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Climate Change Impacts on the Built Environment in Nigeria

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Abstract

The populations, infrastructure and ecology of cities are at risk from the impacts of climate change which affect urban ventilation and cooling, urban drainage and flood risk and water resources. Built areas exert considerable influence over their local climate and environment, and urban populations are already facing a range of weather-related risks such as heat waves, water pollution and flooding. Although climate change is expected to compound these problems, building designers and spatial planners are responding through improved building design and layout of cities. There is also a need for weather data for testing future performance of urban drainage and water supply systems. Urban forestry and associated *programmes are expected to play leading roles in the built environment too. This paper x-rayed significant climate change impacts expected to shape the future character and functioning of urban systems, in Nigeria, people's attitude to the change, the findings have serious implications for how hazards are managed. The paper also highlighted strategies for managing and preventing climate change on built environment. The importance of public awareness through effective hazard education was also suggested.*

Introduction

Increasing attention is being paid to the potential impacts of climate change on urban environments. At present, roughly 50 percent of the world's population live in cities, but this figure is expected to rise over the years. Most of the future growth of the urban population is anticipated in the developing world. Many low-income countries are already exposed to shortages of clean drinking water and poor sanitation, and often occupy high-risk areas such as floodplains and coastal zones (Haines et al., 2006). As the concentration of urban populations is increasingly mixed up with growing risks of extreme events, millions of naira is lost and the cost is increasing by the day.

The significant contribution made by the world's major cities to global climate change and the urgent need for energy efficient infrastructure and changed patterns of resource consumption is notable (Hunt, 2004). With such a range of issues to tackle, it is not surprising that there have been calls for wider participation and more effective interaction between complementary disciplines (Oke, 2006).

Climate change will increase the frequency and intensity of heavy rainfall events, thereby increasing the risk of urban flooding. While addressing infrastructure issues is a necessary component of reducing urban flood risk, individual homeowners can have a significant role in reducing risk through protecting their own homes and reducing their contributions of stormwater to municipal sanitary sewers and stormwater management systems. However, the barriers of low public awareness will have to be overcome to effectively engage

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homeowners in urban flood risk reduction. Some cities have been working to improve homeowner knowledge and risk-reducing behaviour through education and financial assistance programs in the advance world In Anambra state recently. Measures meant to ameliorate some hazardous effects of climate charge like flood is well noted by the local populace.

Urban flooding occurs in urban areas, where the impacts of extreme rainfall are exacerbated by high concentrations of impervious surface, infrastructure, buildings, property and people. Urban flooding can have serious implications for both buildings and infrastructure, as extreme flows of water during heavy rainfall events can damage both overland and underground stormwater management infrastructure and road pavements.

Flooding has also become the greatest reasons for the numerous gully erosion problems because of concentration and discharge to many unsafe areas. These are mainly due to poor road designs, numerous public and private building springing up and exposing land surface in many built up areas.

Types of urban flooding

1. **Overbank flooding**: Filled to capacity because of heavy rain or melting snow, the water within a river overflows its banks and spreads across the land around it. Sometimes the area covered is wide and flat; water tends to spread out.

2. **Flash floods**: Water from floods can take time to build up, allowing the population in an area time to be warned in advance. But sometimes flooding occurs quickly. Flash floods carry debris that elevate their potential to damage structures and injure people.

3. **Coastal flooding** occurs along the edges of rivers and oceans.

4. **Engineering issues:** Flooding may be caused by manmade issues, as well. A weakly constructed dam could receive a

more substantive battering than it was designed for and give way, creating a flash flood in the regions downstream.

5. **Overland Flooding:** When extreme rainfall exceeds the capacity of underground storm sewer systems and above-ground overland flow routes, overland flooding can occur. Overland flow routes have not been incorporated into new developments and are not designed to handle excess stormwater flows when rainfall exceeds the capacity of underground pipes or drains. This factor of safety is imperative.

6. **Infiltration flooding** can also occur when heavy rainfalls infiltrate into the soil beside foundation walls, where it can then enter the basements through cracks in walls.

Climate change and urban flooding

Under a changing climate, an increase in the frequency of drought, extreme rainfall, high temperatures, wind events is expected and we can expect an exacerbation of the health impacts associated with these events. It has been argued that extreme events that currently have return frequencies of 1 in 100 years could have return frequencies of 1 in 5 or 1 in 10 years by prevailing climate change conditions.

