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EVALUATION OF IMPACTS OF CLIMATE CHANGE AND URBANIZATION ON THE WATER SUPPLY OF ABUJA, NIGERIA

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ABSTRACT

The impact of climate change on water resources is a serious challenge across the world. This is made worse by urbanization and increase in population which constantly alter the water demand and supply schedules. This work applied some statistical tools to study the effect of climate change on the water supply situation in Abuja, Nigeria, with emphasis on temperature and precipitation changes and human perceptions of climate change. The results showed a worsening water availability scenario resulting from increasing temperatures and decreasing rainfall trends which reduces water availability. It is also clear that most of the residents (96%) are aware of climate change issues and perceive temperature (67%) and rainfall (47%) increases over the years. Human activities (53%) is considered as the main cause of the change and 45% think that population increase and urbanization has a greater effect on the supply of water to Abuja than the climate change.

Keywords: Climate Change, Temperature, Precipitation, Runoff, Urbanization, Population

INTRODUCTION

Water resources and climate are interrelated in the sense that a change in the climatic condition of any geographical location over a long period of time results into a notable change in its water resources. Accessible water is generally vulnerable to changes in their fresh state as a result of human activities and natural forces. According to Mailer and Yates (2006), freshwater and water resources generally are not only highly sensitive but susceptible to variations in weather and climate. The undeniable impact of climate change is experienced most directly through water availability. It has and will continue to impact the water cycle in direct and indirect ways: by affecting precipitations and evaporation cycles, as well as by changing patterns of consumption. In turn, evolving consumption patterns and economic development increases demands for water supply. The impacts also results in water stress due to reduction in freshwater availability. The phenomenon has dual effects on water supplies: firstly, water catchment areas will get less precipitation. These changes in precipitation regimes will bring about reductions in river flows and falling in groundwater tables. Secondly, temperature increases and heat waves will increase demand for water and water consumption (IPCC, 2000a; Satterthwaite, et al., 2007).

The challenges posed by climate change and variability on the teaming population of any nation is revealed on their water resources in terms of the quantity and quality of their water supply. Profoundly, the impact of climate change is felt on world's water supply causing water scarcity while putting enormous stress on water infrastructures, thereby reducing how communities can reliably access clean water. Under climate change scenario, Loftus, et al (2011) reported that flows into rivers, lakes and reservoirs as well as groundwater will be affected and water supply will be reduced as a result of altered precipitation patterns and increased temperatures.

In most developed and developing countries, increasing population as a result of urbanization and economic growth, has created rising challenges for municipalities to develop and effectively manage water resources, thereby water supply is constantly overstressed in a changing climate situation. Accordingly, Yang, et al (2005) submitted that as population increases with increase in human activities, the impacts of climate change becomes more intense with fluctuation in annual storm water runoff, reduced base-flow, and degradation of stream habitat's condition negatively affecting aquatic lives.

Several evidences of climate change and variability has been reported by researchers over the years in Nigeria. David (2011) reported series of weather variations in different places on earth, with evidences in Nigeria as revealed through torrential rainfall, massive erosion and desert encroachment among a series of weather aberrations. Also, the Nigerian Environmental Study/Action Team, (NEST, 2011), revealed that there is an increasing trend in atmospheric temperature and rainfall amount in Ondo and Akwa Ibom States in the past three decades. In the Nigeria of today, Karmalkar, et al (2010) specifically submitted that mean annual temperature increased by 0.8°C between 1960 and 2006, at an average rate of 0.18°C per decade while precipitation shows a statistically decreasing trend of 3.5 mm per month (1.8%) per decade in the same period.

On water supply, Boko, et al, (2007), reported variability of precipitation across the African continent, leading to decrease in annual precipitation while an increase in inter-annual variability has been noted with the indication that extreme precipitation events (floods, droughts) are on the rise. Similarly, climate change has brought about water-stress due to reduction in freshwater availability thereby affecting water supplies as water catchment areas gets less precipitation. Hence, changes in precipitation regimes brings about reductions in river flows and falling groundwater tables (Satterthwaite et al., 2007). For example, freshwater availability at the coast of Peru, has seen a reduction of 12% over a period of 35 years (Bates et al 2008).

Development goals are threatened by climate change, with the heaviest impacts on poor countries and poor people and unmitigated climate change is incompatible with sustainable development. It imposes an added burden on development (WDR, 2010: Bates et al, 2008). Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Yohe et al, 2007). In many developing countries like Nigeria, present needs are hardly met and this paints a gloomy picture of the future. The Intergovernmental Panel on Climate Change (IPCC) identified agriculture, food and water as the key vulnerable sectors in Africa and identified sub-Saharan Africa as the region expected to suffer the most deprivation (IPCC, 2007). In facing the challenges of climate change, the priorities for African countries are to achieve high political recognition for Africa on the platform of international negotiations, allocate resources appropriately, ensure food and energy security, and manage and adapt to long-term climate risk (Osman-Elasha, 2009).

