URBANIZATION AND WATER SUPPLY IN LAGOS STATE, NIGERIA: THE CHALLENGES IN A CLIMATE CHANGE SCENARIO

By

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Abstract
Population and water production data on Lagos State between 1963 and 2006 were collected, and used for trend and projection analyses. Land use/Land cover maps 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 (RH) decreased consistently. Based on the current trends, the Lagos State population and required water are expected to increase to about 19.8millions and 2418.9ML/D respectively by the year 2026. Rainfall is likely to decrease by -6.68cm while temperature will increase by 0.95^0C by 2026. Urban land use is expected to increase by about 20% with expectation of serious congestion in the suburb areas. With these results, over 50% of the urban inhabitants will be highly water poor in years to come if the present trends continue unabated.

Key Words: Urbanization, water supply and climate change

Introduction

In spite of Man's remarkable advances in science and technology, his 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 shown to have had 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 causes 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 and such fluctuations have had 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 such as Lagos. Each and every 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 and USDA 2008). It will affect water utilities of people who rely on water for daily purposes. This is because, higher temperatures and reduced precipitation levels will cause shortages in available supply due to slower recharge rates of groundwater resources and/or reduced availability of surface water. 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. Lots of efforts will be needed to bridge the gap if water demand in Lagos State should be met. Therefore, it is based on these facts that the impacts of such

climatic variables, urbanization and population on water supply in Lagos State Nigeria remain the focus of this research interest. The paper also discusses various future associated risks without addressing the threatening climate change, rapid urban expansion problems and fast growing population issues.

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 respectively and between Latitude $6^0$22'N and $6^0$42'N (Fig. 1). It is bounded in the north and east by Ogun State of Nigeria, in the west by the Republic of Benin, and stretches over 180 kilometers along the Coast of the Atlantic Ocean. 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, which 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 a UN study and the State Regional Master Plan, the State is estimated to have about 12 million inhabitants.

