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THE CHALLENGE OF WATER SUPPLY IN URBAN LAGOS UNDER INCREASING CLIMATIC VARIABILITY

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Abstract

This study examines the impact of climate, urbanization, and population on water supply in Lagos State. Population and water production data in Lagos State between 1963 and 2006 were collected, and used for time series analyses. Multi-temporal land-sat images of 1975, 1995 and NigeriaSat-1 imagery of 2007 were used for land use change analysis. The population of Lagos State increased by about 557.1% between 1963 and 2006, correspondingly, safe water supply increased by 554%. Currently, 60% of domestic water use in urban areas of Lagos State is from groundwater while 75% of rural water is from unsafe surface water. Between 1975 and 2007, urban land use increased by about 235.9%. The 46years climatic records revealed that temperature and evaporation decreased slightly while rainfall and relatively humidity decreased consistently. Urban land use is expected to increase by 20% with expectation of serious congestion in the suburb areas. Based on these trends and using 4 % annual growth rate of the Lagos State population, the required water is expected to increase to about 19.8million and 3,213,058m^3/d respectively by the year 2026. The implication is that the percentage of unaccounted residents to public pipe borne water in Lagos may increase to over 65% in the nearest future while citizens have to provide about 50% of their required water through boreholes and dug wells (in the urban area), and rivers, streams, and ponds (in the rural areas).

Key Words: Challenges, climate, scenario, urbanization and water supply

Introduction

In spite of human's remarkable advances in science and technology, people's economic and social well-being still depend on weather and climate. Different time and spatial scales studies on annual distribution and variability of climatic variables, urban land use and population have revealed substantial impact on water supply (Adeyemi, 2000, Vorosmarty *et al*, 2000 and Ayeni *et al*, 2011). About 75% of commercial energy is consumed in urban and peri-urban areas. In addition, about 80% of all waste is generated from the cities and about 60% of greenhouse gas emissions that cause global climate change emanate from cities (El-Sioufi, 2010). Extreme weather patterns such as erratic rainfall, temperature, and other climatic factors fluctuations/inconsistencies are inherent characteristics of climate change and such fluctuations have had resulted to diverse effects such as drought and flood and more importantly on water supply (Olaniran, 1990; Adejuwon, 2004 and Kilsby *et al*, 2007). For instance, availability of surface water or shallow groundwater depends on the precipitation (EEA 2007 and IPCC 2008). Therefore, increasing severe weather risk and its threats to human settlements has become a great concern especially in coastal areas like Lagos. Each day, climate refugees from rural areas that have been hit by drought or flooding intensify migration to the cities. Essentially, majority of rural population who are characterized with poor health conditions, unemployment or social segregation are more vulnerable to the effects of climate change and therefore, tend to migrate to cities within or outside their countries e.g. migration from far northern Nigeria States (e.g. Sokoto, Kano, Borno) to Lagos State. The UN predicts that there will be millions of environmental migrants by 2020, and climate change is one of the major drivers. Therefore, there is no doubt that climate change aggravates existing socio-economic and environmental problems especially pressure on water supply and many other new challenges (Arnell, 1999 and 2004; United Nations 2009).Climate change will therefore affect water resource base especially water availability, quantity, quality, timing, and distribution, and other watershed services in as much availability of clean drinking water is a critical issue for most people in the world (Ringler, 2008; USDA 2008; Abbott, 2011). It will affect water utilities of people who rely on water for daily purposes. This is because, higher temperatures and reduced precipitation levels to some extent could cause shortages in available water supply due to slower recharge rates of groundwater resources and/or reduced availability of surface water (Pimentel et al., 2004). The world's urban poor are the most affected today and will be in future if the present scenario continued.

The above scenario describes the water situation in most parts of Lagos State. The provision of adequate safe water to the growing population of urban residents, especially the urban poor of Lagos State, remain one of the biggest challenges facing government and local authorities. Efforts will be needed to bridge the gap between water demand and water supply in Lagos State. This paper examines the impacts of some climatic variables, urbanization and population on water supply in Lagos State, Nigeria. The paper also discusses various future implication posed by rapid urbanization to water supply in the face of changing climate.

The Study Area

Lagos State is located in the south western part of Nigeria on the narrow coastal plain of the Bight of Benin. It lies approximately on longitude $2^0$42'E and $3^0$22'East and between Latitude $6^0$22'N and $6^0$42'N (Fig. 1). It is bounded to the north and east by Ogun State of Nigeria, to the west by the Republic of Benin, and stretches along the Coast of the Atlantic Ocean in the south. Politically, Lagos State encompasses an area of about 3,577sqkm. The dominant vegetation of the State is the swamp forest consisting of fresh water and mangrove both of which are influenced by the double rainfall pattern. This makes the environment a wetland region and receives between 1400mm and 1800mm of rainfall per annum with a little dry spell in August. The State has two climatic seasons (the dry from November to March and Wet from April to - October) and experiences high air temperatures ranging from 30^0C to 38^0C (Uluocha and Ekop, 2002; Adejuwon, 2004). The drainage system of the State is characterized by a maze of lagoons and waterways which constitutes about 22 percent of the State total landmass. The major water bodies are the Lagos and Lekki Lagoons, Yewa and Ogun Rivers. Others are Ologe Lagoon, Kuramo Waters, Badagry, Five Cowries, and Owu. According to the 2006 census, the State has a population of about 9.01millions (6.44%) out of 140.003millions of the nation total population. The State is divided into 20 Local Government Areas (LGAs) with varying population of rural, semi-urban and urban areas in each LGA (Fig. 2). However, based on the UN study and the State Regional Master Plan, the State is estimated to have about 12 million inhabitants.