Providing an adequate water supply plays vital role in the development of a nation and it becomes the government's objectives in the water sector. Considering the growth rate of urban centres such as Abuja (Federal Capital Territory-FCT), an optimal operation of water supply reservoir for sustainability of water supply including the conservation of water for the future is paramount. The FCT is endowed with both surface and groundwater resources to carter for the water needs of its populace. But recently, due to the impacts of climate change and variability affecting the water resources of FCT coupled with the influx of people into the city, the water sector has been stressed so much that the water supply source, Lower Usman Dam had to be augmented by the Gurara Inter-basin Water Transfer Project. As shown in Table 1, the future water demand/supply is on the deficit with the ever increasing population. Hence, this study seeks to evaluate the impacts of climate change and variability coupled with urbanization on water supply of the FCT Abuja. It is in the study's objective to evaluate the monthly and annual trends and fluctuation patterns of climate variables in relation to the hydrology of the study area and to estimate how urbanization has worsened the impacts of climate change and variability.

THE STUDY AREA

Abuja, the capital city of Nigeria, was created in 1976 as a planned city with a master plan design to define all major structures and infrastructures and to include a well-structured water supply and central sewerage system. It is 8000 Km^2 in size, centrally located and accessible to all parts of the Federation as shown in Figure 1 (IPA, 1979). Located in the tropics, it experiences two weather conditions annually namely, the rainy season and the dry season. The rainy season begins from April and ends in October with mean annual rainfall within the range 1100mm to 1600mm. During the dry season, the temperature ranges from 30.4^{o}C and 35.1^{o}C with the high altitudes and undulating terrain of the FCT acting majorly as moderating influence on the weather (Medugu, 2009; Aondoakaa, 2012). Accordingly, the African Internet Governance Forum (AfiGF, 2014) put it forth that the climatic dictates of FCT are essentially from the South West to the

North West due to the rising elevation from the Gurara valley in the Southwest, to the Bwari-Aso hills and the AgwaKaru hills to the Northeast.

Table 1: Summary of estimated and projected analysis of the water demand surplus/deficit and Population for the FCT

Year		2006	2010	2020	2030	2040	2050
Population / Projected Population		1,450,201	1,679,426	2,736,508	3,590,418	4,712,446	6,185,259
Min Water Demand (@191l/c/d) m^3/day		267,438	320,770	522,673	685,770	900,077	1,181,385
Max Water Demand (@250l/c/d)		350,050	419,856	684,127	897,604	1,178,112	1,546,315
Max. Production per day m^3/day Phase 1&2 Treatment Plant		240,000	240,000	240,000	240,000	240,000	240,000
Phase 3&4 Treatment Plant		-	-	720,000	720,000	720,000	720,000
Allow 20% unaccounted for water		192,000	192,000	768,000	768,000	768,000	768,000
Minimum Water Demand	Surplus	-	-	245,327 (-10.20%)	83,000 (12%)	-	-
	Deficit	75,438 (28%)	128,370 (40%)	-		132,777 (15%)	413,385 (-35%)
Maximum Water Demand	Surplus	-	-	83,873 (12%)	-	-	-
	Deficit	158,050 (45%)	227,856 (54.3%)	-	129,604 (-14.40%)	410,112 (35%)	778,315 (-50%)

(Source: FCT-Water Board, 2010)