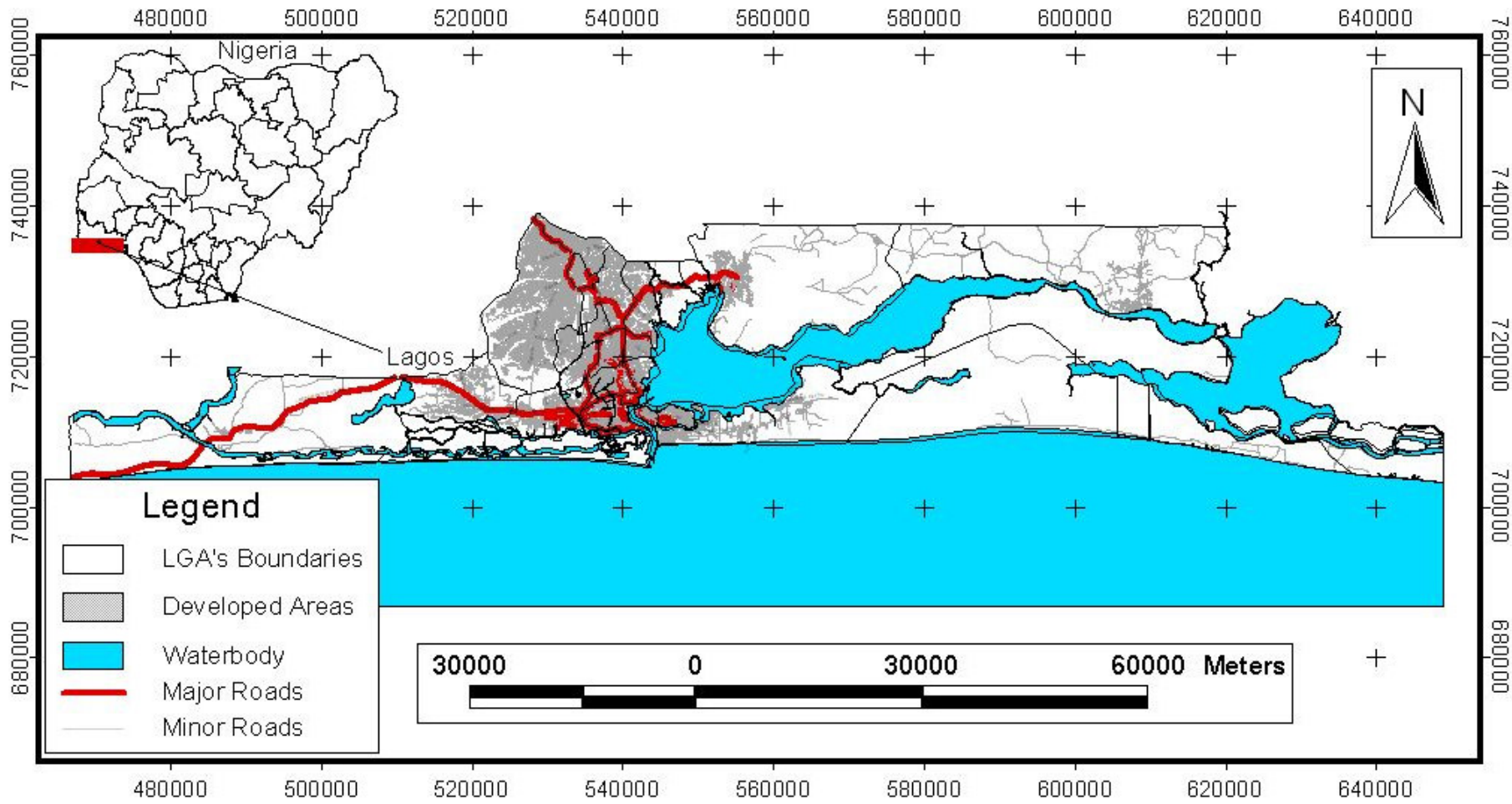

Fig. 1: Study Area

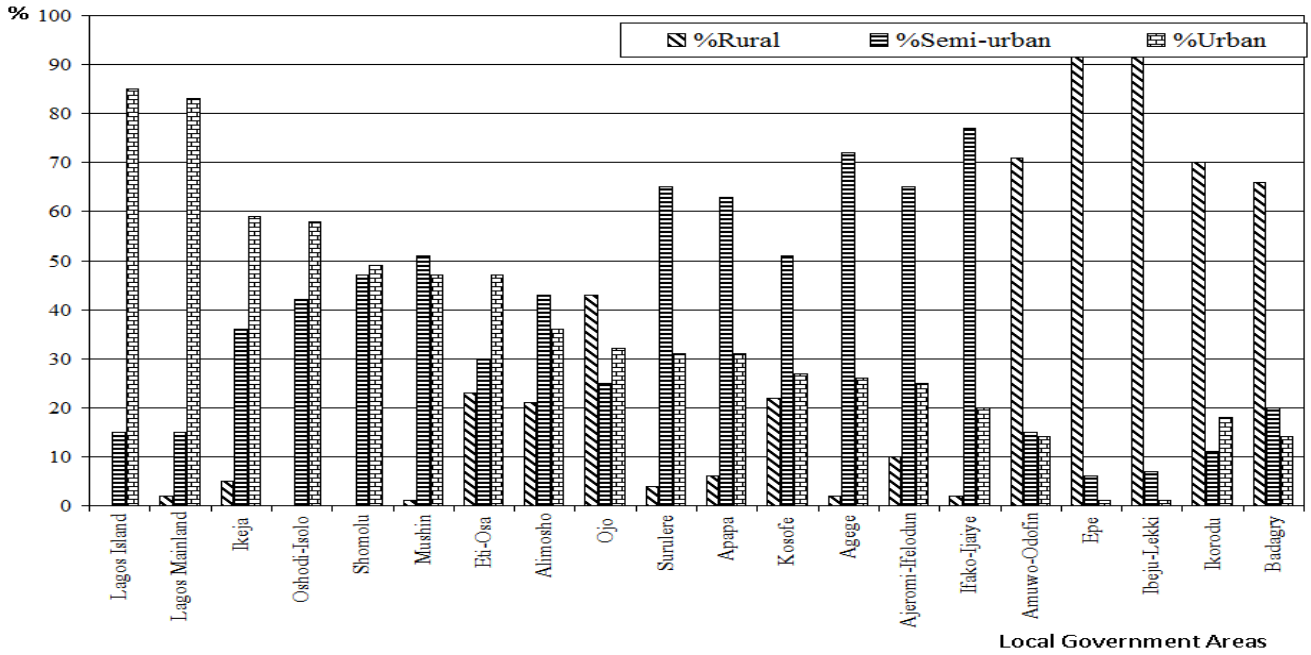

Fig. 2: Percentages of Rural, Semi-Urban and Urban Population in Lagos State LGAs

