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Effect of Climate Change on Groundwater Resources in South West, Nigeria

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Abstract
This study examined the impact of climate change on groundwater resources of the south-western region of Nigeria. First, chronological climate (meteorological) and geological and hydrogeological data of Ondo State the various catchment areas within the region which spanned over a period of 30 years (1982 – 2012) were analyzed with a view to determine whether there has been any climate change in the study area. The Meteorological data such as rainfall and temperature were obtained from the Nigerian Meteorological Agency located in Lagos, while the hydrogeological data such as borehole yield were collected from Benin-Owena river basin in Ondo state. For each location, the graphs of Rainfall versus Month and Maximum Temperature (Tmax), Minimum Temperature (Tmin) versus Month were plotted as a means of obviating the probable change in climate. It was discovered that there was a slight increase in both rainfall and the mean temperature 2% - 8% and 0.1^0c – 0.7^0c respectively. Thus climate change was observed as a result of increase in the average yearly rainfall and mean temperature. The effect was concluded as not pronounced or significant on the groundwater after all the analyses and studies.
Keywords: groundwater, climate change, temperature, rainfall, south-western, Nigeria.

Introduction

Climate patterns play a fundamental role in shaping natural ecosystems, and the human economies and cultures that depend on them. Our climate is rapidly changing with disruptive impacts. Climate change can be viewed from different perspectives. While some refer to climate change as global warming, some defined climate change as a change in the weather pattern. Generally, climate change has been defined according to Bourqoui et'al, (1999) as a change in the statistical properties of the climate system over periods of decades or longer, regardless of the cause. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warming (American Research council, 2010); Ranjan et'al (2006).

Because so many systems are tied to climate, a change in climate can affect many related aspects of where and how people, plants and animals live, such as food production, availability and use of water, and health risks. For example, a change in the usual timing of rains or temperatures can affect when plants bloom and set fruit, when insects hatch or when streams are at their fullest. This can affect historically synchronized pollination of crops, food for migrating birds, spawning of fish, water supplies for drinking and irrigation, forest health, as well as groundwater resources. Groundwater get recharged from rain, streams, rivers and ocean. When these sources of groundwater recharge are affected by changing climate, it is expected that the groundwater will also be affected. Several studies has shown that climate change has effects on groundwater resources (Shar Tushar (2009); Rosenberg et al.1999; Singh and Kumar (2010); Vaccaro,1992; Richardson and Wright, 1984)

Climate change poses uncertainties to the supply and management of water resources (Kumar, 2012). The Intergovernmental Panel on Climate Change (IPCC, 2001) estimates that the global mean surface temperature has increased 0.6 ± 0.2 ^oC since 1861, and predicts an increase of 2 to 4^o to cover the next 100 years. 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).

Groundwater is an important part of the global freshwater supply and is affected by climate change (Nyenje and Batelaan, 2009). One of the most severe consequences of climate change will be the alteration of the hydrological cycle, which will impact on the quantity and quality of regional water resources (Toews Michael (2007). African countries are more likely vulnerable to these changes as a result of lack of institutional capacity and economic development. According to Nyenje and Batelaan (2009), IPCC (2001, 2007) reports that on the overall, Africa has warmed by 0.7 ^0C over the 20^{th} century while rainfalls have increased by 5-10%. Several studies have been conducted on effects of climate change on surface water and very little is done on the potential effects on groundwater. Yet the effects on groundwater are far reaching and need to be investigated, thus, this study investigate the effects of climate change on groundwater.

2. The study area

The south west region of Nigeria is located between latitudes 6° and 9° North of the Equator, and longitudes 3° and 6° East of the greenwich Meridian. Presently, the Region comprises Lagos, Ogun, Oyo, Ondo, Osun and Ekiti states.

The climate of South West Region of Nigeria is dominated by the influence of two major wind currents, just like any other parts of Nigeria. The wind currents 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 and Ondo states that are very close to the Atlantic Ocean experience rainfall in all the months of the year, that is, January to December.