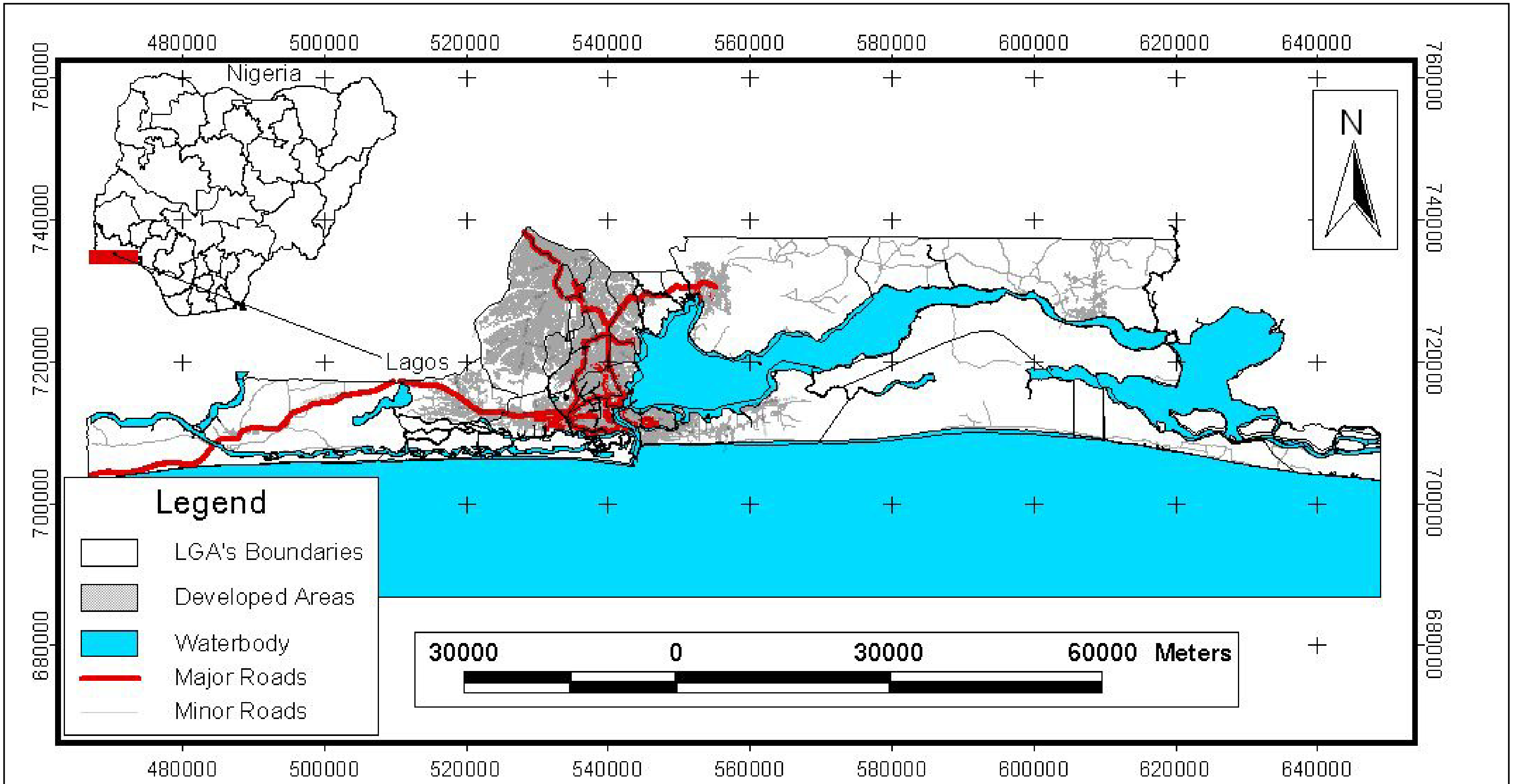


Fig. 1: Study Area

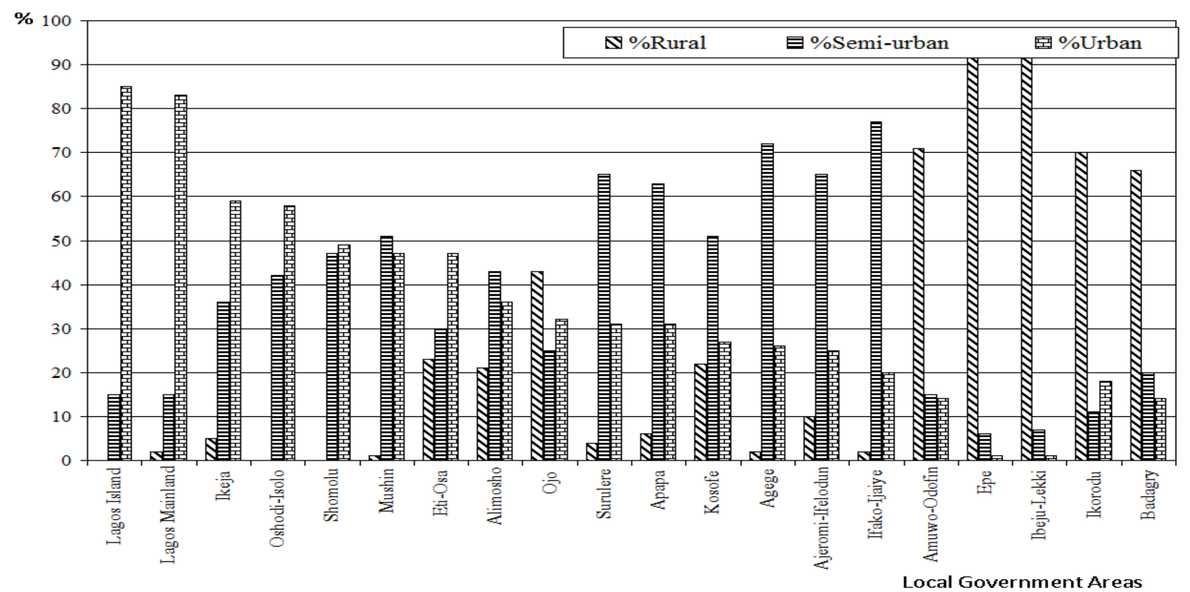


Fig. 2: Percentages of Rural, Semi-Urban and Urban Population in Lagos State LGAs

Methodology

Daily temperature, rainfall and relative humidity data between 1960 to 2006 (46years) and evaporation data between 1965 and 1999 (34years) were collected from the Nigerian Meteorological Agency (NIMET), Oshodi. The data were originally generated from the three synoptic stations in Lagos (Ikeja, Island and Oshodi) on daily basis. It was later sorted out on monthly basis for the purpose of this study. Land-use/Land-cover maps of 1975, 1995 and NigeriaSat-1 satellite imagery of 2007 generated through Arc-GIS software at the Department of Geography, University of Lagos, Nigeria were sourced from the Remote Sensing and GIS Archives of the SEDEC Associates, and used for land-use analysis. On the other hand,population data were collected from the National Bureau of Statistics, Abuja-Nigeria while information on water production, demand & supply were collected from the Lagos State Water Corporation for this study. The population baseline data used for this research were the provisional census data for 1963, 1973, 1991 and 2006. For trend analysis and 20years projection of climatic and water variables, linear regression analysis was adopted using the formula:

$$y = a + bx$$

where:

y is the dependent variable
x is the independent variable
a is the intercept (i.e. value of when x = 0)
b is the slope

Using population projection, data for 1963, 1973 and 1991 were projected appropriately for the subsequent years based on each census annual growth rate while the 2006 figure was used for year 20 years (2026) projection. The projection was based on the below formula:

