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Adapting Nigeria Cities to Climate Change using Design Options: A Review

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Authors' contributions

This work was carried out in collaboration between all authors. ICE, AME, PCA designed the study, wrote the protocol and wrote the draft of the manuscript. ICE, MCO managed the analysis of the study. All authors managed the literature searches. All authors read and approved the final manuscript.

Review Article

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ABSTRACT

Problem Statement: Nigeria like the rest of the entire continent of Africa is considered highly vulnerable to climate change because of its high exposure and sensitivity, limited adaptive capacity, poverty, illiteracy, food insecurity, and disease all of which interact with Climate change.
Approach: The aim of the study is to introduce the need to utilize design options as an approach to climate change adaptation strategy in Nigeria cities. Literatures were identified for review through a comprehensive search by using electronic and non-electronic databases. Related published literature and documents were searched in a systematic way using a range of key words relating to climate change vulnerability and adaptation.
Results: The literature review indicates that adaptation to climate change is hazard specific and factors that determine whether or not adaptation occurs will operate at a variety of scales. The review also indicates that the fight against climate change in our cities could be pursued through three scales: Conurbation/catchment Scale, Neighborhood Scale and Building Scales; using architectural design options. These designs will have additional ecological, biodiversity, recreational, health and flood storage benefits to the environment.
Conclusion: Reducing climate-induced threats that contribute to environmental degradation, there will be a need to develop an integrated approach at different scales and implement sustainable adaptive strategies using design options.

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1. INTRODUCTION

Adaptation of cities to climate change had not been a prominent issue on societal responses to global climate change for a long time (IIED, 2007). The associated concern is that increased attention on adaptation would reduce the pressure for mitigation action – and thus the continuing emission of anthropogenic greenhouse gases (GHGs) into the atmosphere (Dirk et al., 2011). This perspective is starting to change. Today adaptation is increasingly seen as an essential and integral part of proposed and implemented climate policy. Increasingly, countries are recognizing the need to assess the likely impact of climate change on their desired development pathways and take steps to ensure all policies and activities are "climate-proofed" (Reid et al., 2007). An important way for a city to help reduce the ecological impacts of climate change is by initiating conditions that make it easier for species and humans to adapt.

The recent Intergovernmental Panel on Climate Change (IPCC) Report (IPCC, 2007) states:

> *"There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emission will continue to grow over the next few decades".*

This view coincides with a 'growing political voice for adaptation mainly in countries and cities that are likely to be affected most severely' (Pielke et al., 2007). The impact of climate change can be vast. In Nigeria, this means that some stable ecosystems such as the Sahel Savanna may become vulnerable because warming will reinforce existing patterns of water scarcity and increase the risk of drought in Nigeria and indeed most countries in West-Africa. As well, the country's aquatic ecosystems, wetlands and other habitats will create overwhelming problems for an already impoverished populace (BNRCC, 2008).

Preliminary studies on the vulnerability of various sectors of the Nigeria economy to climate change were conducted by NEST (2000). The sectors evaluated were on seven natural and human systems identified by the IPCC (2007).The study determined that virtually all of the sectors analyzed manifested some evidence of vulnerability to climate change. None were unaffected, nor will remain unaffected in future by changes to climatic conditions. Infact, more recent assessment, although in regional and global scale, not only corroborate the patterns established by CN-CCCDP reports but captured more disturbing scenarios using more embracing and sophisticated approaches (IPCC, 2007). Indicators are that the climate system is more sensitive than originally thought.

The paucity of published work on climate change impacts on Nigeria notwithstanding, the biogeophysical, social and economic conditions in the country may fittingly be regarded as the epitome of conditions in the developing world where the effects of climate change likely to be most pronounced and wide-ranging. Nigeria, like the rest of the entire continent of Africa is considered highly vulnerable to climate change because of the following characteristics (IPCC, 1998): a high exposure and sensitivity to climate change; limited adaptive capacity in its current state of development; and large proportions of the population are subjected to other stresses such as poverty, illiteracy, food insecurity, malnutrition and disease, all of which could interact with climate change. Based on this; our view is that the fight against climate change must be collective and multi-dimensional. And in this context, we explore innovative designs and how they translate into scenarios of response to climate

change. The aim of this paper, therefore, is to introduce the need to utilize design options as an approach to climate change adaptation strategy in Nigeria cities. This will help build informed responses to climate change in Nigeria cities.