Methodology

Four climatic variables data used for this research were collected from Nigerian Meteorological Agency (NIMET) Oshodi – Lagos. The variables included temperature, Rainfall and relative humidity between 1960 to 2006 (46years) and evaporation data between 1965 and 1999 (34years). 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 data for the purpose of the study. Land-use/Land-cover maps of 1975, 1995 and NigeriaSat-1 satellite imagery of 2007 generated through Arc-GIS software were sourced from the Remote Sensing and GIS Archives of the Department of Geography, University of Lagos and were used for land-use analysis. On the other hand, population and water production data for this study were collected from the National Bureau of Statistics, Abuja-Nigeria and Lagos State Water Corporation respectively. 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 on climatic and water variables, linear regression analysis was adopted using the formula of $y = a + bx$. Using population projection formula of $PO = Pa\ (1 + r)^n$, data for 1963, 1973 and 1991 were projected appropriately for their subsequent years based on each census annual growth rate while the 2006 figure was used for year 20 years (2026) projection.

Findings and Discussions

Weather and Climate

The average 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. The finding also reveals that there was consistent increase in temperature between 1999 and 2006. The 46years temperature trend shows a slight decrease (Fig 3). The decrease 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 (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).

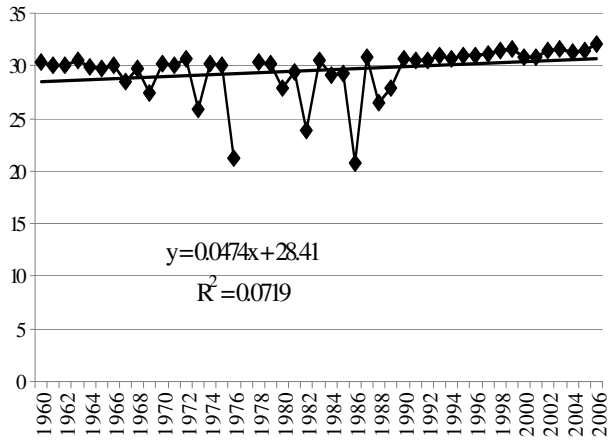

Fig 3: Average Annual Temperature (^0C)

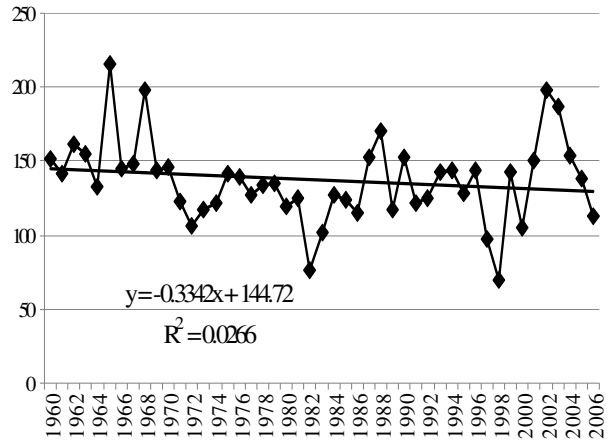

Fig 4: Average Annual Rainfall (mm)