$$PO = Pa\,(1 + r)^n,$$

where:

PO is the projection

Pa is the actual population to be projected

r defined as Growth rate / 100

n is the number of year

In addition, the Climate Predictability Tool (CPT), a software package designed for seasonal climate prediction (Mason and Tippett, 2016) was used to predict rainfall and temperature to the year 2026.

Findings and Discussions

Weather and Climate: The average annual (?) temperature from 1960 to 2006 was 29.55^{0}C. The lowest and highest were 20.71^{0}C in 1986 and 32.02^{0}C in 2006 respectively. There was consistent increase in temperature between 1999 and 2006. As shown in fig. 3, the 46years temperature trend shows a slight increase (0.0474^{0}C). The increase in the temperature may have resulted from variation in urban heat generated from urban congestion, high volume of vehicular emissions among others. The lowest and highest rainfall was 69.89cm in 1998 and 215.41mm in 1965 with 46years average of 136.70cm. The finding reveals that there was consistent decrease in rainfall between 2002 and 2006. The 46years rainfall trend reveals a sharp decrease of 3.342mm (Fig. 4). The average relative humidity was 79.08%; the lowest and highest were 58.79% in 1976 and 86.08% in 1979 respectively. The 46years relative humidity trend show consistent decrease (Fig. 5). Between 1965 and 1999, the average evaporation was 3.11mm; the lowest and highest was 0.85mm in 1998 and 4.40mm in 1992 respectively. The 34years evaporation trend depicts a slight decrease (Fig. 6).