2. EFFECTS OF CLIMATE CHANGE

Cities are expected to face major stresses on water availability. Particular concerns relate to issues of supply scarcity, contamination and salt water infiltration (Enete, 2008; Enete and Ezenwaji, 2011), higher demands, and growing dependency on external supply. In addition, distribution conflicts exits between sectors and population groups. The impacts of climate change on health are another area of concern, including air pollution, heat island effects, and spread of disease vectors. The consequences on human settlements due to sea-level rise or coastal and inland flooding are a further concern that could lead to serious disruption in the transportation and infrastructure service (Enete, 2008).

Increase in global temperatures, rising energy demands (Enete and Alabi, 2011) and increased heat island effects (Enete and Ijioma, 2011), are identified as other issues of primary concern. It is considered very likely that increasing global temperatures will lead to higher maximum temperatures, more heat waves and fewer cold days over most land areas. Disruption of sensitive ecosystems, loss of biodiversity and food security problems will be witnessed. Wildfire is dramatically escalating in frequency and extent. Forest could be lost due to frequent and more intense fires (Reid et al., 2007). Other climate change impacts include shifting ranges and seasonal behaviors, changes in growth rates, in the relative abundance of species and in processes like water and nutrient cycling and in the risk of disturbance from fire, insects and invasive species (Johnson and Moghori, 2008).

Interestingly, these climate change problems are reinforced by local conditions and trends. In-migration to ecological sensitive areas and associated land-use changes are major factors. Another common factor is the adoption of western consumption patterns that increase per capita demands for water, energy, food and land. A final aspect is the highly inequitable distribution of associated risks across population groups and locations, with rising vulnerability within marginalized populations (Dirk et al., 2011).

3. SOME FACTS ON CLIMATE CHANGE

a. CO_2 emission has grown up about 80% between 1970 and 2003; almost all other greenhouse gases have also shown significant increase in the same time periods.
b. The years 1995 to 2006 rank among the 12 warmest years of surface temperature since 1850.
c. Global average sea-level rose at an average rate of 1.8mm per year between 1961 and 1993 and the rate 1993 to 2003 was 3.1 mm.
d. Globally, about 20 to 30% of plant and animal species are highly vulnerable (risk of extinction) to a change of temperature of 1.5 to 2.5^{0C}
e. Glaciers and ice caps have experienced widespread mass losses and have contributed to sea-level rise during the 20th Century (Khatun and Islam, 2009).

The physical processes that cause climate change are scientifically well documented; both human activities and natural variability are contributing to global and regional warming. According to the Intergovernmental Panel on Climate Change, it is very likely that most of

the observed warming over the past 50years is the result of increased greenhouse gases generated by human activities (Smith and Schellnhuber, 2001; Forster et al., 2007).

Nigeria has experienced increased warming in the past few years, with increased intensity since 1999. Droughts, unprecedented flooding and livestock losses are becoming too frequent to be ignored. In 2011, the Ogunkpa River flooding in Ibadan City South-West, Nigeria and the Sokoto flooding resulted in crop damage, community relocations and dam collapse.

4. CONCEPTUAL FRAMEWORK

This conceptual framework is based on the vulnerability and adaptation concept developed by Brooks (2003). The study of the vulnerability of human and natural systems to climate change and variability and of their ability to adapt to changes in climate hazards, is a relatively new field (Brooks and Adger (2003). The growing body of literature on vulnerability and adaptation contains sometimes bewildering array of terms: vulnerability, sensitivity, resilience, adaptation, adaptive capacity, risk, hazard, coping range, adaptation baseline and so on (IPCC, 2001; Adger et al., 2002; Burton et al., 2002). The relationships between these terms are often unclear and the same term may have different meanings when used in different contexts and by different authors.

Definitions of vulnerability in the climate change related literature tend to fall into two categories, viewing vulnerability either in terms of the amount of (potential) damage caused to a system by a particular climate-related event or hazard (Jones and Boer, 2003) or as a state that exists within a system before it encounters a hazard event (Allen, 2003). The IPCC Third Assessment Report (TAR) describes vulnerability as:

> *"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2001).*

Nonetheless, it is essential to stress that we can only talk meaningfully about the vulnerability of a specified system to a specified hazard or range of hazards. The term adaptation is used here to mean adjustments in a system's behavior and characteristics that enhance its ability to cope with external stresses. The direct effect of adaptation is therefore to reduce vulnerability.

Adaptation does not occur instantaneously; a system requires time to realize its adaptive capacity as adaptation. However, a system's vulnerability to more gradual, longer-term change will be a function of its ability to adapt. To assess existing adaptive capacity, we must understand how it is translated into adaptation. In other words, we must understand the adaptation process. This process will depend on the nature of the systems that are adapting; for example, the processes via which a household or local community adapts to changes in climatic conditions will be very different from those via which a nation/state adapts.