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

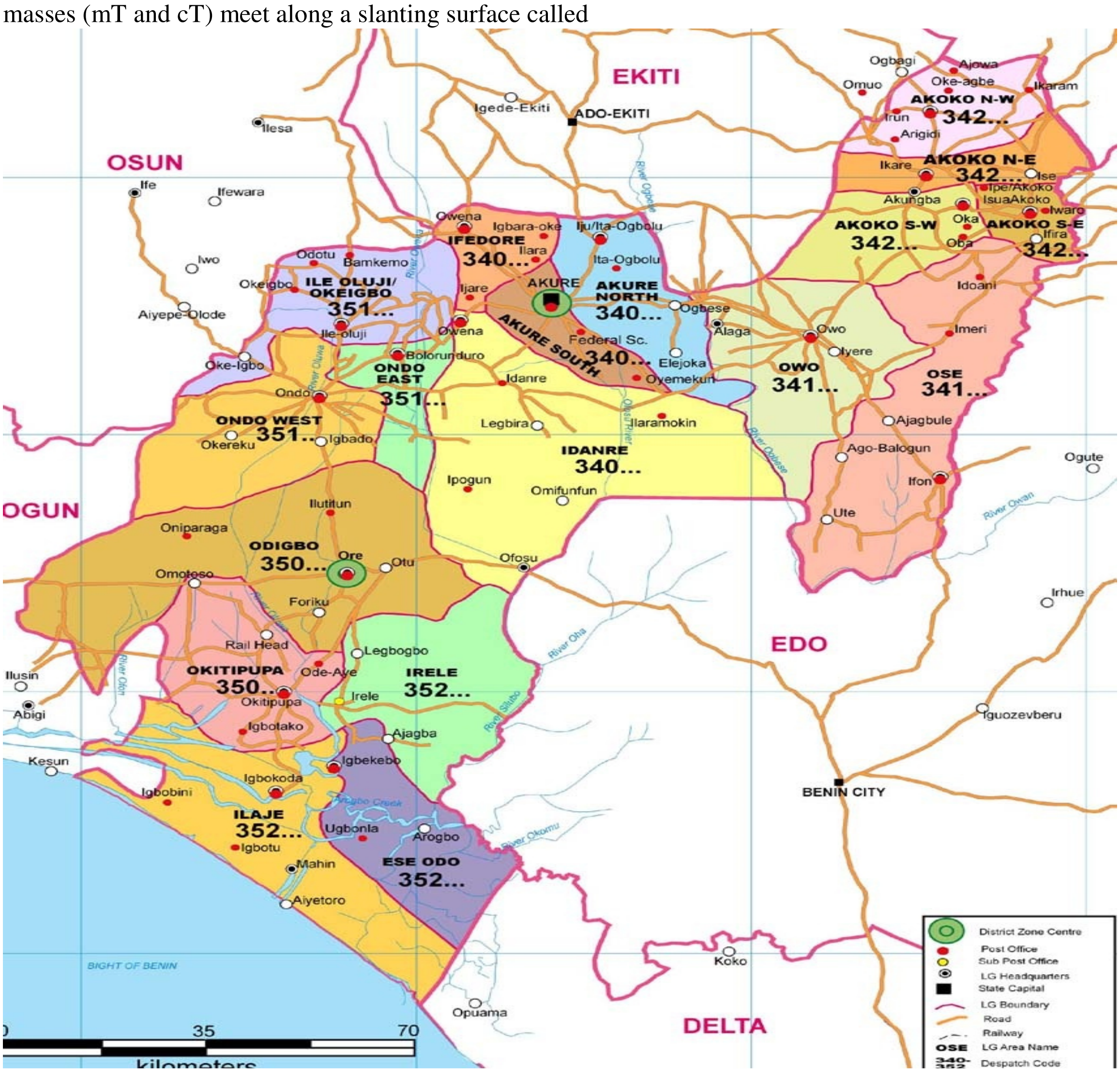

Figure 1. Map of Ondo State of Nigeria showing the data stations

the Inter Tropical Discontinuity (ITD) (Ayoade, 1988, Ranjan et'al 2006). 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 (Omogbai, 2010).

The vegetation of South West Nigeria consists of forest and savanna. The forest zone comprises salt water and fresh water swamps located in the southernmost part of the region, the tropical rainforest or equatorial forest with three distinct layers of upper, middle and lower layer located immediately north of the salt water and fresh water swamp forest.

