT. The mT air mass originates from the southern high pressure belt located off the coast of Namibia, and in its trajectory, picks up moisture from the Atlantic Ocean, crosses the Equator and enters South West Nigeria. Thus, it brings rainfall to the latitudinal location of such areas within the region. It must be noted that some areas in Lagos State, which is very close to the Atlantic Ocean experience rainfall in all the months of the year.

The cT air mass originates from the high pressure belt north of the Tropic of Cancer. It picks dusts and aerosols along its path, thus it is dry. Hence, it brings dry season to the region in the months of November through February depending on the latitudinal location of such places within the region. The two major air masses (mT and cT) meet along a slanting surface called the Inter Tropical Discontinuity (ITD) [7,8]. The equatorial easterlies (not so pronounced) are rather erratic cool air masses, which come from the east and flow in the upper atmosphere along the ITD. Occasionally, however, the air mass dives down, undercuts the mT and cT air masses and gives rise to line squalls or dust devils. The savanna regions, that is, the Guinea Savanna and Sudan Savanna, are found in the northern parts of the region, particularly Oyo State.

2.1 Classification condition of the study area

Three major climatic zones can be recognized in the study area: Tropical rainforest climate (Af), Savanna climate (Aw) and Tropical monsoon climate (Am). Lagos State which is a coastal area is mainly Tropical rainforest climate (Af), while some parts of the States have Savanna climate (Aw) and Tropical monsoon climate (Am).

According to the Koppen's climatic classification the characteristic of the A climate are scheme [7]:

i. Coldest month has a mean temperature greater than 18°C.
ii. The 18 °C winter isotherm is critical for the survival of certain tropical plants.
iii. The annual rainfall is greater than the annual evapotranspiration.

The sub-division f indicates no long dry season, but wet virtually all the year round; w means summer rain and m indicates monsoonal, with short dry season and heavy rain during the rest of the year.

2.2 Geology of the study area

The South-Western part of Nigeria is categorized into two geological zones, that is, the basement complex and the sedimentary terrains. The basement complex is composed mainly of igneous and metamorphic rocks while the sedimentary terrains constitute soft rocks and sediments which are of coastal origin. The basement complex covers over seventy percent of the entire south-western part of Nigeria [9]. Oyo and Osun States fall predominantly within the basement complex, while Ogun State has dual geologic characteristics, i.e. It is partly within basement and sedimentary terrains. Lagos state is basically a sedimentary terrain.

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3. METHODOLOGY

This study which establishes whether there is climate change in four states (Lagos, Ogun Oyo and Osun States) in South Western part of Nigeria and its effect on the groundwater recharge was carried out by: (i) establishing the climate trend from climate data collected; (ii) determining the yield trend of the boreholes to check if there is any change in groundwater resources and (iii) comparing the climate trend to the yield trend.

3.1 Determination of climate trend

These climatic data considered in this study include the temperature and precipitation. The period of 30 years (1980-2012) was considered. Data collected include the cumulative rainfall (mm), the number of days it rained, the month of a study year with maximum rainfall and the value, the month of a study year with maximum temperature and the value and the average temperature for the study year. The period considered was grouped into three, that is, 1980-1990, 1991-2001 and 2002-2012. The percent difference in the average cumulative rainfall and temperature between two periods were calculated and analyzed. The summary of the climatic data are presented in section 4. The data were collected from the Nigerian Meteorological Agency located in Lagos State.

3.2 Determination of the yield trend

The data of the borehole sunk in the area under investigation were collected and analyzed. Data collected include yield of wells, static water level, depth of borehole, date of drilling. The yields of various boreholes were carefully studied by checking the yields of the boreholes in that area from their different dates of construction and operation within the study period to know if there has been any notable change in the yield values. This method was then used to identify or note if the groundwater resources has been affected or not. The data were collected from Rural Water Sanitation Agency (RUWATSAN) in each State.

4. RESULTS AND DISCUSSION

4.1 Climatic data

Tables 1 and 2 show the summaries of the climatic data and the percent change in the average cumulative rainfall and surface air temperature, respectively. It can be seen in Table 2 that the percent change in the average cumulative rainfall for Osogbo, Osun State, Ibadan, Oyo State, Ikeja, Lagos State and Abeokuta, Ogun State range from 1.2-4.4, 3.1 to 15.4, 7-16.3 and (-)14-18, respectively. Also, the that the percent change in the average surface air temperature for Osogbo, Osun State, Ibadan, Oyo State, Ikeja, Lagos State and Abeokuta, Ogun State range from 0.64-1.61, -0.94-1.27, -1.92-0.97 and -2.74- (-)0.27, respectively. The percent change in the rainfall indicates there has been increase in the amount of precipitation over the decades considered, except in Ogun State where a reduction of 14% was recorded. Also, reduction and increase in temperature were observed. This implies that the climate change may be just beginning.

