

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

Abstract

Problem Statement: Climate change and climate variability is receiving much attention recently because it has adverse effects on the environment, health and socio-economic activities.

Approach: The aim of the study is to explore innovative designs and how they translate into scenarios of response to climate change adaptation. 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.

Keywords: Adaptation, climate change, design option, cities, hazard and vulnerability.

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29 **Introduction**

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

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

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

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49 In the meantime, cities and their residents have no choice other than to adapt to the
50 impacts of climate change. This view coincides with a growing political voice for
51 adaptation mainly in countries and cities that are likely to be affected most severely
52 (Pielke et al, 2007). 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.

Effects of Climate Change

Nigeria 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, there will be distribution conflicts 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 will be 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).

Some Facts on Climate Change

- a. CO₂ 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 3.1mm.
- 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 50 years 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.

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 a 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 hazard is used here to refer specifically to physical manifestations of climatic variability or change, such as droughts, floods, storms, episodes of heavy rainfall, long-term changes in the mean values of climatic variables, potential future shifts in climatic regimes and so on.

Exposure is defined in the same report as “the nature and degree to which a system is exposed to significant climatic variations”. Sensitivity is “the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Adaptive capacity is the ability or capacity of a system to modify or change its characteristics or behavior so as to cope better with existing or anticipated external stress. 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 incrementally and responsively, and its vulnerability to hazards occurring in the future will be a function of its ability to anticipate and pre-empt those hazards via appropriate planned adaptation strategies.

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. Different systems are characterized by different scales and different systems will interact with one another.

Based on this, we made an attempt to project adaptation process of an urban environment into three scales: Conurbation or Catchment Scale, Neighborhood scale and Building Scale.

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.

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.

Design Strategies

Shaw et al (2007) outlined some adaptation strategies that could be a guide for building sustainable cities in the face of a changing climate:

A .Managing High Temperatures at the Conurbation Scale

Scale, efforts should focus on the opportunities for reducing UHI effects through large scale infrastructure. This should consider a number of climate risk

management options including:

- 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 spots facilities, community gardens, village greens, private gardens, and green roofs and walls.

- **Blue space**, such as 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.

B . 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.
- **Cool 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 **cool roofs** made of light colored materials to prevent solar heat gain and reduce the need for mechanical cooling.

C .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.

D .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.
- **Hard, permanent flood defenses and barriers.** 
- Diversion of flood flows away from vulnerable areas or constructing a second flood channel.
- **SUDS to manage and slow down surface water run-off and release it to the natural water cycle.**  SUDS can deal with flood, water quality and resource risks while also bringing ecological and amenity benefits.

E .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.
- **Impermeable surfaces**  can be replaced by SUDS, such as 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.
-  **Smaller scale hard barriers or managed realignment schemes.**
- 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.

F .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:

- **Green roofs** to reduce runoff and ease pressure on drainage systems.
- Managing flood pathways and removing **“pinch points”** 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.

G .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 planting or Xeriscaping to create public and private landscapes that do not require irrigation.

H .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 store water.
- Grey water recycling to use waste water from plumbing systems for toilet flushing and irrigation.
- Xeriscaping or 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.

I .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 increasingly 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.

Conclusion

The examination of adaptation 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 exercise demonstrates that the issue of climate change adaptation to a large extent connects to local development and that adaptations are hazard specific. 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's our view that improving our understanding of the synergies, conflicts and trade-offs between mitigation and adaptation measures would enable more integrated and effective climate change adaptation design options to emerge (McEvoy, Lindley and Handley, 2006). The study also acknowledges that the "political economy" of adapting to climate change may soon become a critical factor, as contests emerge about how, and for whom, climate change adaptation should take place (Hug et al, 2007).