As temperatures increase, evaporation will also increase and the atmosphere will be able to hold more moisture. Higher amounts of moisture in the atmosphere will result in more severe precipitation in Anambra State. Although the precise impacts of climate change will differ depending on the climatic and environmental characteristics of specific regions, it is often thought that extreme precipitation events could increase in severity by approximately 15 percent.

Stormwater management infrastructure in Anambra State has traditionally been designed with the assumption that weather and climate conditions are static, and historical climate conditions can be used to accurately predict the future climate. Increasing frequencies of extreme rainfall events caused by climate change will mean that stormwater management infrastructure design standards will be less reflective of the frequency and intensity of events that we will experience in the future.

Understanding public perceptions of natural hazards is an important part of non-structural hazard management. In comparison to structural approaches to hazard management, which attempt to alter the hazard to reduce risks to population (e.g., building dams and levees to control flooding), non-structural approaches attempt to alter human behaviour to reduce vulnerability. A commonly applied non-structural measure may be the use of floodplain maps to steer development away from flood prone areas. Non-structural measures also include education programs and actions designed to increase the awareness and risk-reducing actions of the individuals who are exposed to hazard risk.

Hazard perception studies were first conducted in the 1960s, and throughout this time, a few findings have generally remained constant in the literature. First, people who live in areas subject to hazards are largely unaware that they could sustain damages, personal injury, or death. In most cases, less than half are aware of their exposure to natural hazards.

Second, people who live in hazard prone areas rarely take actions to protect themselves. Many studies have revealed that less than 15 percent of individuals exposed to hazards take actions to reduce their risk of sustaining damages. When people do take action, they generally take inexpensive and less effective actions such as evacuating at the last minute, or moving valuable items to a higher level in their home during a flood event typically of what obtained in some built environment in Ogbaru local Government, Nigeria. Since early September 2013, vulnerable areas are expected to take precautionary measures which have not be done till now.

Finally, perception studies have frequently revealed that people with property prone to flooding rely highly on government built structural mitigation mechanisms, such as dams, levees and floodwalls, to protect them from damages. Studies have also revealed a high reliance on the government for flood protection, and that often the blame for damages caused by natural hazards is placed on government rather than extreme natural events or on those who choose to occupy hazard prone areas. Presently it is suggested that government must build shoreline protection structures along various rivers in Anambra state the billions of Naira that will go with it notwithstanding.

Homeowners are more likely to attribute responsibility to their municipalities than to take action themselves to reduce urban flood risk. Those findings have serious implications for how hazards are managed, specifically highlighting the importance of public awareness through effective hazard education.

Changing Global and Urban Climate

It has been established by study that most of the global warming over the last 50 years is attributable to human activities; that human activities will continue to change the composition of the atmosphere; and that global mean temperatures and sea levels will continue to rise for many centuries to come. The risk of a heat wave like that experienced across Europe in 2003 is thought to have doubled due to historic greenhouse gas emissions (Stott et al., 2004).

However, the range of potential impacts is expected to go beyond heat waves. Other anticipated consequences of climate change for Nigerian cities include fewer periods of extreme cold; increased frequency of air and water pollution, rising and changes in the timing, frequency and severity of urban flooding associated with it.

Detection of climate driven trends at the scale of individual cities is problematic due to the high inter-annual variability of local weather and factors such as land-use change or urbanization effects. It has long been recognized that built areas can have urban heat island **(UHI)** that may be up to 5-6^{o}C warmer than surrounding countryside (Oke, 1982). Compared with vegetated surfaces, building materials retain more solar energy during the day, and have lower rates of radiant cooling during the night. Urban areas also have lower wind speeds,

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less convective heat losses and evapotranspiration, yielding more energy for surface warming. Artificial space heating, air conditioning, transportation, cooking and industrial processes introduce additional sources of heat into the urban environment causing distinct weekly cycles in UHI intensity (Wilby, 2003a).

The physical constituents of built areas and human activities within urban centres also interact with other climate drivers. For example, runoff from impervious surfaces can have dramatic effects on downstream risks of flooding and erosion (Hollis, 1988), as well as water quality via uncontrolled discharges of storm water (Paul and Meyer, 2001). Urban air pollution concentrations may also increase during heat waves with significant consequences for mortality. This is because high temperatures and solar radiation stimulate the production of photochemicals among as well as ozone precursor biogenic volatile organic compounds **(VOCs)** by some plants.