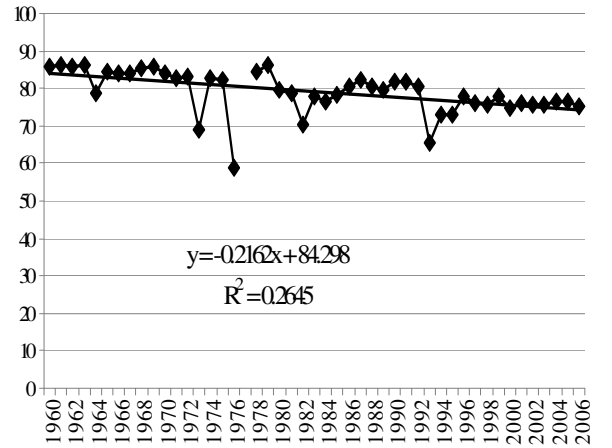

Fig 5: Average Annual RH (in %)

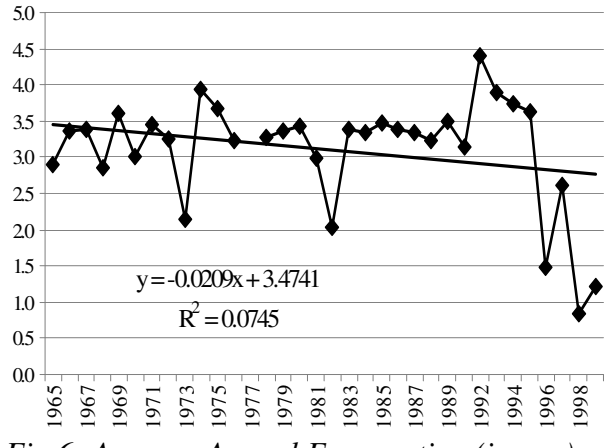

Fig 6: Average Annual Evaporation (in mm)

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. 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		
Forest	232.0	6.4	6.0	0.2	878.7	25.7
Urban	230.8	6.4	583.2	16.1	734.2	21.5
Water	743.4	20.6	824.0	22.7	519.8	15.2
Wetlands	1268.7	35.1	1290.6	35.5	369.8	10.8
Others			24.9	0.6	916.5	26.8

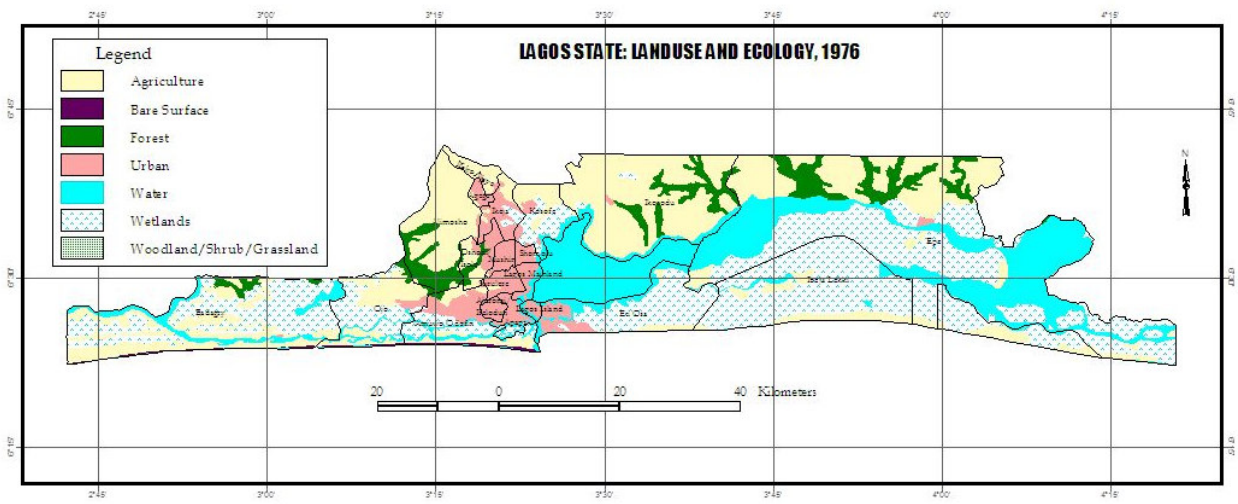

Fig. 7: Lagos State Land-use (1976)