The savanna regions, that is, the Guinea Savanna and Sudan Savanna, are found in the northern parts of the region, particularly Oyo and Ekiti states. Human cultivation for agricultural purposes has led to a kind of vegetation that can be described as \`Sudano-Savanna\` also found in the northern part of the South West region.

2.1 Classification of the study area into climatic zones

Three major climatic zones can be recognized in South West Nigeria according to Koppen\`s (1846-1940) climatic classification schemes. These are:

i. Tropical rainforest climate (Af) found in the southernmost part of the region especially in Lagos and Ondo States coastal areas.
ii. Savanna climate (Aw) found in the \`middle belts\` and northern parts of the region that cut across all the six states in the region.
iii. Tropical monsoon climate (Am) sandwiched between the southernmost and \`middle belt\` part of the region. This climatic zone also cut across all the six states in the region.

According to the Koppen\`s climatic classification scheme (Ayoade, 1988, Adebayo, 2007), the characteristic of the A climate are:

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

The sub-divisions of f, w and m can be explained as follow:
f indicates no long dry season, but wet virtually all the year round.
w indicates summer rain.
m indicates monsoonal, with short dry season and heavy rain during the rest of the year.

2.2 Classification of the study area into geological zones

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 (Rahaman 1976). States such as Oyo, Osun and Ekiti fall predominantly within the basement complex, while states such as Ondo and Ogun possesses dual geologic characteristics, i.e. they are partly within basement and sedimentary terrains. Lagos state is basically a sedimentary terrain.

3. Methodology

Investigation into the effect of climate change on groundwater resources within the south-western region of Nigeria involves three major steps which are as follows:

i. Observation of climate trend to check if there is any climate change (from climate data collected);
ii. Observation of the yield trend of the boreholes in select localities to check if there is any change in groundwater resources; and
iii. Comparing the climate trend to the borehole yield trend.

In order to determine the effect of climate change on ground water resources, it is expected that a change in climate must be established. Certain climatic index is needed to be studied within a period of time to establish both climate change and the extent of the change. Such data includes temperature (maximum and minimum), precipitation, humidity, evapo-transpiration etc. These data which covers a period of 30 years (1982-2012) were collected from the Nigerian Meteorological Agency located in Lagos.

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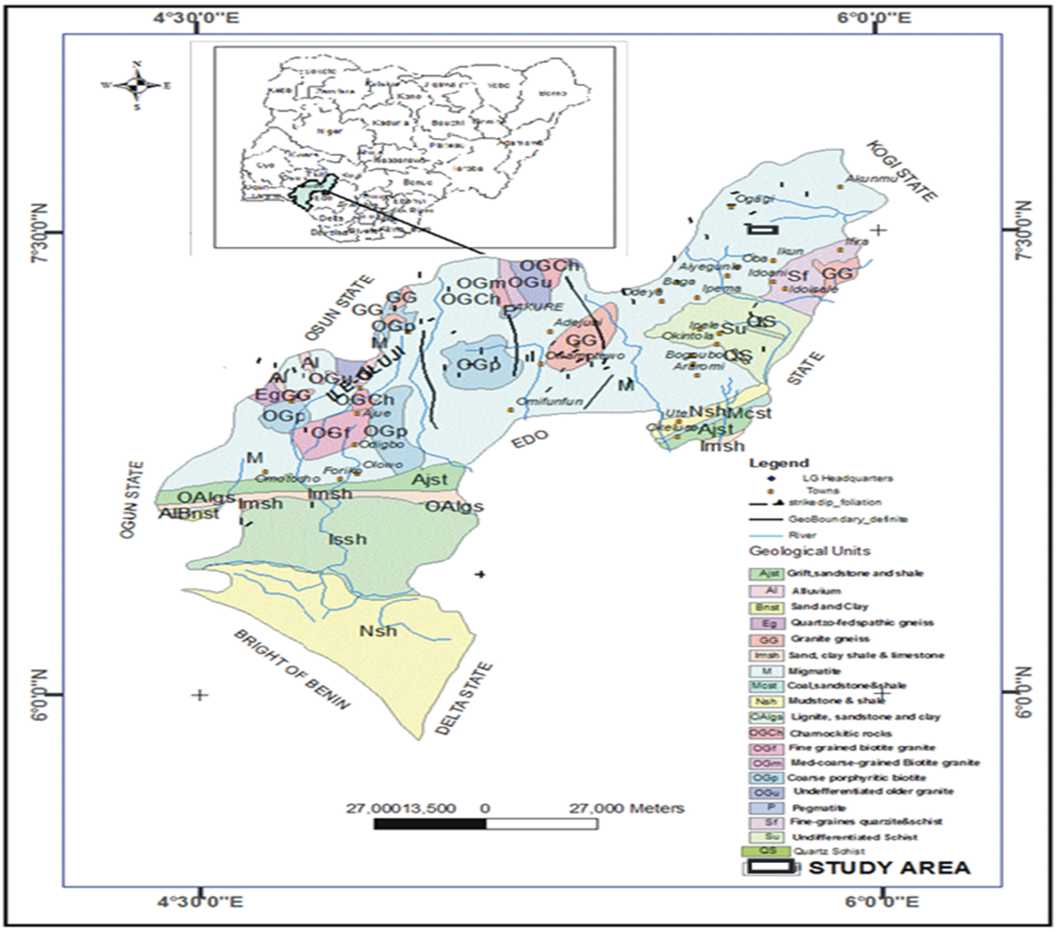