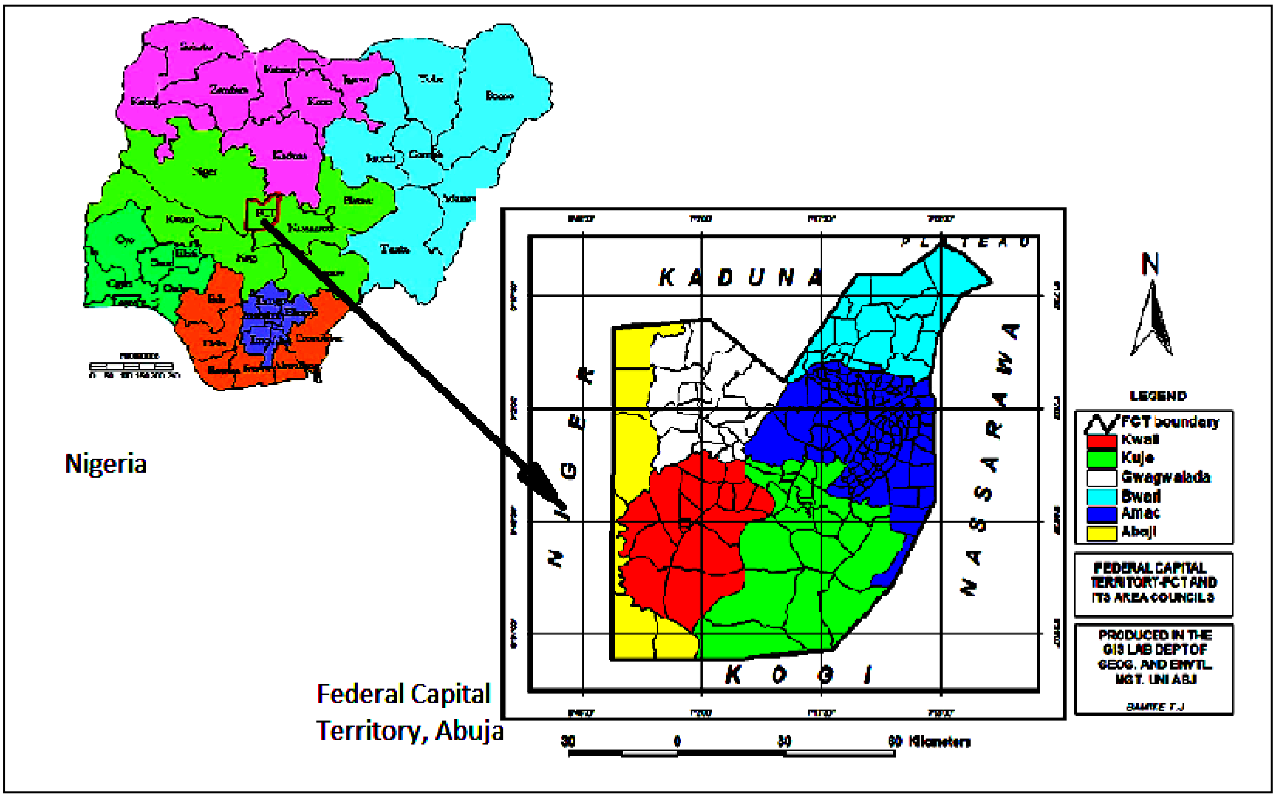

Figure 1: Map of Nigeria showing FCT-Abuja, the study Area

FCT Abuja is endowed with both surface and groundwater resources as it is well-drained by several rivers such as Gurara, Usman, Jabi, Jere, Pegna, Izom, Gerinya and others. Development of water resources in FCT started with a 6 million m^3 Jabi Dam in 1981 with several others such as the 30 million m^3 Pandam dam, 100 million m^3 Usman dam, and 850 million m^3 Gurara Inter Basin Water Transfer Scheme implemented between 2001 and 2007 while several others are proposed. (FCT Water Board, 2010).

MATERIALS AND METHOD

Data Collection

The preliminary part of the data collection involved a descriptive literature review approach. This seeks to dig into the available previously conducted researches, reports, and communications on climate change and variability and it impacts on water sector globally, regionally and specifically in the FCT Abuja. The field work involved several visits to Ministries, Agencies and Water Resources Managers in the FCT.

Hydrologic data for a period of 55years was collected from the Lower Usman Dam Station and the Nigerian Hydrological Services Agency (NIHSA). Meteorological data for 35years was obtained from World Meteorological Association (www.waterbase.org.) through the Nigerian Meteorological Agency (NIMET). Also, the use of structured questionnaires and personal interviews were employed to some extent. A total of 400 questionnaires were administered randomly with 40 questionnaires each specifically administered to water board and NIMET officials respectively while others were administered to the general public.

Data Analysis

The selected meteorological data used in this study are precipitation, minimum and maximum temperature and solar radiation from the synoptic meteorological station on longitude 7.5° and latitude 8.9° within the FCT-Abuja from 1979-2013. Also, simulated hydrological data for the years 1951-2006 from the gauge station at the Lower Usman dam were obtained.. The hydro-meteorological parameters were subjected to statistical analysis trend and fluctuation analysis using standardized anomaly index (SAI).

Statistical Analysis

This study employed both measures of central tendency (maximum, minimum and mean values) and measure of dispersion (standard deviation, variance, range, etc) as the statistical tools for the meteorological and hydrological data analysis.

Standardized Anomaly Index

The standardized anomaly index (SAI) is a statistical tool used to illustrate the variations exhibited by the hydro-meteorological parameters. The SAI is an easy tool to use as it utilizes a single gamma distribution to reveals the significant changes and behaviour of the changes in the entire data set considered. It was first utilized as a statistical tool in the year 1977 to evaluate and depict the average area behaviour of precipitation at a specific time period (Kraus, 1977). Babatolu (1998) reported the effectiveness of the index for rainfall variability in the Niger basin area. Similarly, Ojoeye (2012) used SAI to test for the variability of hydro-meteorological parameters in the study of climate change impact on water resources and adaptation strategies in the Sudano-Sahelian Ecological Zone (SSEZ) of Nigeria by adopting the index name to suit the parameter under consideration. The various anomalies indexes to be performed are discussed below.