REFERENCES

- Adger, W.N, Huq, S, Brown, K, Conway, D and Hulme, M (2002). *Adaptation to Climate Change: Setting the Agenda for Development Policy and Research*, Tyndall Centre for Climate Change Research Working Paper 16.
- Allen, K (2003). *Vulnerability Reduction and the Community – based Approach*, in Pelling (ed), *Natural Disasters and Development in a Globalizing World*, 170 – 184.
- Brooks, N and Adger, W.N. (2003). *Country Level Risk Measures of Climate – related Natural Disasters and Implications for Adaptation to Climate Change*. Tyndall Centre Working Paper 26:(http://www.tyndall.ac.uk/publications/working_papers/wp26pdf).
- Brooks, N. (2003). *Vulnerability, Risk and Adaptation: A Conceptual Framework*, Tyndall Centre Working Paper 38.
- Burton, I, Kates, R, Lim, B, Pilifosova, O and Schipper, E.L (2002). *From Impacts Assessment to Adaptation Priorities: The Shaping of Adaptation Policies*, *Climate Policy*, 2, 145 – 159.
- Dirk; Rimjhim, A. Jonathan, I Erach, B. Carsten, B (2011). *Adapting Cities to Climate Change: Opportunities and Constraints In. Cities and Climate Change: Responding to an Urgent Agenda* by D. Hoornwey, M. Freire, M.T. Lee, P. Bhada-Tata and B. Yuen (eds). The World Bank, Washington, D.C.
- Enete, I.C (2008). *Potential Impacts of Climate Change on Coastal Settlements of Nigeria*. A paper presented at the 15th Annual conference of the Environment and Behavior Association of Nigeria (EBAN) held at Babcock University between 6-9th may.
- Enete, I.C and Ijioma, M.A (2011). *Analysis of Temporal and Spatial Characteristics of Enugu Urban Heat Island using Multiple Techniques*. *OIDA International Journal of Sustainable Development*. Vol.2 No.6.pp.29-36.

- Enete, I.C and Ezewaji, E.E (2011). *Implications of Climate Variability on Water Resources of Nigeria. A Review. Journal of Geography and Regional Planning*. Vol.4(13).pp.678-682.
- Enete, I.C and Alabi, M.O (2011). *Potential Impacts of Global Climate Change on Power and Energy Generation. Journal of Knowledge Management, Economics and Information Technology*. (Scientific papers, www.scientificpapers.org). Issue.6
- Forster, P, Ramaswamy, V, Artaxo P, Bernsten T, Betts R, Fahey, D.W, Haywood, Lean J, Lowe DC, Myhre G, Nganga J, Prinn R, Raga G, Schulz M, Van Dorland R (2007): *Changes in Atmospheric Constituents and in Radioactive Forcing. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, SD. Qin, M. Manning, Z. Chen, M. Marquies, K.B. Averyt, M. Tignor and H.L Miller (eds)]. Cambridge University Press, Cambridge, UK and New York, USA.
- Huq, S., S. Kovats, H. Reid and D. Satterthwaite (2007). "Editorial: *Reducing Risks to Cities from Disasters and Climate Change*". *Environment and Urbanization* 19(3): 3 – 15.
- IIED (International Institute for Environmental and Development) (2007). "Reducing Risks to Cities from Climate Change: An Environmental or Development Agenda". *Environment and Urbanization Brief* 15, IIED, London.
- IPCC (Intergovernmental Panel on Climate Change) (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva: IPCC.
- Johnson, A.F, and Moghori, F (2008). *Ecological Impacts of Climate Change Booklet*. p.8 – 10. www.nas.edu/climatechange. Retrieved 16th May, 2012.

Jones, R and Boer, R (2003). *Assessing Current Climate Risks Adaptation Policy Framework: A Guide for Policies to Facilitate Adaptation to Climate Change*, UNDP, in Review (<http://www.undp.org/cc/apf-outline.htm>).

Khatun, F, Islam, A.N (2009). *Policy Agenda addressing Climate Change in Bangladesh, Copenhagen and Beyond*, Centre for Policy Dialogue (CPD), Dhaka.

McEvoy, D., S. Lindley, and J. Handley (2006). "Adaptation and Mitigation in Urban Areas: Synergies and Conflicts" *Municipal Engineer* 159 (4): 185 – 91.

Pielke, R, G. Prins, S. Rayner, and D. Sarewitz (2007). "Lifting the Taboo on Adaptation". *Nature* 445: 597 – 98.

Reid H, Mac Gregor J, Sahlen L, Staye, J (2007). Counting the Cost of Climate Change in Namibia: Sustainable Development Opinion. International Institute for Environment and Development. www.iied.org. Retrieved 16th May, 2012.

Shaw, R, Colley, M and Connell, R (2007). *Climate Change Adaptation by Design: A Guide for Sustainable Communities*. TCPA, London.

Smith, J.B, Schellnhuber, H.J (2001). Vulnerability to Climate Change and Reasons for Concern: A Synthesis. In McCarthy, J.J, Canziani, O.F, Leary, N.A, Dokken, D.J and White, K.S (Eds), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, Contributions of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 913 – 967.

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