Figure 2. Geological Map of Ondo State Nigeria showing the rock types
(After Geological Survey Agency of Nigeria)

The required data which are needed to study certain groundwater indices such as yield of wells, static water level, depth of borehole, date of drilling were collected from Benin-Owena River Basin Authority in Ondo state and the Rural water sanitation agency (RUWATSAN) in each of the states of the south-western Nigeria. The study was carried out by comparing the various data of the wells in the different locations covering the study periods.

The data collected were first grouped or arranged into a series of five years for each 30 to 32 years of available data for each location within the south-west. Thereafter, a general trend analysis was performed to investigate whether climate has actually changed within the catchment in the past years. The analysis was performed using the Microsoft Excel package. For each location, the graphs of Rainfall versus Month and Maximum Temperature (Tmax), Minimum Temperature (Tmin) versus Month were plotted as a means of taking note of any probable change in climate,

The yield of various boreholes in the study area were equally carefully studied by checking the yields of the boreholes in that area commencing from their different dates of construction and operation, and especially within the study period to know if there has been any notable change in the yield values. This method is then used to identify or note if the groundwater resources has been affected or not.

Results and Discussion

Table 4.1: Climatic data analysis for Ondo State

Year	Max. Rainfall (mm)(month)	Rain days	Cummulative rainfall (mm)	T-max (month) (^{0}c)	Average temp (^{0}c)
1980	297.2 (JUN)	16	1418.9	33.8 (MAR)	31.1
1981	258.6 (JUN)	14	1424.2	35.4 (MAR)	31.6
1982	269.6 (OCT)	15	1379.2	34.5 (FEB)	31.3
1983	343.6 (SEP)	17	1354.5	36.5 (MAR)	31.9
1984	218.3 (JUN)	1	1499.4	36 (FEB)	31.6
Year	**Max. Rainfall (mm)(month)**	**Rain days**	**Cummulative rainfall (mm)**	**T-max (month) (^{0}c)**	**Average temp (^{0}c)**
1985	326.6 (AUG)	20	1644.1	35 (MAR)	31.5
1986	217.9 (SEP)	18	1159.8	33.9 (FEB)	30.5
1987	384.4 (AUG)	22	1401.4	34.3 (APR)	31.8
1988	278.1 (SEP)	20	1555.8	34 (FEB)	30.8
1989	357.4 (AUG)	18	1449.9	33.3 (MAR)	31.0
			AVRG : 1428.7		AVG: 31.3
1990	370.3 (JUL)	13	1577.9	36.4 (MAR)	31.0
1991	463 (JUL)	18	1853.4	33.4 (FEB)	30.6
1992	348.1 (SEP)	23	1485	36 (FEB)	31.1
1993	328.7 (SEP)	12	1134	34.6 (FEB)	31.4
1994	225.7 (JUN)	12	1115	34.1 (FEB)	31.2
1995	379.6 (AUG)	20	1913.6	35.9 (FEB)	31.6
1996	218.3 (APR)	7	1248.5	34.1 (FEB)	30.9
1997	218.3 (JUL)	13	1516.1	34.4 (FEB)	30.9
1998	273.3 (OCT)	18	1453.6	36 (MAR)	31.7
1999	245.6 (OCT)	21	1397.3	33.9 (FEB)	30.5
2000	299.3 (JUN)	13	1535.2	35.9 (MAR)	31.7
