CHAPTER 10: The Future of Innovations and Adaptive Urban Infrastructure to Climate Change

Abstract

This chapter explores the innovations and adaptive urban infrastructure to climate change showing the increasing present-day challenges from climate change and urbanisation. Half of the earth's population lives in urban areas, and projections suggest that this share will increase up to 66% by the mid-21st century. This urban expansion will heavily draw on natural resources including open space and will have severe effects on ecosystems and the services they provide. Cities are the first to experience impacts from climate change. Rising temperatures, heatwaves, extreme precipitation events, flooding and droughts are causing economic losses, social insecurity and affecting health and human well-being. This chapter is based on a desktop study where a literature review was gathered from Google Scholar in the form of articles, magazines, secondary government reports and newspapers. The methodology used in this study included thematic content and textual analysis of different materials. The study is against the backdrop that traditionally, urban planners and practitioners in land and resource management have relied on conventional engineering solutions to adapt to climate change, but this may not always be cost-effective, sufficient or sustainable. Nature-based solutions can address societal challenges from climate change and urbanisation in a sustainable way. By using ecosystem services, nature-based solutions are innovative solutions that use natural elements to achieve environmental and societal goals. They offer significant potential to provide energy and resource-efficient responses to climate change and to enhance the natural capital. Nature-based solutions provide additional multiple benefits to city residents such as improvements in health and wellbeing and improvements of the local green economy. Understanding and anticipating these changes will help cities prepare for a more sustainable future.

INTRODUCTION

The chapter argues that making cities more resilient to climate-related disasters and managing long-term climate risks in ways that protect people and encourage prosperity includes improving a city's ability to reduce greenhouse gas (GHG) emissions. This chapter demonstrates the

importance of taking a systemic approach to combine knowledge from different fields such as urban planning, nature conservation, urban engineering, governance or social justice and public health to address complex issues sustainably. To date, an increasing number of nature-based solutions (NBS) projects have been implemented. The international climate science research community has concluded that human activities are changing the earth's climate in ways that increase the risk to cities. This conclusion is based on different types of evidence including the earth's climate history, observations of changes in the recent historical climate record, emerging new patterns of climate extremes, and global climate models. Cities and their citizens have begun to experience the effects of climate change.

Innovation is key to coping with climate change impacts. At a local level, communities are responding to climate stresses in innovative ways. Replicating successful solutions in other parts of a country or region can save valuable time and money. By setting up pilot projects and carefully monitoring their results, insights and best practices can be fed into policy processes, helping to scale up successful approaches (White *et al.,* 2005). Africa will be one of the continents hardest hit by the effects of climate change. Increased drought, desertification, variability in rainfall and other consequences resulting from environmental changes, undermine the continent's ability to adapt. Many African countries are marked by grinding poverty and possess unsupportable infrastructures and weak governance mechanisms that contribute to political instability. In September 2015, the United Nations endorsed the new Sustainable Development Goal 11, which is to "make cities and human settlements inclusive, safe, resilient and sustainable" (United Nations, 2015). This new sustainability goal cannot be met without explicitly recognising climate change as a key component. Likewise, effective responses to climate change cannot proceed without understanding the larger context of sustainability. As cities mitigate the causes of climate change and adapt to new climate conditions, profound changes will be required in urban energy, transportation, water use, land-use, ecosystems, growth patterns, consumption, and lifestyles. New systems for urban sustainability that encompass more cooperative and integrated urban-rural, peri-urban, and metropolitan regional linkages will need to emerge.

Importantly, research from the natural and social sciences is combined and results are interlinked with urban governance and local participation.

This volume demonstrates the importance of taking a systemic approach to combine knowledge from different fields, such as urban planning, nature conservation, urban engineering, governance or social justice and public health to address complex issues sustainably. This integrated view to sustainable urban development is also emphasized in the 2030 Agenda for Sustainable Development, the New Urban Agenda adopted at the United Nations HABITAT III conference and supported by the European Commission's research and innovation policy on nature-based solutions (United Nations, 2015). By understanding the value of nature-based solutions to climate change adaptation for society and by developing the policies, research and practice to implement them, there can be contributions to enhancing the preparedness of cities and their communities to meet environmental and societal challenges.