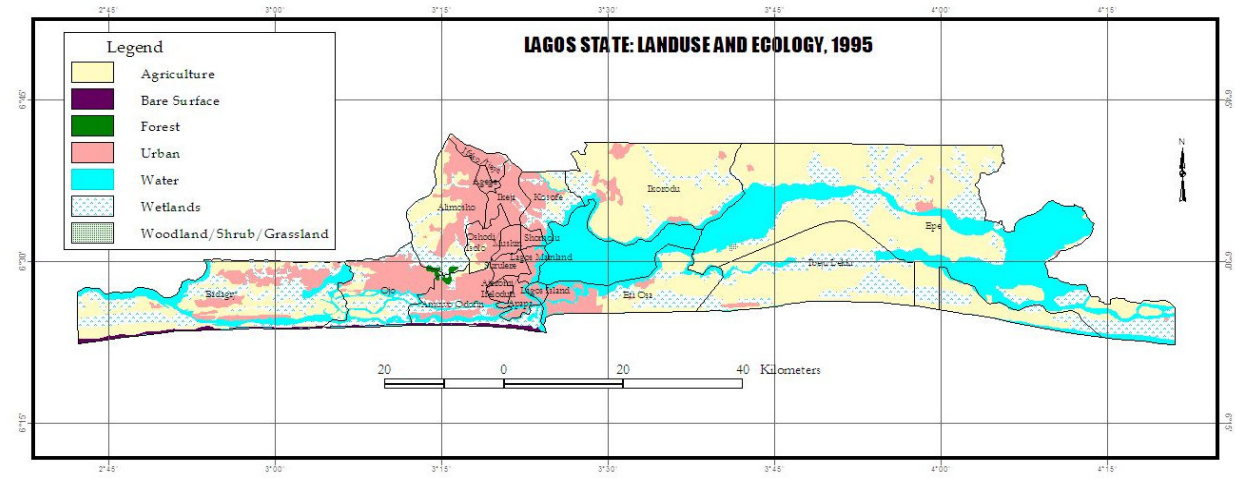

Fig. 8: Lagos State Land-use (1995)

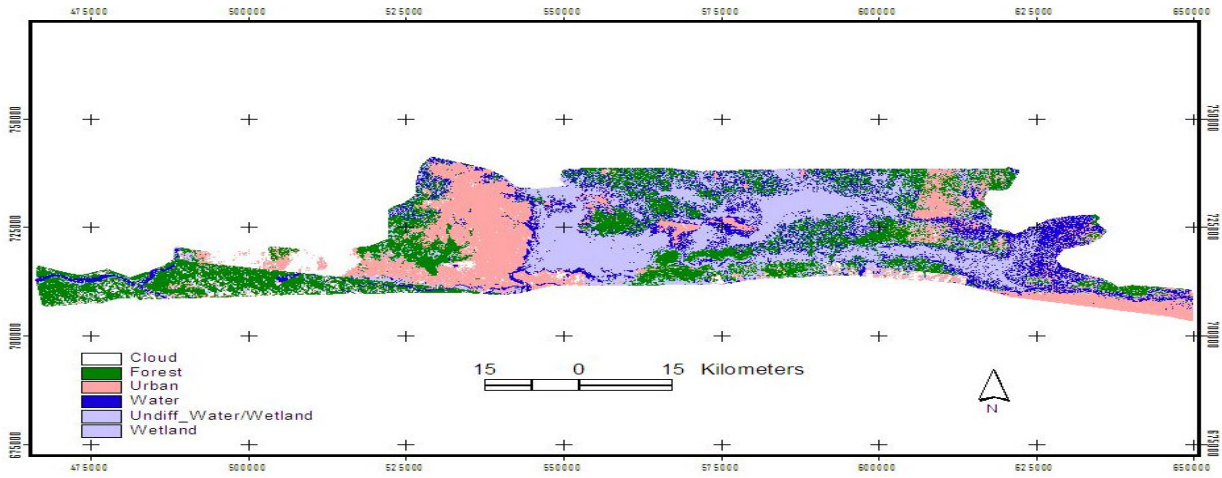

Fig. 9: Lagos State Land use (2007)

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). Based on this trend, water demand rose from about 43.5MLD in 1960 to about 1093.6MLD in 2006 which represents an increase of about 2,403.7% within 46years. On the other hand, within the same period, safe water supply increased from about 109MLD in 1965 to about 712.9MLD in 2006. This represents an increase of about 554%.