Potential climate change impacts of built environment in Nigeria

Flooding	*	More frequent and intense rainfalls leading to flooding and overwhelming of urban drainage systems.
Water Resources	*	Heightened water demand in hot, dry times
	*	Reduced soil moisture and groundwater replenishment.
Health	*	Poorer air quality affects asthmatics and causes damage to plants and buildings.
	*	Higher mortality rates in Nov. - June due to heat stress.

Biodiversity	*	Increased competition from exotic species, spread of disease and pests, affecting both fauna and flora.
	*	Increased ground movement in affecting underground pipes and cables.
	*	Reduced comfort and productivity of workers.
Transport	*	Increased disruption to transport systems by extreme weather.
	*	Reduction in cold weather-related disruption.

Urban drainage and flood risk

Assessing urban flood risk is further complicated by the performance of the urban drainage system, which responds to highly localized effects such as blocked culverts or overwhelming of the hydraulic capacity of sewers (Ashely et al., 2005). There is also a wide variety of tangible and non-tangible secondary impacts associated with flooding in urban areas. Urban litters and blockages remain major problems in Nigeria.

In Nigeria Reports estimates that may urban properties are presently at risk from flooding caused by heavy downpours, yielding average annual damages of billions of Naira. However, the authors concede that considerable uncertainty surrounds the incidence of flooding because of the complex interplay between the amount of precipitation change in relation to the excess capacity of drain and drainage pipes and it is also difficult to quantify other costs associated with water flooding, or risks to human health such as diarrhoeal and respiratory diseases (Ahern et al., 2005). There could also be significant disruption to system-wide performance of transportation networks all over the urban areas.

Urban Forests and Climate Change

The purpose of the urban forestry:

The total cover and distribution of all vegetation in cities and suburbs are important in making cities more liveable, and play key roles in making urban regions more economically and ecologically sustainable. If we are to optimize the benefits society derives from its investment in urban forests, then policy makers and the public must more broadly appreciate that urban vegetation functions as a city's green infrastructure and, therefore, requires similar attention to its development, maintenance and repair as does our built infrastructure.

How the urban forest reduces the urban carbon:

(1) Direct Carbon Uptake

An urban forest, especially trees, provides the ecosystem service of reducing a city's carbon footprint in two major ways, directly by carbon uptake from the atmosphere and long-term storage in wood, and indirectly by reducing a city's energy use. All plants take up CO2 from the atmosphere and convert the carbon into their living tissues. Unlike grasses and other herbaceous plants, however, only shrubs and trees store carbon in woody tissue for decades to centuries, and so keep enough CO2 out of atmospheric circulation over a sufficient time frame to reduce the rate of climate change.

Urban and suburban housing lots typically store and sequester most of a city's tree carbon, particularly if neighbourhoods are old and contain mature trees, and also if larger trees were not removed during development. The potential to plant more trees in yards and on streets exists and, if realized, could increase tree density and the multiple ecosystem benefits trees provide for both individual households and the city as a whole.

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Regulation and planning

Regulation (and targeted procurement) by governments can help to inform and guide the architectural profession as to necessary changes in practice. Historically, regulation has most often been reactive in nature: for instance where flooding, coastal inundation and bushfire disasters have accelerated modifications to building regulations and design requirements for rebuilding communities devastated by such occurrences.

At the planning level, Kousky and Cooke (2009) argue that successful adaptation policy might effectively decouple risks. The 1906 earthquake in San Francisco is given as an example where both an extreme earthquake and a resultant fire which burned for three days damaged a city, destroying 28,000 buildings. The severity of the damage was increased by the city's dependence on gas and water pipes that could not withstand a high magnitude quake. If gas pipes break, fire is more likely, and if water pipes break, flames cannot be controlled, leading any fire to likely be a conflagration. In this case, de-coupling the knock on effects of these two risks involves the design and installation of pipes that can better withstand extreme earthquakes.