BACKGROUND AND OVERVIEW

Recently, Hurricane Sandy, the most destructive and second-costliest for the US after 2005's Katrina, affected millions of people, including many in the Caribbean. It caused more than US$50 billion in economic loss and over US$5 billion in damage to New York's urban infrastructure (Wakefield, 2020). In the Philippines, Typhoon Haiyan (2013) affected about 25 million people, and two years after, Typhoon Koppu affected one million people with damages of US$160 million. These facts represent only a fraction of what climate change, associated sea-level rise, and extreme climatic events can do. Observed data also reveal that since the early 20th century, the global mean sea-level increase has ranged between 1.3 and 1.7 mm per year. However, from 1993, the rate has risen to between 2.8 and 3.6 mm, varying regionally. For example, in the tropical western Pacific, this rate is four times higher (i.e., 12 mm/year) than the global average (Nurse *et al.,* 2014). In addition to the direct impacts on humans and infrastructure, climatic impacts, and rising sea levels and temperature significantly damage natural resources and ecosystems, particularly in coastal areas which might otherwise have natural and long-term resilience to cope with such events. Mangroves in many coastal areas, for instance, increase resilience naturally, reducing the impacts of sea-level rise, particularly wave energy, beach erosion and storm surges. However, climate change impacts along with anthropogenic interventions, have caused mangrove deforestation at a rate of 1% to 2% annually (Alongi, 2015).

Climate change presents one of the greatest challenges to society today. Effects on nature and people are first experienced in cities (White *et al.,* 2005). Cities form microcosms with extreme temperature gradients and about half of the human population globally lives in urban areas (United Nations, Department of Economic and Social Affairs 2014). Climate change has a significant impact on biodiversity and ecosystem functioning through threatening current habitat conditions due to heat and water stress (European Environment Agency, 2012). Climatic stress leads to a decrease in the distribution of typical native species and facilitates the establishment of alien invasive species (Knapp *et al.,* 2010). The influences of climate change on society include health-related effects and socio-economic impacts induced by increased numbers of heatwaves, droughts and flooding events (European Environment Agency, 2016). In addition to climate change, urbanisation and the accompanying increases in the number and size of cities, are impacting ecosystems as urbanisation is driving a significant conversion of rural to urban landscapes (Seto *et al.,* 2011).

Several interlinked pressures, such as loss and degradation of natural areas, soil sealing and the densification of built-up areas, pose additional significant challenges to ecosystem functionality and human well-being in cities around the world. These processes may lead to biodiversity loss (Goddard *et al.,* 2010) and a reduction of functions and services that urban ecosystems provide (Haase *et al.,* 2014). However, urban green and blue spaces have the potential to counteract these pressures by providing habitats for a range of species (Niemela 1999; Goddard *et al.,* 2010) and several environmental and cultural benefits while contributing to climate change adaptation and mitigation (Kabisch *et al.,* 2015; Kabisch *et al.,* 2016a).

Scholars (Carina and Keskitalo, 2008; Douglas *et al.,* 2008; Barnett *et al.,* 2005) tend to agree that climate change will potentially increase the frequency and intensity of extreme events. Its impact on cities will be more adverse because most of the developments taking place rarely take into consideration the impacts of potential changes to the climate (Houghton, 2004). Climate change impact is expected to vary between places and among individuals owing to their differing levels of vulnerability. The impact will, therefore, be potentially higher where settlements are located in low-lying coastal areas, flood plains and hill slopes (Adger *et al.,* 2003). The extent to which impacts will occur will

also depend on the level of development in different places (UNFCCC, 2008:10). Agrawal *et al.*(2008:33) have shown that institutional and social factors are important determinants of the level of climate change impacts. They argue that the way institutions shape climate change impacts can be explained in terms of how individuals are differentially affected by the same climatic event. The work uses the examples of particular cases to explain these differences, by focusing principally on the differential access of individuals and households to resources, information and decision-making processes. Similar sentiments have been voiced by Adger *et al.* (2003:181) and Hardoy and Romero Lankao (2011), who have explained it in terms of the differences in the entitlement of individuals and groups to call upon collective resources.

THEORIES INFORMING THE STUDY

This chapter builds on Friedmann's transactive planning model to construct a theoretical framework that combines the experiential knowledge from Community Based Adaptation (CBA) and Ecological Based Adaptation (EbA), the expert knowledge from landscape ecological urbanism and the participatory methods of urban planning to address climate change adaptation in vulnerable coastal communities. The proposed approach deploys the design charrette, a participatory tool, to operationalize this framework in Africa and Zimbabwe areas vulnerable to climate change. In exploring these multi-disciplinary theoretical and empirical links amongst EbA, CBA, landscape ecological urbanism and urban planning, this study builds on Steiner's (2014) recommendation for the development of an integrated approach to address climate change adaptation through design. In particular, this study addresses Steiner's (2014:308) question: "how can concepts such as resilience and green infrastructure be advanced to design settlements to mitigate extreme weather events?"