			AVRG : 1475.4		AVG: 31.1
2001	255 (APR)	7	1026.4	35.3 (FEB)	31.4
2002	272.8 (JUN)	11	1549.4	35.3 (FEB)	31.2
2003	259.8 (SEP)	20	1473.1	34.6 (MAR)	31.5
Year	**Max. Rainfall (mm)(month)**	**Rain days**	**Cummulative rainfall (mm)**	**T-max (month) (^{0}c)**	**Average temp (^{0}c)**
2004	234.8 (APR)	11	1462.4	35 (FEB)	30.4
2005	252.8 (JUN)	15	1400	36.4 (MAR)	31.0
2006	243.5 (SEP)	14	1380.7	33.4 (FEB)	30.6
2007	279.6 (SEP)	15	1512.3	36 (FEB)	31.1
2008	290.6 (SEP)	16	1913.6	34.6 (FEB)	31.4
2009	218.3 (APR)	9	1248.5	34.1 (FEB)	31.2
2010	278.5 (AUG)	18	1385.6	35.9 (FEB)	31.6
			AVRG : 1435.2		AVG: 31.1

Between first and second periods:

$$\frac{1475.4 - 1428.7}{1428.7} \times 100 = 3.27\%$$

Between second and third periods:

$$\frac{1435.2 - 1475.4}{1475.4} \times 100 = -2.72\%$$

From the calculations above, it is observed that there has not been obvious increment in the rainfall and temperature, for the considered period of 30 years in Akure, Ondo state.

Table 4.9: summary of borehole data in ondo state.

State	Location	Date of drilling	Total borehole dept (m)	Static water level (m)	Borehole yield (l/s)
Ondo	Ipele	21-04-05	50	5.5	1.02
″	Ifira-akoko	08-06-05	40	5	0.85
″	Ikakumo-akoko	08-06-05	50	3	0.85
″	Idoani	06-08-05	50	9	0.85
″	Idogun	06-08-05	50	8	0.85
″	Ikun-akoko	08-09-05	45	5	0.85
″	Ikare-akoko	09-09-05	45	4	0.85
″	Ifon	12-09-05	60	10.5	0.85
″	Ipele	06-10-05	45	6	0.85
″	Akunnu-akoko	10-10-05	40	4	0.85
″	Eshe-akoko	11-10-05	40	4.9	0.85
″	Ipe-akoko	10-11-05	50	9.5	0.85
″	Ikaramu-akoko	10-11-05	50	5	0.85
″	Oyin-akoko	0-03-06	100	18	0.79
″	Futa	01-06-06	72	4	0.8
″	Igbindo	March '08	70	5.1	1
″	Igbindo	March '08	70	4.6	1
″	Igushin	March '08	70	5.1	1
″	Idanre	March '08	70	3.01	1
″	Ondo west	March '08	70	5.1	1.1
″	Igushin	March '08	70	5.1	1.1
″	Agopanu owo	April '08	70	5.1	1
″	Ipoba olu idanre	May '08	70	6.5	1
″	Afo, ose	June '08	100	4.6	1.1
″	Idanre	June '08		6.2	1.1
″	Afo, ose	June '08	100	6.2	1.1
″	Ondo west	August '08	70	5.1	1
″	Tologo, ondo west	August '08	70	5.1	1.1
″	Owo	Sept '08	70	5.1	1
″	Ayetimbo	Oct '08	70	4.1	1
″	Oloruntedo ondo west	Oct '08	70	3.2	1
″	Ondo west	Oct '08	70	4.1	1
″	Ondo west	Oct '08	70	4.1	1.1
″	Ajebambo	Oct '08	70	4.1	1
″	Ikun-akoko	08-03-11	50	5.4	1
″	Oke ifun	July '11	30	3.53	1
″	Ipesi	July '11	41	4.59	1
″	Ode aye	July '11	43	3.12	1.1
″	Okiti pupa	July '11	43	4.6	1.1
″	Igbodigo	July '11	50	6.3	1.2
″	Irowa	July '11	41	4.3	1
″	Alayere	July '11	32	3.92	1
″	Ese ikare	July '11	37	1.3	1
″	Akure north	July '11	36	1.7	1
″	Ilalekeji	August '11	27	3.8	1
″	Ugbe-akoko	August '11	44	4.4	1
″	Auga-akoko	August '11	42	4.7	1
″	Oke ila ikare	August '11	36	4.7	1
″	Iromu	August '11	34	3.5	1.1
″	Isua	August '11	34	3.4	1
″	Barogbo	Sept '11	30	8.9	1
″	Iyani akoko	Sept '11	40	2.14	1.3
″	Odonna	Sept '11	40	4.7	0.8