Table 1: Summary of the Climatic data

Period (Group)	Average Cumm. Rainfall (mm)	Average Temperature (℃)	Average Rain days (mm)

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Osogbo, Osun State			
1980-1989 (1)	1331.1	31.1	19
1990-2000 (2)	1373.2	31.4	18
2001-2010 (3)	1389.2	31.6	17
Ibadan, Oyo State			
1980-1990 (1)	1274.1	31.5	15
1991-2001 (2)	1313.1	31.9	14
2002-2012 (3)	1470.0	31.6	14
Ikeja, Lagos State			
1980-1990 (1)	1403.5	31.0	11
1991-2001 (2)	1525.5	31.3	14
2002-2012 (3)	1631.8	30.7	18
Abeokuta, Ogun State			
1980-1990 (1)	1149.3	36.5	-
1991-2001 (2)	12	36.4	-
2002-2012 (3)	1468.2	35.5	-

Table 2: Percent change in the average cumulative rainfall and temperature

Group	**Change in Average Cumm. Rainfall (%)**	**Change in Average Temperature (%)**
Osogbo, Osun State		
Groups 1 and 2	3.2	0.96
Groups 2 and 3	1.2	0.64
Groups 1 and 3	4.4	1.61
Ibadan, Oyo State		
Groups 1 and 2	3.1	1.27

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Groups 2 and 3	12	-0.94
Groups 1 and 3	15.4	0.32
Ikeja, Lagos State		
Groups 1 and 2	8.7	0.97
Groups 2 and 3	7	-1.92
Groups 1 and 3	16.3	-0.97
Abeokuta, Ogun State		
Groups 1 and 2	-14	-0.27
Groups 2 and 3	17	-2.47
Groups 1 and 3	28	-2.74

4.2 Yield trend of the boreholes

Tables 3 and 4 show the Summary of borehole data collected for Lagos and Ogun States, respectively. Table 3 shows that the static water level for Lagos State for the period (2012-2013) range from 1.5-18m, while Table 4 shows that the yield and the static water level for the period (2006-2018) range from 0.62 to 1.32l/s and 0.6-23m respectively. Most of the data for the period (1980-2012) considered in this study were not available. However, the data available indicates that yield has not changed significantly.

Table 3: Summary of boreholes in Lagos State

S/N	YEAR	BOREHOLE LOCATION	LGA	B/H DEPTH	S.W.L	PERIOD
1	2013	Oriba community	Epe	12m	3m	July
2	2013	Denton (Oyingbo)	Ebute Meta	9m	1.5	June
3	2013	Erunwen oloye	Ikorodu	30m	10m	September
4	2013	Aboni	Iyana Ipaja	35m	7m	August
5	2013	Olorunsogo	Ijegun	50m	18m	
6	2013	Bariga	Bariga	42m	10m	August
7	2013	Amule ayobo		24m	6m	August
8	2013	Agunloye	Ikorodu	35m	12m	September

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9	2013	Isanwo	Badagry	45m	7m	September
10	2012	Maya	Ikorodu	36m	14m	September
11	2012	Igborosun	Badagry	20m	12m	July

Table 4: Summary of borehole data in Ogun State

S/N	Date	Location	LGA	Depth	SWL	Period	Yield
1	2006	Sopade village 1	Odeda	30m	4.6m	October	1.02L/S
2	2006	Alagbaa village	Odeda	32m	5.2mm	December	1.32L/S
3	2007	Imagbon pry. Sch.	Remo north	42.5m	22.5m	February	0.67L/S
4	2007	Ogboye	Odeda	44.3m	10.4m	August	1.5L/S
5	2007	Asa town	Yewa north	19m	0.60m	October	0.76L/S
6	2007	Lowa community	Owode	30m	23m	October	0.62L/S
7	2007	Apena kenta village	Odeda	42.67m	2.5m	November	1.21L/S
8	2007	Agbedi village	Owode	79.3m	42m	December	1.20L/S
9	2008	Sopade village 2	Odeda	43.89m	2.26m	January	0.76L/S

5. CONCLUSION

This study analyzed existing climatic data in the southwestern part of Nigeria to establish if climate change has been occurring. It also evaluates the available hydrogeological data of boreholes to establish whether climate change affects the groundwater yield. It was found that amount of rainfall have been increasing for the decades considered and the surface air temperature has changed slightly. Therefore, climate change may just be beginning to occur. The data available for the boreholes indicates that the climate change has not had significant impact on the yield of the boreholes.

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