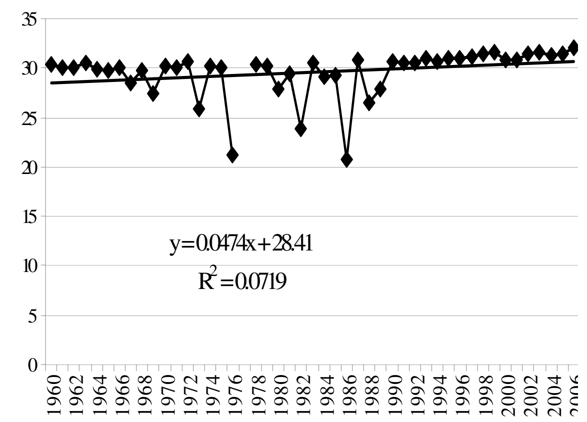


Fig 3: Average Annual Temperature (^{0}C)

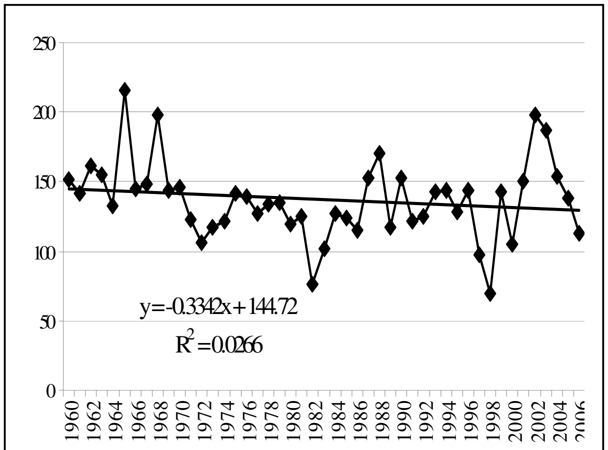
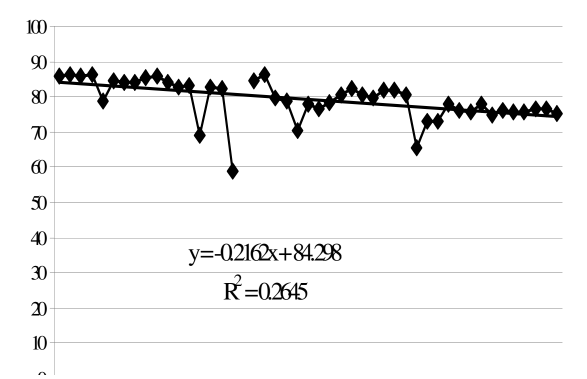
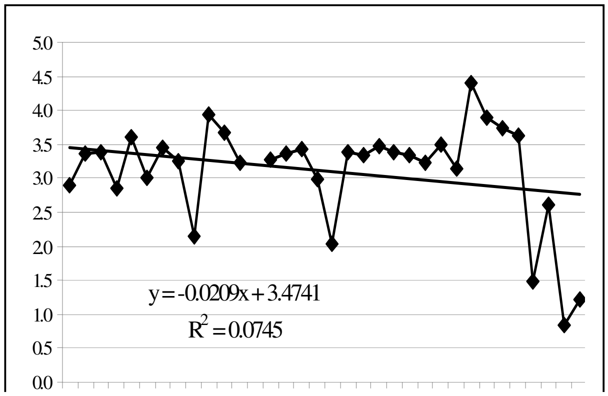


Fig 4: Average Annual Rainfall (mm)





Based on the above climatic baseline information, the results of climate predictability tool (CPT) revealed that rainfall is likely to decrease by -6.68mm while temperature will increase by 0.95^0C by 2026.

Land Use: In Lagos, most of land use types have experienced changes with the intention of improving the living standard of the population and strengthening urban CBDs through intensive residential built-up, industrialization, and commercialization. Data on land use shows that the urban area has increased from 230.8km^2 in 1975 to 538.2km^2 in 1995 and 734.2km^2 in 2007 (Table 1, Fig. 7 - 9). This represents an increase of about 235.9% in 32years. The urban land uses are mostly developed for residential, industrial and commercial purposes. If this trend continues, urban land use is expected to increase by about 20% with expectation of serious congestion in the suburb areas. Indeed, with increasing demand for housing, new land areas vulnerable to environmental hazards especially flooding are being developed in all part of Lagos without proper adherence to land use acts/regulations.In spite of the positive changes in urbanization, slight negative changes were noted in the climatic factors. Nevertheless, urban land use will continue its expansion while suburb areas such as Ikorodu, Epe and Badagry will also witness rapid growth.

Table 1: Urban Land-use change in Lagos between 1963 and 2004

Land use	**1976 (km^2)**	**%**	**1995 (km^2)**	**%**	**2007 (km^2)**	**%**
Agriculture	1138.4	31.5	903.9	24.9	86.4	2.4
Forest	232.0	6.4	6.0	0.2	501.2	14.2
Urban	***230.8***	***6.4***	***583.2***	***16.1***	***620.3***	17.6
Water	743.4	20.6	824.0	22.7	1033.8	29.3
Wetlands	1268.7	35.1	1290.6	35.5	1221.8	34.6
Others	-	-	24.9	0.6	69.6	2.0
Total	**3613.3**	**100**	**3632.6**	**100**	**3533.06**	**100**