Standardized temperature anomaly index (STAI): As shown in equation 1, STAI was used in the study to examine the temperature variability at the selected meteorological station within the FCT-Abuja for the period of 1979-2013 (Mohammed, 2012).

$$X_{mn} = \frac{\sigma}{N_n} \sum_{m=1}^{N_n} (T_{mn} - T_n) \qquad (1)$$

Where: X_{mn} is the temperature departure for the nth year; T_{mn} is the year's temperature totals; T_n is the mean temperature for the base period; σ is the standard deviation for the base period and; N_n is the number of years when the data are available.

Similarly, the Standardized precipitation anomaly index (SPAI) and Standardized runoff anomaly index (SRAI) were used for precipitation and runoff.

RESULTS AND DISCUSSION

Statistical Analysis

The monthly and annual hydro-meteorological data for FCT Abuja is used for the analysis. The data covers the maximum and minimum temperature and precipitation from 1979 to 2013 and the simulated runoff of the Usman River from 1951 to 2006.

Trends in the hydro-meteorological parameters

The result of the trend analysis for the meteorological parameter such as minimum and maximum temperature and precipitation for the period of 35years using the appropriate SAI is presented as follows:

Minimum Temperature Trend

The STAI was used to evaluate the variability observed in the minimum and maximum temperature distribution over a period of 35years and the trend analysis is as illustrated in Figures 2 and 3.

The annual statistics for the minimum temperature revealed that the mean value was 19.02℃ in 2000 and 20.78℃ in 2013. The standard deviation for the selected years was 0.44 while the mean is 19.97℃. This was repeated for maximum temperature trend for a period of 35 years and the annual statistics for the maximum temperature revealed that the mean value was 31.69℃ in 1992 and 35.76℃ in 2005. The standard deviation for the selected years was 1.15 while the mean is 33.33℃. Variations were observed within the monthly and annual maximum temperature with low negative trends until the late 1990's when an abrupt positive trend was observed. Also, an indication of abnormal temperature rise was observed between 1999 and 2007. These could be attributed to the effect of global warming causing an increase in average temperature and consequently increasing the rate of water losses from surface water bodies and groundwater. This temperature trend, if unabated, suggests that average minimum values in 2030 and 2050 may be above 23ºC and 25ºC respectively and average maximums for the same years may be more than 43ºC and 50ºC. These estimates assume a constant rate of increase for the projections. A continuously increasing rate has been predicted for the US in the same period (Roy et al, 2010).