Table 2: Population and water supply trend in Lagos State

Year	Population (Census & Projected)	Water Supply (MLD)	Year	Population (Census & Projected)	Water Supply (MLD)	Year	Population (Census & Projected)	Water Supply (MLD)
1960	364000		1976	2778414		1992	5891144	
1961	379000		1977	2889551	177	1993	6067879	
1962	394000		1978	3005133		1994	6249915	
1963	*1440000 (Census)*		1979	3125338		1995	6437413	
1964	1523520		1980	3250351		1996	6630535	
1965	1611884	109	1981	3380366		1997	6829451	
1966	1705373		1982	3515580		1998	7034334	
1967	1804285		1983	3656203		1999	7245364	
1968	1908934		1984	3802452		2000	7462725	
1969	2019652		1985	3954550	204	2001	7686607	
1970	2136792		1986	4112732		2002	7917205	377
1971	2260726		1987	4277241		2003	8154722	
1972	2391848		1988	4448330		2004	8399363	
1973	*2470000 (Census)*	159	1989	4626264		2005	8651344	
1974	2568800		1990	4811314		*2006*	*9113605 (Census)*	712.9
1975	2671552		*1991*	*5725116 (Census)*				

Source: National Bureau of Statistics, 1960 - 2007 and Lagos Water Corporation, 2008

The findings show that water demand in Lagos state has 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. Nevertheless, observation on both in and out door heat experienced by some individuals has proved evidence of urban thermal discomfort in Lagos in the last few years. 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 be responsible for a wider gap between water demand and supply in recent years.

Finding reveals that water for domestic uses is being sourced from three surface rivers (the Adiyan, Iju and Ishashi) through their supply scheme plants and contributes about 340MLD 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 11 LGAs in the State (Fasona et al, 2005 and LWC 2008). As at 2006, Lagos State has an installed water supply capacity of 712.9MLD and faced with problems of ageing supply lines, ageing water works, poor public electricity and irregular production rate, illegal connections and tapping of pubic water, high damage of water infrastructure and lack of maintenance. Hence, it is operating at 48% capacity or capable of meeting only 36% of water demand. Currently, only about 50% of Lagos urban inhabitants are being served with potable water while over 75% of rural populations are faced with serious water sourcing problem.

Implication in a climate change scenario

Variability in climatic parameters and other factors such as population, socio-economic as well as cultural influence has contributes to the decrease in the domestic water supply in Lagos state. These have resulted to situation where about 55% population of Lagos rural area and urban suburb depends on wells to meet up with their daily domestic water needs. As observed recently in the area, there is evidence of thermal discomfort yet sun intensity is not much. This could have resulting from various urbanization characteristics such as high traffic, industrial activities, housing congestions and among others. 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 2027). As at December 2008, the percentage of unaccounted water in Lagos State was about 55% (LWC, 2009). With increase in population, it may increase to over 65% in the nearest future. The implication of this is that the citizens have to provide about 50% of their required water through boreholes, dug wells, rivers, streams and ponds. 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 2026while safe water demand is expected to increase to about 2418.9ML/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

In as much the past emissions of greenhouse gases will still remain in the atmosphere for decades or more, today's reduction of emissions from cars, power plants, land use, and other sources will determine the kind of safe future environment our next generation will live. Hence, 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. Higher efficiency appliances such as advanced wind turbines, solar photovoltaics and other renewable energy technologies should be encouraged. Also, strategies to protect and restore threatened natural resources should be established and global laws that protect them should also be enforced.

In conclusion, the nature is a complex system while the future effects are difficult to predict. Conversely, lots of surprises should be expected. Drier may become either wetter or drier depending on their locations and vice versa. With the nature and complexity of global change coupled with rapidly increasing urbanization, the

consequences are many and in most cases deleterious to human and its environment. Future impacts on man become more difficult to predict because changes may be self-reinforcing with human being to cope within. While in some, it may be self-canceling or self re-structuring but everything will depend on today's plans.

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