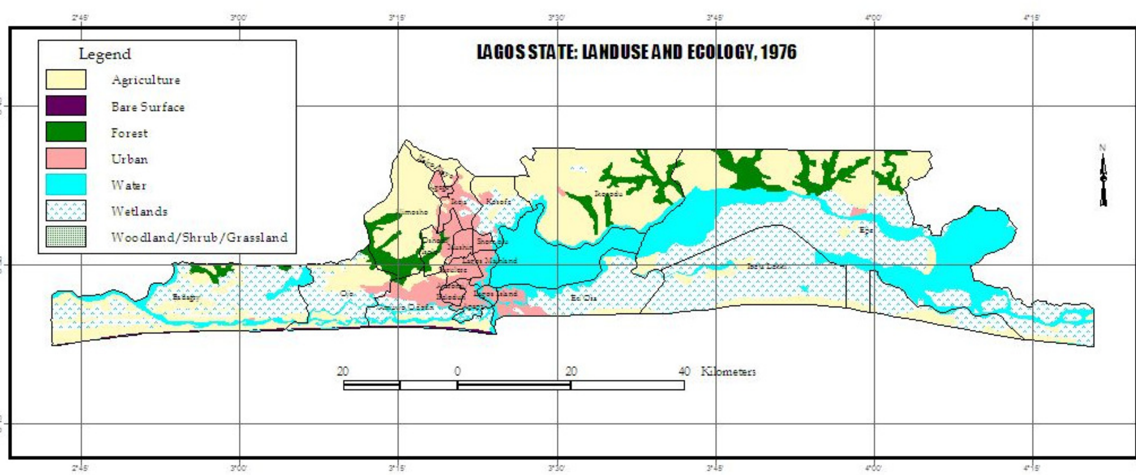


Fig. 7: Lagos State Land-use (1976) *Source: SEDEC Associates, 2008*

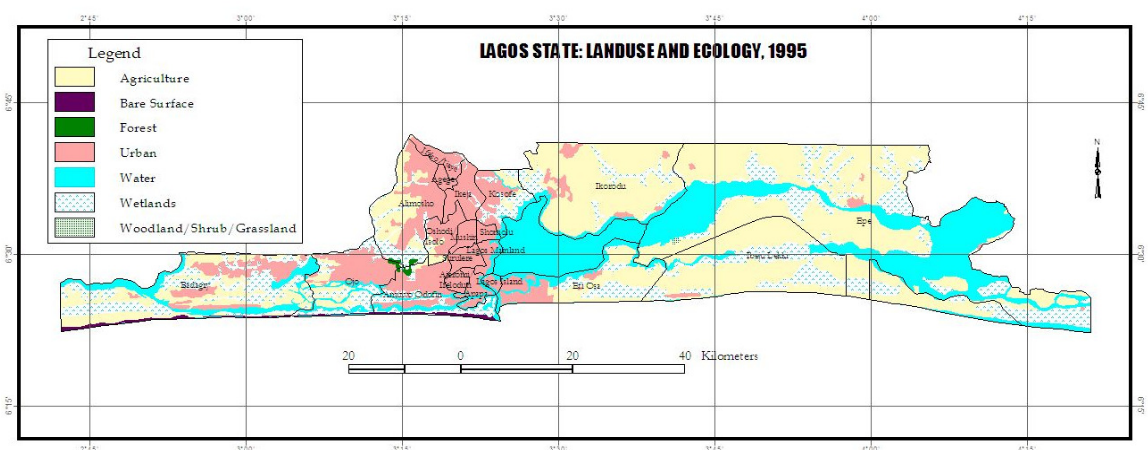


Fig. 8: Lagos State Land-use (1995)*Source: SEDEC Associates, 2008*

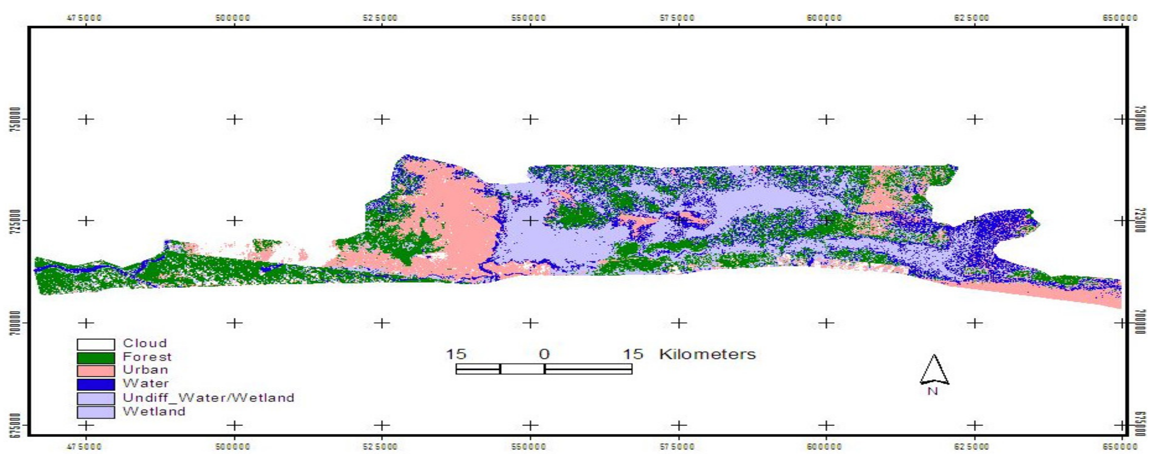


Fig. 9: Lagos State Land use (2007)*Source: SEDEC Associates, 2008*

Population and water supply

Table 2 shows the Lagos State population and water supply trend between 1960 and 2006. The population rose from about 364,000 in 1960 to about 9.2 million in 2006 (i.e. an increase of about 2,427.5% within 46years). Correspondingly, water demand rose from about 43,500 m^3/d to about 1.09Mm^3/d which represents an increase of about 2,403.7% within 46years. On the other hand, safe water supply increased from about 109,000m^3/d in 1965 to about 712,900m^3/d in 2006 within the same period. This represents an increase of about 554%.

Table 2: Population and water supply trend in Lagos State

Year	Population (Census & Projected)	Water Supply (m^3/d)	Year	Population (Census & Projected)	Water Supply (m^3/d)	Year	Population (Census & Projected)	Water Supply (m^3/d)
1960	364000		1977	2889551	177,000	1994	6249915	
1961	379000		1978	3005133		1995	6437413	

1962	394000		1979	3125338		1996	6630535	
1963	***1440000(C)***	**70,000**	1980	3250351		1997	6829451	
1964	1523520		1981	3380366		1998	7034334	
1965	1611884	109,000	1982	3515580		1999	7245364	
1966	1705373		1983	3656203		2000	7462725	
1967	1804285		1984	3802452		2001	7686607	
1968	1908934		1985	3954550	204,000	2002	7917205	377,000
1969	2019652		1986	4112732		2003	8154722	
1970	2136792		1987	4277241		2004	8399363	
1971	2260726		1988	4448330		2005	8651344	
1972	2391848		1989	4626264		***2006***	***9013534(C)***	**712,.900**
1973	***2470000(C)***	159,000	1990	4811314		2007	9374075	705,400
1974	2568800		***1991***	***5725116(C)***	**241,500**	2008	9749038	612,300
1975	2671552		1992	5891144		2009	10139000	595,000
1976	2778414		1993	6067879		2010	10544560	794,937

Sources: National Bureau of Statistics, 1960 – 2007, Lagos Water Corporation, 2008 and Lagos Bureau of Statistics. ***Note:*** ***(C)*** *= Census figures*