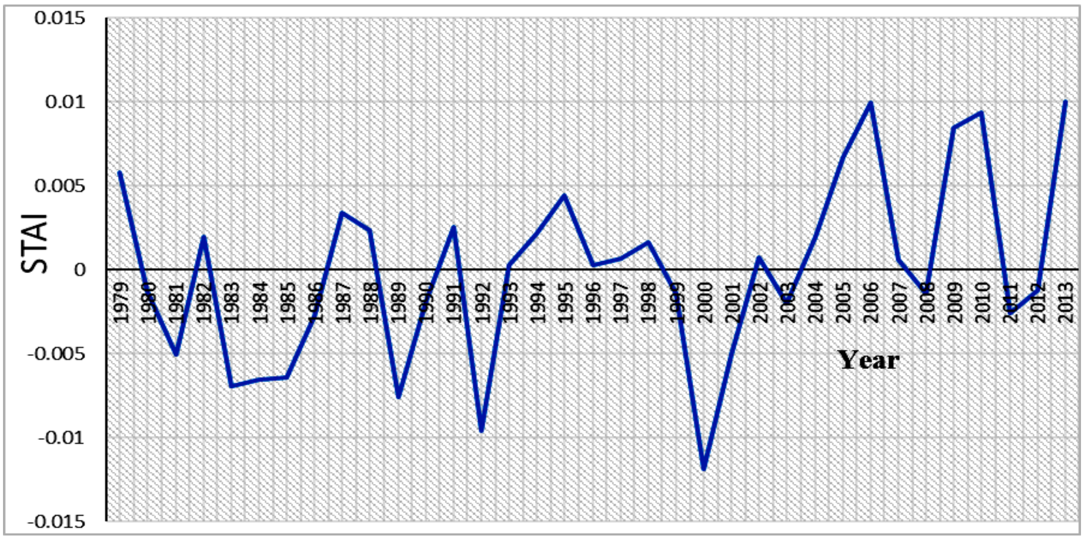

Figure 2: Trend Analysis for minimum temperature

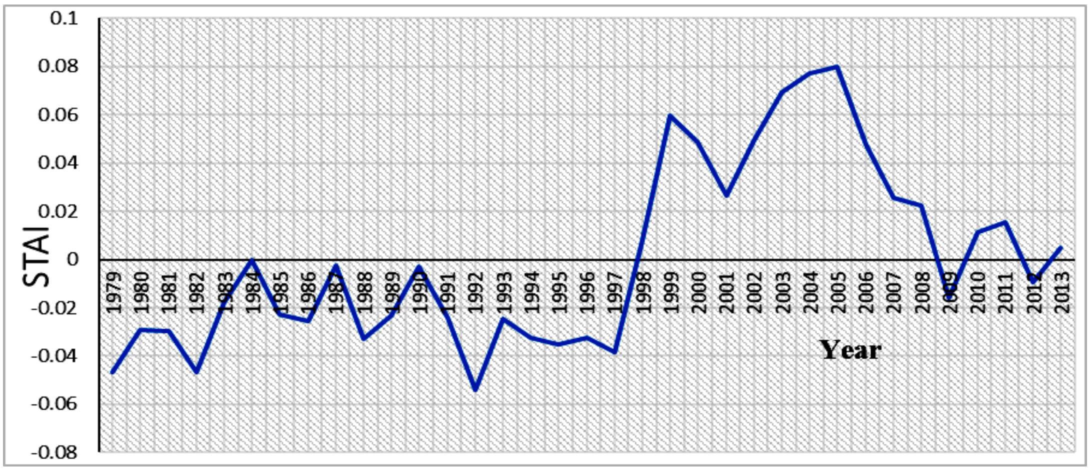

Figure 3: Trend Analysis for maximum temperature

Precipitation Trend

The standardized precipitation anomaly index (SPAI) was used for the trend analysis to examine the variability in the precipitation and it distribution over the period of 1979-2013. The trend analysis is as illustrated in Figure 4.

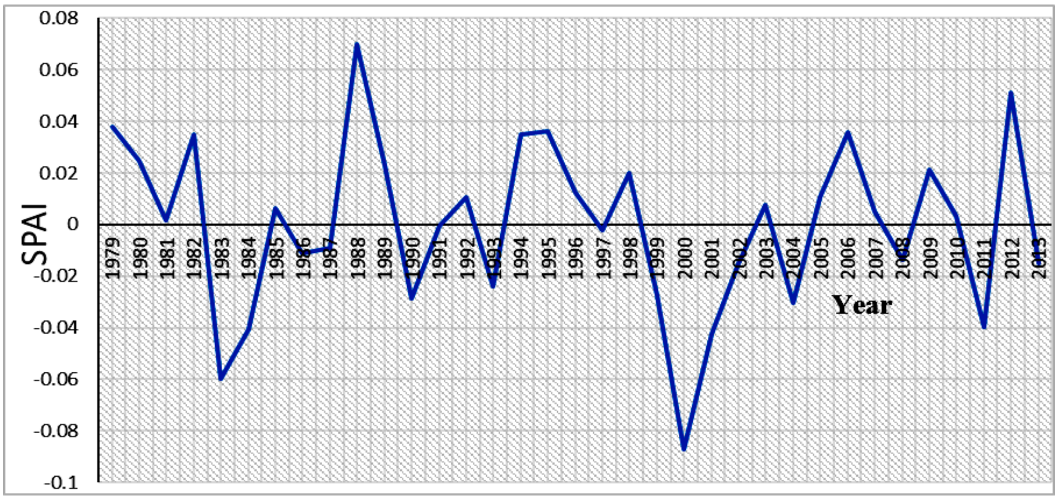

Figure 4: Trend analysis for annual precipitation

The annual precipitation varied irregularly, ranging from 694mm in 1988, 180mm in 2000 and 633mm in 2012. The precipitation pattern maintained a relatively positive trend with some anomalies in few years. This variation influences the volume of water available at the Lower Usman Dam, consequently affecting water supply in the Abuja. The standard deviation for the years selected is 1.07 while the mean precipitation is 466mm.

Runoff Trend

The standardized runoff anomaly index (SRAI) for the simulated annual runoff at the Lower Usman Dam River was evaluated and the trend is as shown in Figure 5.

The simulated runoff for the Lower Usman Dam revealed that total storage ranges from 157.2m^3 in 2006 to 376.9m^3 in 1978 while runoff consequently ranges from 58.7m^3 to 140.7m^3 respectively. The mean annual runoff for the simulated years considered in this study is 22.16m^3 while the standard deviation is 4.46. The variation observed in the simulated runoff at the Lower Usman Dam is not commensurate with the projected population of the city as shown in Table 1. This will affect the reservoir water level and consequently, affects the water availability for the populace of the FCT, Abuja. As revealed in the runoff trend (Figure 5), there is a problem of inflow from 1980 which is a clear indication of insufficient inflow into the reservoir which could lead to water shortage. With predicted rise in average temperature, water loss is expected to increase which will also affect inflow into the reservoirs. Even though there are predictions of increase in the intensity of wet five-day large-scale weather events in most parts of the world due to climate change (WHO, 2009), there is no evidence that the water stress will abate. When juxtaposed with the projected population increase and the subsequent increase in water demand (Table 1), the water stress scenario becomes clearer.