Building design also has urban-scale impacts, and also has the potential to double risks. For example, higher building density can increase local urban heat island effects and urban flooding, while strategies of greening buildings can ameliorate such issues. For example, capturing and filtering water that falls on buildings also will reduce excessive runoff during flash flooding. Interrelationships between built environment professions are at the core of integrated, whole urban design principles. They will be essential if the habitability and asset value of existing and new buildings are to be preserved in the face of increasingly unpredictable and extreme climate change threats.

Adaptive strategies for building design

Building flexibility into design to allow for the unexpected makes investment decisions robust to most possible changes in climate conditions. This may include no-regret strategies that bring benefits even in the absence of future climate change, e.g. strengthening tile fixtures securely to a roof to avoid wind damage.

Beyond these measures, designers should be researching localised risks of climate change and preparing their buildings for the predicted hazards which may include: increasing temperatures, coastal storm surges and inundation, flooding, tropical cyclones and intensified downpours.

Increasing temperatures

Passive design strategies have the double benefit of countering increasing temperatures without undermining mitigation efforts. The fundamentals of passive design are:

- Thermal mass to reduce the internal temperature variation
- Insulation and the use of low emissivity roofing paints and high performance glazing to reduce the rate of heat transfer through building structures
- External shading of vulnerable building surfaces, and strategic sitting of deciduous vegetation cross ventilation and mixed-mode design to cool internal spaces.
- Green roof and roof design technology
- Photovoltaic glazing
- Low heat producing lighting, equipment and plant
- Photovoltaic, solar, biomass, and wind-powered cooling technology

Architects should assess whether these provide sufficient protection against climate change impacts anticipated for the lifetime of the

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building. Given that individuals can pay off the higher construction costs over the life of a mortgage, building design measures that can adapt to a certain level of flooding can be a cost-effective and affordable approach.

Besides citing, there are many options available to reduce the flooding risk and damage potential when designing and constructing new buildings. In order of priority, these are:

Exceed minimum floor levels, Consider multi-storey construction, Design and construct buildings for flooding occurrences, Use water-resistant materials, Design to ensure water can easily escape once flooding has subsided, Raise flood awareness and preparedness with building occupants, including designing and providing information about access routes

For existing buildings, the recommendations are similar to those for new buildings. Raise or move the building, Build a second or multiple stories and use the lower storey as non-living or ‘non-productive’ space, Replace cladding, flooring, and linings with water-resistant materials, Build a levee or flood wall around the building, Raise flood awareness and preparedness with building occupants.

Typically, commercial buildings are at greater risk of flooding than houses, mostly due to their urban location, being surrounded by impermeable surfaces, and the likelihood of urban storm water drainage systems being overburdened. Therefore, these buildings may be at risk of more damage than houses.

Water resources

Water resources planning has viewed climate as stationary, a position that is increasingly untenable give that infrastructure can be in place for many decades, even centuries.

Long-term planning taking into account climate variability and change must also accommodate the various, and often conflicting, demands for water as well as the need to protect the wider environment. In developing countries, failure of water supplies and irrigation systems can lead to poor sanitation in urban areas, as well as food shortage and reduced power generation (Magadza, 2000). Reduced reliability of surface water supplies could shift reliance to groundwater resources.

Urban water supplies can be disrupted through deteriorating quality, and climate change has the potential to affect water quality in several ways.

Conclusion

There is no doubt that the populations, infrastructure and ecology of cities are at risk from the impacts of climate change. However, tools are becoming available for addressing some of the worst effects. For example, appropriate building design and climate sensitive planning, avoidance of high-risk areas through more stringent development control, incorporation of climate change allowances in engineering standards applied to flood defences and water supply systems, shoreline protection works. Citizens also have a responsibility to mitigate their collective impact on the local and global environment through reduced resource consumption and changed behaviour (Hunt, 2004).

This review has described the most significant climate change impacts expected to shape the future character and functioning of urban systems, in Nigeria. Several important knowledge gaps have emerged. First, there is an ongoing need to improve preparedness and forecasting of climatic hazards, such as intense heat island or air pollution episodes, to safeguard human comfort and health in Nigeria.

Second, there is clearly a need for improved representation of intra-urban flooding, at local, city and catchment scales.

New modelling techniques will also be needed to exploit fully emergent probabilistic climate change information. But there could be new cost implications arising from the use of such data, dependent on the level of risk and uncertainty that is acceptable in the resultant engineering design. This has been done successfully in years 2012 and 2013 by NIMET in Nigeria.

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