The findings show that water demand in Lagos state outpaced the supply over the years. Potable water supply increased by about 112.9% between 1977 and 2002. The climatic factors show a decrease in their trends between 1960 and 2006. However, observations on both in and out door heat experienced by some individuals have proved evidence of urban thermal discomfort in Lagos in the last few years (Sangowawa, et al.,.2008; Oluwafemi et al., 2010; Abotutu, and Ojeh, 2013). The fluctuation in the climatic factors (especially, the consistent increase in temperature since 1999 and decrease in rainfall since 2002), increased in population, and rapid urbanization have been noted to have responsible for a wider gap between water demand and supply in recent years (GlobeScan and MRC, 2006; Mirkin, 2010; Akinrotimi et al., 2011).

In general, water for domestic uses is being sourced from three surface rivers (the Adiyan, Iju and Ishashi) through their supply scheme plants and contributes about 340,000m^3/d of the total surface water supply available to meet the continuously growing population. These sources, which can be said to belong to the global renewable water account for about 47.6% of the total water production distributed across Lagos. The rest of the water is produced through groundwater in 37 boreholes distributed around eleven (11) LGAs in the State (Fasona *et al.,* 2005 and LWC 2009). As at 2006, Lagos State has an installed water supply capacity of 712,900m^3/d and reduced to 595,000m^3/d in 2009.

Implication in a climate change scenario

As at 2010, the actual water demand was 2.044,122m^3/d) as against the production capacity of 794,937m^3/d. This gives a demand gap of 1,249,186m^3/d. Although, the Lagos State Water Supply has a master plan to improve the water supply system in the state. The three phases master plan via-a-vis short term (2010-2013), medium term (2014-2017), and long term (2018-2020) is set to provide pipe borne water for every citizen based on the 2010 baseline data and projections of population growth, water production and the availability of water, water demand and the demand gap (Jideonwo, 2014). Using the LWC, 2010 estimated

136.2lcpd, the projected water demand for the Lagos megacity in 2020 is estimated to be 2,774,707m3/d and this would be met by the projected production capacity of 2,820,132m^3/d