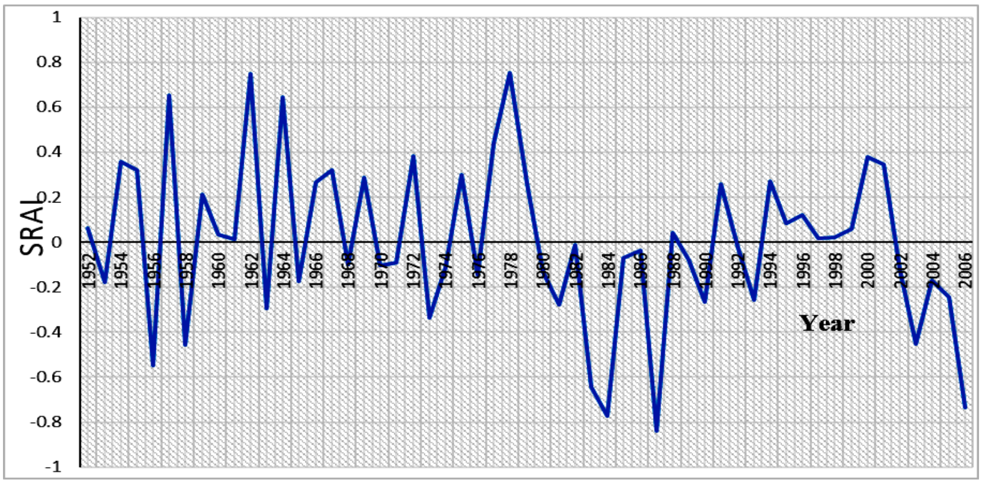

Figure 5: Trend analysis for annual runoff

Fluctuations in the hydro-meteorological parameters

In order to depict the fluctuation pattern of the meteorological variables, the SAI for minimum temperature, maximum temperature, precipitation and runoff were plotted against year and the results is as presented in Figures 5 to 8.

Minimum Temperature Fluctuation Pattern

A series of non-directional and irregular fluctuation in the minimum temperature is observed by the fluctuation series in the Figure 6. The series fluctuations were above and below the average value. The highest minimum temperature deficit was noticed in the year 2000 although with a relatively constant deficit minimum temperature recorded within the year 1982 to1987 while the highest surplus was observed in the year 2006 and 2013.

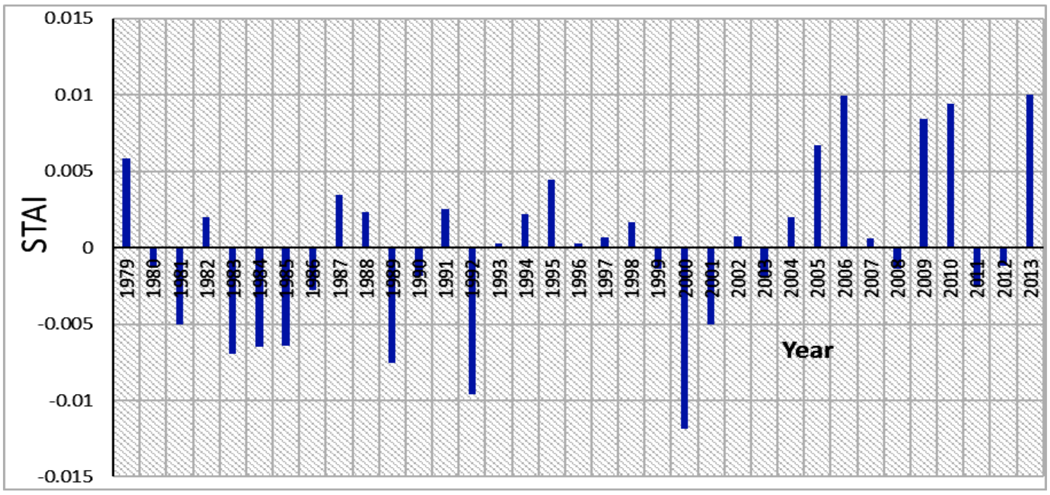

Figure 6: Annual minimum temperature fluctuation

Maximum Temperature Fluctuation Pattern

The fluctuations in the maximum temperature (Figure 7) revealed a series of fluctuations above and below the average value. There was relatively definite directional fluctuation in the maximum temperature as observed in the station considered within the FCT. There was a deficit fluctuation in the maximum temperature spanning from 1979-1998 with no exception. On the other hand, there was a fluctuation surplus in the maximum temperature from 1999-2009 with irregular fluctuations till 2013.