The factors that determine whether or not adaptation occurs will operate at a variety of scales and will depend on how the "system" being assessed is defined. Based on this, we made an attempt to project adaptation process of an urban environment in conurbation or catchment scale, climate change adaptation at this scale will potentially serve the whole city

and is likely to include a variety of land uses. Neighborhood scale involves developments of discrete groups of dwellings, including a mix of uses and can vary in size from an individual block to a large estate. Consideration will need to be given to adapting the public realm and spaces between buildings and developments; while building scale is smaller developments including individual dwellings, apartment blocks or commercial buildings. This provides opportunities for integrating climate change adaptation into or around buildings. This concept becomes handy now in Nigeria because of where we are in urbanization chart. New cities are spring up and old ones are renewed.

5. CLIMATE CHANGE IN NIGERIA: AN OVERVIEW

A review of current literature on climate change impacts in Nigeria shows that very little work has been carried out at the country level. Studies that directly or indirectly address climate change issues in Nigeria include those by Awosike (1992), Awosika et al. (1992); French et al. (1990). Others are Ibe and Quelennac (1989); Nicholas et al. (1993); and Ojo (1988, 1998). Consequently, understanding of the significant issues of the environment and particularly the problems related to global warming and climate change in Nigeria is severely limited. Nevertheless, many climate impacts on the Nigeria environment are known well enough (at least qualitatively) to facilitate the identification of areas particularly at risk from climate change impacts (Nwafor, 2006).

Nigeria's average temperature has risen by 1.7 degrees in the period 1901-2005 (Adefolalu, 1999). The increase has been higher in the semi- arid regions and lower in the coastal zone. The paper also demonstrates that the rate of change has increased since 1970's. The consequence for the Nigeria people is a geographical pincer threat from desertification in the north and coastal erosion in the south. Through a combination of overgrazing, abuse of woodland for fuel and increasingly unreliable rainfall, the Sahara is advancing at an estimated rate of 600 meters per annum and over 55 million people in 10 northern states could be affected (NEST, 1991).

Similarly, rising sea levels threaten Nigeria's coastal regions. The Niger Delta may be the source of oil wealth but its low-lying terrain problem, crossed with waterways makes it extremely vulnerable to flooding and salinisation. The protective mangroves of this coastline have been largely lost to human intervention. Half of the 15 million population of the 15 million population of the city of Lagos lives less than six feet above sea level (One world Guides, 2008). The wealthiest areas of Victoria Island are in the front line, alongside the Mushroom slum settlements.

In the rural economy, almost all small farms presume stable rainfall patterns in their choice of seeds and planting times and are therefore, at risk of the vagaries of climate change in addition to more familiar social and economic pressures. Another factor that is encouraging climate change in Nigeria is deforestation. According to the 2010 MDG progress report, Nigeria's forest cover has dropped from 18.9% to 9.9% in two decades since 1990, one of the highest rates of deforestation in the world (One World Guides, 2008). The main cause is the demand for wood fuel. In the absence of affordable alternative energy sources, charcoal is popular even the cities, boosting its uncontrolled production. Clearance for agriculture, roads and other development are further implacable drivers of deforestation. Current laws to protect forests are weak and poorly enforced.

Major industries in the country's coastal zone include three refineries, two petrochemical plants, liquefied natural gas plants (LNG), a fertilizer plant, a major steel and gas and fuel oil

fired electricity generating plants around which numerous other economic activities revolve. Above all, there is the on-shore and rapidly expanding offshore petroleum and gas operations which have seen the entire delta crisscrossed by oil and gas pipelines and riddled with wells (World Bank, 1996). The sector accounts for 96 percent of the country's external earnings. For Nigeria, climate change will have a severe impact on its coastal system which is already under stress.

6. METHODOLOGY

Literatures were identified for review through a comprehensive search by using electronic and non-electronic database. Related published literature and documents were searched in a systematic way using a range of key words relating to climate change impacts and adaptations.

7. CLIMATE CHANGE ADAPTATION ATTEMPTS IN NIGERIA

According to climate funds update database, Nigeria has not yet received any adaptation funding from external bilateral or multilateral sources. This may in part be attributable to the country's slow- moving institutional response to climate change (One World Guide, 2008). The focal point for coordination of government polcies is intended to be a National Climate Change Commission. The bill to establish the commission was introduced to parliament as long as 2007 but still awaits presidential signature.