Nonetheless, the continuous increase in population and other socio-economic factors such as industrialization, agriculture are also on continuous increase which the existing water infrastructural development in Lagos State may not likely meet in future if not well addressed now. These have resulted to situation where about 55% population of Lagos rural and urban suburb areas depend on wells to meet up with their daily domestic water needs. For instance, the rural areas of Badagry, Epe, Ibeju-Lekki, and Ikorodu LGAs are highly depending on unsafe surface waters like ponds, springs and lagoon. As observed recently in the metropolitan Lagos, there is evidence of thermal discomfort yet sun intensity is not much. This could have resulting from location of Lagos and various urbanization characteristics such as high traffic, industrial activities, and housing congestions, nature of work as well as the level of heat stress (Sawka and Montain, 2001). For example, Lagos city is located on a complex interlock of lagoons and creeks that cause albedo to increase as one move towards city island (Haider, 1997). In addition, the total daily fluid requirements have been shown to range from as little as 2 liters per day to 16 liters per day (Gisolfi, 1993) as it may be for Lagos depending on the nature of urban characteristics These may cause profuse sweating and lead to high rate of water consumption in order not to be dehydrated. It may also attributable to the increase in evaporation and evapotranspiration rate in the city (Appah-Dankyi and Koranteng 2012). If this present trends continue, water shortage will become more severe in the future as a result of the following: increase in population will result to more water consumption and more pressure on available sources of water; poor management in water supply sector, act of vandalized, as well as illegal connection may results to more deterioration of public water infrastructure. The outcome of these will be water supply shortage. More so, more people will be ‘water poor’ (i.e. water poverty index will likely decrease below 25 in 2026). As at December 2008, the percentage of unaccounted residents to public pipe borne water in Lagos State was about 55% (LWC, 2009). With increase in population, it may increase to over 65% in the nearest future because there is no new extension of urban water borne pipe line. The implication of this is that the citizens have to provide about 50% of their required water through boreholes and dug wells (in the urban area), and rivers, streams, and ponds (in the rural areas). Therefore, for sustainable safe water supply, more efforts will be needed to bridge the gap between water supply and demand in Lagos State. Presently, water supplies in Lagos State have only succeeded in meeting less than 40% of water demand. Based on 4% annual growth rate and if the present trend continue, the population of Lagos State is likely to increase to about 19.8millions in year 2026 while safe water demand is expected to increase to about 3,213,058m^3/d for the corresponding year. For Lagos State Government to meet this rapid growth, between US $1.8 billion and $2.5 billion financial outlay will be required (LWC 2009).

Conclusion and Suggestions

The solutions to the climate change threats on water supply sources lies in the hand of governments, corporate organizations, and individuals by adopting various options for increasing water supply schemes and capacity as well as reducing greenhouse gasses emissions. More water supply infrastructure should be planned and developed for future generation. This can be achieved by developing highly and efficient water supply scheme, encouragement of community water development and management strategies that will take cognizance of increasing variability in the climatic conditions of the State. Also, strategies to protect and restore threatened natural resources should be established and global laws that protect them should also be enforced in Lagos State.

In conclusion, the nature is a complex system while the future effects are difficult to predict. Unexpected cases should be expected for instance dry areas may become wet or even drier or vice versa depending on their locations. The consequences of impact from these complexities are many and deleterious as the ffuture impacts on human and its environment become more difficult to predict. The impacts may be self-reinforcing with human to strive to cope while on the other hand it may be self-canceling or self-re-structuring due to the nature

References:

Abbott, J. (2011): Water Scarcity and Land use Planning, RICS Research Report, Published by RICSParliament Square, London, UK, pp. 54

Abotutu, A. A. and V. N. Ojeh, (2013): Structural Properties of Dwelling and Thermal Comfort in Tropical Cities: Evidence from Warri, Nigeria, International Journal of Science and Technology Bahir Dar, Ethiopia 2(2): 67-98

Adejuwon S. A. (2004): "Impacts of Climate Variability and Climate Change on Crop Yield in Nigeria", Stakeholders' Workshop on Assessment of Impacts and Adaptation to Climate Change (AIACC), Conference Centre Obafemi Awolowo University, Ile-Ife 20 - 21 September 2004.

Adeyemi A. S. (2000): "Climate Change and Environmental Threats", In: Jimoh H.I and I.P. Ifabiyi (eds), *Contemporary Issues in Environmental Studies*, Ilorin, Haytee Press and Publishing, pp. 158 - *164*.

Akinrotimi, O.A., O. M. G Abu and A. A. Aranyo (2011): Environmental Friendly Aquaculture Key to Sustainable Fish Farming Development in Nigeria, *Continental J. Fisheries and Aquatic Science 5(2): 17 - 31*

Appah-Dankyi, J. and C. Koranteng (2012): An Assessment of Thermal Comfort in a Warm and Humid School Building at Accra, Ghana. Advances in Applied Science Research, 3(1), Pp. 535- 547.