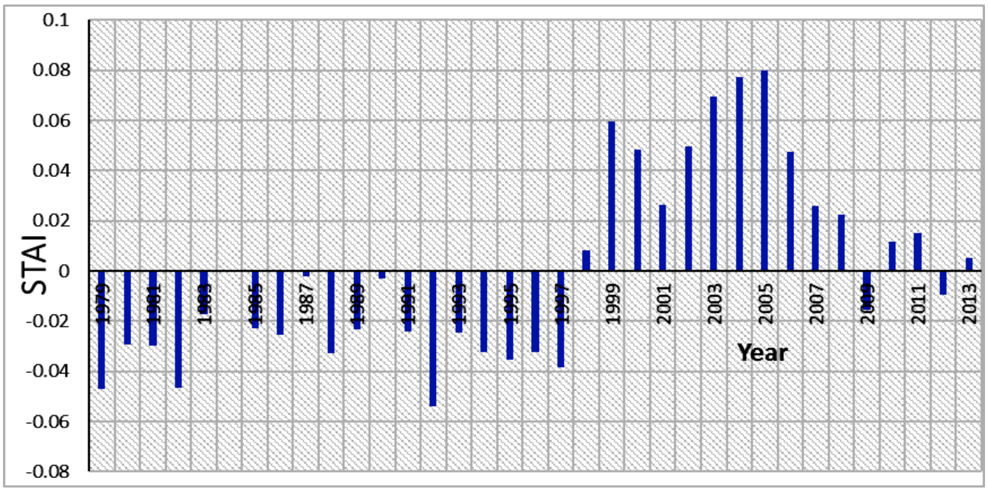

Figure 7: Annual maximum temperature fluctuation

Precipitation Fluctuation Pattern

Generally, a non-direction series of fluctuation above and below the average value was observed for the annual precipitation with some regular directional fluctuations. There were fluctuation surplus in precipitation in 1979-1982, 1988-1990, 1994-1997 etc and a deficit in 1983-1985, 1998-2003. Also, while a fluctuation surplus was observed in 2012, the year 2013 recorded a fluctuation deficit of precipitation (Figure 8).

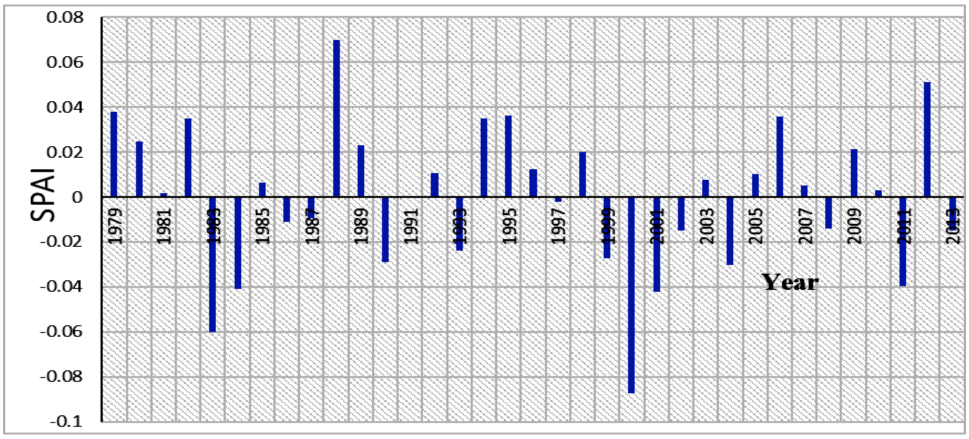

Figure 8: Annual precipitation fluctuation

Runoff Fluctuation Pattern

The runoff fluctuation pattern as shown in Figure 9 generally depicts both non-directional and direction series of fluctuations above and below the average value. There was a relatively non directional fluctuation pattern from 1952-1976 and a directional fluctuation surplus from 1977-1980, 1994-2001 and a deficit from 1981-1988 and 2002-2006. This deficiency has the tendency to be the dominant occurrence in frequency and magnitude till the year 2030 and beyond, going by the trend since 1980. The implication of this is the suggestion that less and less surface water will be available to serve the increasing population.