″	Oke agbe	Sept ‘11	40	0.2	1.5
″	Ayeteju	Sept ‘11	40	1.5	1.2
″	Oke agbe	Sept ‘11	40	1.5	1.2
″	Oba ile	Sept ‘11	33	2.48	0.8
″	Araromi	Sept ‘11	33	3.3	1
″	Odole ore	Sept ‘11	30	3.4	1
″	Iseu	Sept ‘11	40	1.6	1.3
″	Ileluji	Sept ‘11	40	4.4	1
″	Ileluji	Sept ‘11	40	4.1	1
″	Ijigba	Oct ‘11	40	5.6	1
″	Aduralere	Oct ‘11	40	5.6	1.1
″	Sasere dajo	Oct ‘11	27	3.1	1
″	Ago ladokun	Oct ‘11	27	3.8	1
″	Ikare-akoko	Oct ‘11	41	5.1	1
″	Akunnu-akoko	Oct ‘11	41	1.9	0.9
″	Aba adeyeri	Feb ‘12	38	5.9	0.9
″	Ifaramoraye	Feb ‘12	40	8.1	0.8
″	Ipe igbede	Feb ‘12	34	11.3	1
″	Onisere	Feb ‘12	35	4.7	0.8
″	Makinde	Feb ‘12	30	6.5	0.9
″	Oniparaga	Feb ‘12	40	10.8	0.8
″	Daji camp	April ‘12	40	6.9	0.89
″	Pwa ani	April ‘12	40	4.3	0.89
″	Iwoye afo	April ‘12	30	4.8	1
″	Elegbeka	April ‘12	30	3.6	0.87
″	Akungba	May ‘12	30	4.9	1
″	Ayegunle	May ‘12	30	5.7	1
″	Supare	May ‘12	30	5.75	0.8
″	Isakunme ikare	July ‘12	30	3	1

We noted that yield has not significantly change in the regions for which the data was obtained. However, no sufficient yield data of these regions were available, thereby limiting our intended scope analysis for boreholes yield.

Conclusions

It can be concluded that the south-western region of Nigeria has generally not experienced a pronounced change in climate (after studying the available index of climate such as rainfall and temperature). Most parts of the southwest have rainfall increase ranging between 2% and 5%, except for a place like Lagos where rainfall has increased by as much as 15% between 1980 and 2012. Within the south west, the temperature change has not been noticeable. There is also no significant change in the groundwater resources due to the corresponding insignificant change in the borehole yield of the particular locations observed.

It can then be drawn as a note of final conclusion that, since there is no significant change in climate coupled with an insignificant change in the groundwater resources. Based on the available data, there is no significant effect of climate change on groundwater resources, beginning from 2010, slight changes in climate, most especially in rainfall quantity was began to appear.

Recommendation

It is recommended that:

i. Digging of boreholes for groundwater exploration should be regulated so as to enhance recordkeeping and availability of data on groundwater resources;
ii. Having established from this study that climate is changing, there has to be increase in public awareness of this ugly trend awareness; and
iii. Measures to militate against attitudes or behavioral issues causing climate change are to be taken by government and general public.

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