At community level, adaptation strategies are largely consistent with existing responses to poverty and hunger. The fight to halt desertification involves tree planting, the use of alternative fuels such as biogas, and the adaption of more versatile livestock. In more conventional farming regions, smallholders are encouraged to diversify their crops and adopt more efficient rainwater harvesting and irrigation techniques. The coastal regions approach adaptation through management of existing resources. Building and environmental regulations are enforced but poorly due to corruption inherent in the country; for example to stabilize the shoreline by preventing the excavation of sand from beaches.ge

8. DESIGN OPTIONS

The challenges posed by adaption to climate change are increasingly being recognized. Such challenges are usually framed in terms of 'resilient' buildings designed to recover quickly from the impact of flooding through ensuring that essential services (power, water and sanitation) experience minimal disruption (such as by placing power sockets above likely flooding levels; building passive low-energy building or smart buildings (Roaf et al., 2005; Adaptive Building Initiative, 2009). However, these options may be too expensive for a developing country like Nigeria that is already under economic stress. Another design option suitable for Nigeria cities particularly those with exceptionally high temperature is the use of local bricks (mud) in building construction. This design option has been corroborated by the works of (Bianco, 2002; Alagbe, 2011).

Shaw et al. (2007) outlined some adaptation strategies that could be a guide for building sustainable cities in the face of a changing climate. These design options are less expensive, requires no special skill, nor high technology which may not be available in the country, thus can easily be utilized in Nigeria cities.

8.1 Managing High Temperatures at the Conurbation Scale

Scale, efforts should focus on the opportunities for reducing UHI effects through large scale infrastructure. High quality green space, made up of linked network of well-irrigated open spaces that can be used by a range of people. Green infrastructure in urban areas includes open spaces, woodlands, street trees, fields, parks, outdoors sports facilities, community gardens, village greens, private gardens, and green roofs and walls.

- Use of such open bodies of water including rivers, lakes and urban canals.
- Shading and orientation to reduce excessive solar gain (e.g. through narrow streets or canopies of street trees). Efforts to maximize shade in dry season will need to take account of the need for light and warmth in rainy season.
- Passive ventilation captured through orientation and morphology of buildings and streets. Again, efforts to catch breezes and increase canyon ventilation paths must also consider the need for rainy season warmth.

8.2 Managing High Temperatures at Neighborhood Scale

At the neighborhood scale, efforts to manage high temperatures should focus on providing cool and attractive outdoor areas. The key adaptative measures are:

- Evaporative cooling effects from a matrix of green corridors, smaller open spaces, street trees and green or living roofs and walls.
- Increased use of ponds, roadside swales, flood balancing lakes, swimming pools and fountains.
- Orientation of buildings and street to reduce excessive solar gain and catch breezes.
- White pavement materials on roadways or large parking areas – to increase surface reflectivity or increase rainfall permeability to benefit from the cooling effect of evaporation. Porous cool pavements offer the additional benefits of rainwater infiltration at times of heavy rain.
- Networks of white roofs made of light colored materials to prevent solar heat gain and reduce the need for mechanical cooling.

8.3 Managing High Temperature at the Building Scale

At the building scale, a number of structural solutions offer effective means of managing heat risks and reducing thermal discomfort at this scale include:

- Planting, shading and advanced glazing systems to reduce solar heat gain.
- Materials to prevent penetration of heat, including use of cool building materials and green roofs and walls.
- Innovative use of water for cooling, including ground water cooling using aquifers or surface water (possibly as part of SUDS – Sustainable Drainage System).
- Mechanical cooling, including chilled beams and conventional air conditioning system.
- Increasing ventilation and removing heat using fresh air.
- Use of thermal storage or mass to absorb heat during hot periods so that it can dissipate in cooler periods, usually using ventilation.

8.4 Managing Flood Risks at the Catchment Scale

At the conurbation/catchment scale, the aim should be to integrate green and built spaces with flood management strategies. Flood risk management strategies include:

- Strategic flood risk assessment and sequential approach to development in the flood plain.
- Flood attenuation, or provision of temporary water storage capacity during flood events to reduce peak flows. This includes creation of flood retarding basins and sacrificial areas (e.g. sports fields and car parks) that flood during extreme events.
- Upland management through storage (e.g. reservoirs) and planting to reduce runoff.
- Understanding flooding pathways in urban environments, to help manage the probability of flooding and its consequences.
- Diversion of flood flows away from vulnerable areas or constructing a second flood channel. SUDS can deal with flood, water quality and resource risks while also bringing ecological and amenity benefits.