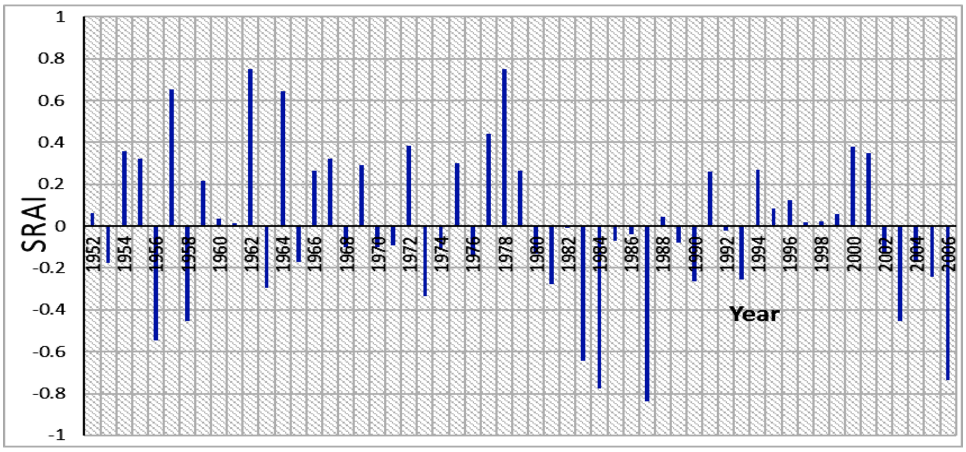

Figure 9: Annual runoff fluctuation

Descriptive Analysis

The socio economic characteristics of the respondents from the administered questionnaires revealed that from a total of 342 respondents of the 400 questionnaires administered, 53% were males while 47% were female. The high percentage of the male is as a result of conscious effort to sampling of the household heads. The educational status of the respondents revealed that 97% had formal education. This high percentage of literacy offer a high degree of confidence in the information provided which is subsequently utilized in analysis. On the employment status, 12% of the respondents are currently unemployed while 10% are students. The study revealed that 27%, 35% and 16% of the respondents are Civil servants, Private employee and Business owners respectively. The high percentage of employed residential of the FCT is an indication of a relatively high income level and high standard of living and as such, high demand for quality water supply.

On climate change awareness and its impacts on water supply in the FCT Abuja, the study revealed that 327 out of the 342 respondents, accounting for about 96% are aware of the term “climate change and variability”. This may be attributed to the high level of literacy among the respondents. Majority of the respondents defined climate change as the changes observed in the temperature and rainfall pattern of a particular place over a long time period. On the observed average temperature pattern, 69%, 16%, 11% and 4% argued increasing, decreasing, constant and fluctuating pattern of temperature respectively. Also, on average rainfall pattern, 47%, 41%, 7% and 5% reported an increasing, decreasing, constant and fluctuating pattern of average rainfall respectively within the FCT-Abuja.

On the causes of the observed changes in climate change and variability, 53% opted for human activities, 38% for natural factors while 9% argued that both human and natural factors are responsible. Most of the respondents believed that the posed challenges can be tackled while 12% thinks that man can only try to adapt and 88% suggested mitigating measures such as awareness raising and controlling activities that enhances such changes in climate. The study revealed that 90% of the respondents think that climate change impacts water supply. 57% reported a decrease in water supply as a result of high temperature and decrease in rainfall, 31% argued an increased in water supply due to increasing rainfall while 13% complained about higher cost of water supply resulting from scarcity of water due to climate change and variability which affects the rainfall pattern of the FCT-Abuja.

Furthermore, the study revealed the perception of the populace regarding the trend of population and water supply in the FCT-Abuja. 43%, 31%, 22% revealed that water supply is constant but population is increasing, water supply is decreasing while population is increasing, and water supply is increasing while population is increasing respectively while the rest argued that water supply is increasing while population is decreasing.

There is no documentation of the amount of water that goes into other uses within the Abuja metropolis outside that of domestic consumption and this will be the hardest hit sector as water scarcity increases. As the cost of exploitation of new water sources increases due to economic reasons, pollution, land degradation and groundwater depletion, the challenges to meet the water demand is also heightened. The Millennium Development Goal (MDG) on water supply has not been met in the study area and the inadequacy of consistent reliable data has made precise future deficit predictions difficult. Current demand for water has not been met.

CONCLUSION

The challenges faced by urban centres in terms of water resources management is complex in nature. The FCT-Abuja, despite being a planned capital city of Nigeria currently faces some of these challenges as a result of rapid development coupled with the changing climatic condition. The complex nature and challenges of water supply in FCT under climate change and rapid urbanization came at its peak in 2001. This led to the Gurara Inter-basin Water Transfer which started operation in 2007.

This study employed a combination of publicly available data on current water use and future trends in population and domestic water demand to estimate future water supply needs under the business as usual scenario and the availability of water under future climate occurrences. The projected climate change predicts increase in average temperature and decrease in runoff which may result from increase in potential evapotranspiration. The trend analysis of the minimum and maximum temperature of FCT were relatively high while precipitation revealed a decreasing trend. There are signs of increased magnitude over a shorter period. Also, the runoff was generally on a non-directional decreasing trend which has ultimately contributed to continual reduction in the water resources of the FCT-Abuja over the years. Similarly, the results of the fluctuation analyses for the hydro-meteorological parameters revealed that different patterns of fluctuations with abrupt changes observed in some years. The future outlook of water resources management for the city reveals a deficit water supply with surplus demand as revealed through estimation, analysis and projection of changing climate leading to fluctuating water resources while the population is on the increase. The rapid development of the city does not commensurate with the implementation and development of the infrastructures as contained in the Abuja master plan and this has led to stress on various sectors of the city especially water resources. It is not intended as a prediction that water shortages will occur, but rather that it is more likely to occur in the study area with an increasing rate.

It is therefore recommended that sensitization campaign on the causes and impacts of climate change on water supply should be embarked upon by the Government and Non-governmental organizations. Also, mitigation measures and stringent control of activities that promotes climate change and variability should be encouraged.

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