Arnell N. W. (1999): Climate change and global water resources, *Global Environmental Change 9, S31 -S49*

Arnell N. W. (2004): Climate change and global water resources: SRES emissions and socio-economic scenarios, *Global Environmental Change 14, 31–52*

Ayeni A. O., A. S. O. Soneye, O. O. Fasunwon, R. T. Miteku and L. A. Djiotang-Tchotchou (2011): Water Resources Development Optimization in a Climate Change Scenario: Case Study of Benin-Owena Basin, Nigeria, *Res. J. Environ. Sciences, 5(1): 56-64*

EEA (2007): Europe's Environment; The Fourth Assessment. Europe Environment Agency, Copenhagen

El-Sioufi M. (2010): Climate Change and Sustainable Cities: Major Challenges Facing Cities and Urban Settlements in the Coming Decades, UN-HABITAT Article of the Month – June 2010

Fasona M., A. Omojola, S. Odunuga, O. Tejuoso and N. Amogu (2005): "An appraisal of sustainable water management solutions for large cities in developing countries through GIS: the case of Lagos, Nigeria" Sustainable Water Management Solutions for Large Cities, *Proceedings of symposium S2 held during the Seventh IAHS Scientific Assembly at Foz do Iguaçu, Brazil, April 2005. IAHS Publ. 293.*

GlobeScan, and MRC McLean Hazel, (2006): Megacity Challenges: A stakeholder perspective, A research project conducted by GlobeScan and MRC McLean Hazel, Sponsored and published by Siemens pp. 67

Gisolfi C. (1993): Water requirements during exercise in the heat. In: Marriott B, editor. Nutritional

Needs in Hot Environments, Washington, DC: National Academy Press, 1993:87-96.

Haider, T. (1997): Urban climates and heat island, evapotranspiration and anthropogenic heat. Energy and building, 25: 99 – 103

IPCC (2008): "Climate Change and Water", IPCC Technical Paper VI prepared under the management of the Intergovernmental Panel on Climate Change working group II, edited by Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof pp 38, 40.

Jideonwo, J. A. (2014): Ensuring Sustainable Water Supply in Lagos, Nigeria, Master of Environmental Studies Capstone Projects University of Pennsylvania Scholarly Commons, pp. 181

Kilsby C. G., P. D. Jones, A. Burton, A. C. Ford, H. J. Fowler, C. Harpham, P. James, A. Smith, R. L. Wilby (2007): A daily weather generator for use in climate change studies, Environmental Modelling & Software 22, 1705 - 1719

LBS (2010), *Basic Statistical Hotline,* published online by Lagos Bureau of Statistics (LBS), Ministry of Economic Planning and Budget, www.lagosstate.gov.ng/statistics/SH.pdf*accessed on 31/10/2011*

LWC (2009): We will soon deliver 15 new water works, Lagos State Water Corporation Alausa Alert, Dec. 30th, '08 - Jan. 18th, '09

Mirkin B. (2010): Population Levels, Trends and Policies in the Arab Region: Challenges and Opportunities, United Nations Development Programme (UNDP), Regional Bureau for Arab States Arab Human Development Report Research Paper Series, pp. 41

National Bureau of Statistics (2007): Federal Republic of Nigeria Official Gazette, States (National and State Provisional Totals 2006 Census) No. 24, Vol. 94, 2007

Oluwafemi, K., O. K Akande, and M. A. Adebamowo (2010): Indoor Thermal Comfort for Residential Buildings in Hot-Dry Climate of Nigeria, Proceedings of Conference: Adapting to Change: New Thinking on Comfort, Cumberland Lodge, Windsor, UK, 9-11 April 2010. London: Network for Comfort pp 1-11

Pimentel, D., B. Berger, D. Filiberto, M. Newton, B. Wolfe, E. Karabinakis, S. Clark, E. Poon, E. Abbett, and S. Nandagopal (2004): Water Resources: Agricultural and Environmental Issues, BioScience, 54(10): 909 - 918.

Ringler C. (2008): The Impact of Climate Variability and Climate Change on Water and Food Outcomes:A Framework for Analysis, International Food Policy Research Institute *sustainable solutions for ending hunger and poverty IFPRI Research brief 15 -1 www.irpri.org accessed on 21/05/2011*

Sangowawa, T., M. A. Adebamowo, and J. Godwin.(2008):Cooling, Comfort and Low energy design in warm humid climate; the case of Lagos, Nigeria. Proceedings of conference in Air conditioning and the low carbon cooling challenges, Cumberland lodge, Windsor,Uk. pp 22-29

Sawka, M. N. and S. J. Montain (2001): Fluid and electrolyte balance: effects on thermoregulation and

exercise in the heat. In: Bowman BA, Russell RM, editors. Present Knowledge in Nutrition,

Washington, DC: ILSI Press, 2001:115-124.

SEDEC Associates (2008): State of the Nigerian Environment Report, Federal Ministry of Environment, Housing and Urban Development

Simon J. Mason, Michael K. Tippett, 2016, Climate Predictability Tool version 15.3, Columbia University Academic Commons, http://dx.doi.org/10.7916/D8NS0TQ6.

Uluocha N.O. and G. Ekop (2002): "Nigeria: Geography". In: Osuntokun A., D. Aworawo and F. Masajuwa (eds), *History and Cultures of Nigeria up to AD 2000*, Lagos, Frankad Publishers, pp. 3-19.

United Nations (2009): "Economic Commission for Europe Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes", Guidance on water and adaptation to climate change, United Nation (UN) Publications.

USDA (2008): Climate Change and Water Perspectives from the Forest Service. The U.S. Department of agriculture (USDA), June 2008

Vorosmarty C. J., P. Green, J. Salisbury and R. B. Lammers (2000): Global Water Resources: Vulnerability from Climate Change and Population Growth, *Science 289: 284 – 289*