8.5 Managing Flood Risks at the Neighborhood Scale

At the neighborhood scale, efforts should focus on understanding and managing flood pathways and protecting areas at risk. Strategies at this level include:

- Strategic flood risk assessment and a sequential approach to development in the flood plain.
- Use permeable pavement, gravel or grass so that water can soak away. Within parks and green spaces storage areas, such as infiltration ponds, can be constructed.
- A second layer of setback flood defense constructed behind the original barrier.
- Use of green open space and green roofs to reduce runoff and ameliorate pressure on drainage systems during heavy rainfall.
- Widening drains to increase drainage capacity.
- Managing flood pathways and removing pinch points so that heavy rainfall can drain away.

8.6 Managing Flood Risks at the Building Scale

The aim at this scale should be to minimize exposure to flooding whilst incorporating structural solutions to reduce vulnerability. Flood risk management strategies at this scale include:

- Trees to reduce runoff and ease pressure on drainage systems.
- Managing flood pathways and removing pot holes so that heavy rainfall can drain away.
- One way valves permanently fitted in drains and sewage pipes to prevent backflow and, as a last resort, widening drains to increase capacity.
- Flood resilient measures, including raising floor levels, electrical fittings and equipment; rain proofing and overhangs to prevent infiltration of heavy rain around doors and windows.

8.7 Managing Water Resources and Quality at the Catchment

At the catchment scale, managing water resources and quality should focus on safeguarding clean rivers and lakes that sustain diverse and healthy ecosystems provide recreation opportunities and support the needs of communities. Strategies include:

- Upland and lowland reservoirs, both natural and manmade, help to ensure sufficient water supplies during dry season while reducing the potential for flooding downstream during heavy rainfall. They also have important aesthetic, recreational, ecological and flood storage roles.
- Treated waste water may be disinfected chemically or physically and the final effluent can be used for irrigation.
- Promoting tighter water efficiency standards in areas where there is water stress.
- Encouraging use of SUDS (Sustainable Drainage Systems) for groundwater recharge.
- Abstraction controls and licensing to manage the needs of water users while ensuring adequate protection of the environment.
- Greater use of separate drainage systems for surface and foul water to send surface water runoff directly back to the water course and significantly reduce the treatment burden.
- More use of reclaimed and recycled water, produced after advanced treatment and filtering of waste water and storm water.
- In order to sustain the evaporative cooling function of vegetation, rainwater harvesting, underground storage and accessing new supplies of lower grade ground water may provide additional water in times of drought.
- Use low water use plants to create public and private landscapes that do not require irrigation.

8.8 Managing Water Resources and Quality at the Neighborhood Scale

At this scale, the following strategies can be implemented:

- Rainwater harvesting and storage from roofs or other surfaces for future use (normally toilet flushing and irrigation). This strategy can also increase soil moisture levels for vegetation, sustaining evaporative cooling and reduce risk of urban flooding.
- SUDS to collect and stone water.
- Grey water recycling to use waste water from plumbing systems for toilet flushing and irrigation.
- Low water use planting can greatly reduce water demand.
- Effective storm overflows management to prevent surface water contamination.
- Managing point source pollution reduces water quality risks.

8.9 Managing Water Resources and Quality at the Building Scale

At the building scale, designers, developers and architects can exploit synergies between water resource management, flood risks and energy conservation. A number of solutions offer effective means of managing water supplies and reducing demand:

- Water efficient fixtures and fittings can significantly reduce demand for water, and those will become increasely important for high density developments.
- Rainwater harvesting and storage. Grey water can then be recycled for irrigation.

- Building Scale SUDS will reduce runoff and satisfy a portion of the buildings demand for water. Green roofs have an important part to play.

9. CONCLUSION

The examination of adaptation to climate change by design options and action plans provides insights on the capacity of local actors (policy makers, town planners, architects, and builders) to internalize climate change into local responses in our cities. The review demonstrates that the issue of climate change adaptation to a large extent connects to local development and that adaptations are hazard specific. As such, it becomes imperative for Nigeria cities to adapt these design options, particularly now that our cities are rapidly expanding. It will save cost, increase aesthetic value, protect the environment and at the same time act as climate change adaption strategy. It also pointed out that local drivers, with the effects of sea level rise, changes in temperature and rainfall, and changes in the intensity and frequency of extreme events determine vulnerability. It is our view that improving our understanding of the design options and adapting it as adaptation measures would protect Nigeria cities better. The reason been that as these cities are still developing and expanding cost will be saved and mistakes of developed countries that are battling now with climate change and did not incorporate climate change impact in their development plans will be avoided.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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