LITERATURE REVIEW

Concerning urban green and blue spaces, NBS can foster and simplify implementation actions in urban landscapes by taking into account the services provided by nature (Secretariat of the Convention on Biological Diversity, 2009). The concept of NBS evolved over the last years and was shaped by several actors (IUCN and the EU Commission). The concept of NBS is particularly embedded in wider discussions on climate change adaptation, ecosystem services and green infrastructure (Kabisch *et al.,* 2016a). Examples of NBS include the provision of urban green such as

parks and street trees that may ameliorate high temperatures in cities (Gill *et al.,* 2007; Bowler *et al.,* 2010) or regulate air and water flows. Allocation of natural habitat space in floodplains may buffer impacts of flood events. Furthermore, architectural solutions for buildings such as green roofs and wall installations for temperature reduction and related energy savings through reduced cooling loads (Castleton *et al.,* 2010), can contribute to NBS. Importantly, by integrating NBS in urban landscapes, multiple benefits related to climate change adaptation and mitigation are increasingly recognised as influential determinants of human health and well-being (Barton and Grant, 2006; Hartig *et al.,* 2014). They relate to the provision and improved availability of urban green spaces and may result in better mental and physical health (Keniger *et al.,* 2013). In addition, NBS may present more efficient and cost-effective solutions than traditional technical approaches (European Commission, 2015). In policy and practice, NBS complement concepts like green infrastructure or ecosystem-based mitigation and adaptation.

Increasing urban densities is seen as a way towards sustainable urban development. Across Europe, there is presently a trend for densification as a planning approach for sustainable development to foster efficient use of resources, efficient transport systems and a vibrant urban life (Haaland and van den Bosch, 2015). Development often takes place in areas that are often viewed as underutilised land (such as green space) or through redevelopment on previous industrial estates (van der Waals, 2000). However, this approach has also been challenged for its threat to urban green spaces (Haaland and van den Bosch, 2015) as with urban brownfields, they potentially have an important role in offering climate change adaptation solutions. The creation, re-establishment, improvement and upkeep of existing vegetation systems and the development of an integrated urban green infrastructure network could provide a valuable asset in which to incorporate the establishment of new NBS to deal with local effects on climate change. The dual inner urban development could be seen as a constructive way forward (BfN, 2008). The approach combines densification of existing built-up areas with a mixture of conservation actions, thereby boosting the presence, quality and usability of green spaces and enhancing other green infrastructure such as street trees, green walls and roofs (*ibid.*).

The distribution of climate-related health burdens is described as almost inverse to the global distribution of GHGs emissions (Patz *et al.,* 2007).

Africa is likely to be affected the most and is where the observed adverse consequences of climate change are most apparent (Collier *et al.,* 2008; Campbell-Lendrum *et al.,* 2003; McMichael *et al.,* 2008). Predictions are that the loss of healthy life years due to global environmental change (including climate change) is 500 times greater in Africa than in Europe and, yet, health is widely recognised globally as a fundamental human right (McMichael *et al.,* 2008). A vital step towards achieving health for all, even in Africa, requires nations to ensure the provision of access to universal health coverage (Garrett *et al.,* 2009). In addition, the World Health Organisation's (WHO) Commission on Social Determinants of Health has emphasized that actions to promote health must go well beyond health care and must focus on people's daily living conditions, including the conditions in which they are born, grow, live, work and age, and on the structural drivers of those conditions such as inequities in access to power, money and other resources (WHO, 2008).

Climate change has significant negative impacts on the social determinants of health. These conditions are intertwined and play a major, albeit indirect, role in creating and perpetuating health inequities within and between nations. In sub-Saharan Africa, rain-fed agriculture provides food for roughly 90%of the population and provides livelihoods for 74% of the poorest people. Therefore, major reductions in the amount of rainfall or changes in its patterns would lead to population ill health. The threats to health by climate change operate through direct consequences from extreme weather and through indirect pathways such as changing patterns of disease and morbidity, water and sanitation, food security, global economic crisis, population pressure, migration and urbanisation (Costello, Abbas and Allen *et al.,* 2007). The spread or resurgence of malaria to the highlands of East Africa is widely cited as an example of a vector-borne disease spreading to new geographical areas as a consequence of climate change (Wanding, Opondo and Olago *et al.,* 2008).

With the current process of climate change, Europe is expected to face major challenges to adapt to and mitigate the consequences of severe weather conditions (Kreibich *et al.,* 2014). The year 2016 saw new temperature records for each month, with July 2016 being the hottest month since the temperature started to be recorded according to NASA measurements (NOAA, 2016). An increase in temperature can cause discomfort, economical loss, migration and increased mortality rates on a

global level (Haines *et al.,* 2006). In addition, there are predicted increases in extreme weather events (e.g. heat and cold waves, floods, droughts, wildfires and windstorms) with several parts of Europe to be exposed to multiple climate hazards (Forzieri *et al.,* 2016). Next to a changing climate, both in Europe and globally, there is an on-going urbanisation process. In the year 2007, half of the world's population lived in urban areas and it is predicted that by 2050, 66% of the world's population will live in urban areas (UN, 2014). The urban climate often differs from the surrounding rural countryside as it is generally polluted, warmer and rainier and less windy (Givoni, 1991). This suggests that the effect of climate change with the predicted increase in temperature and more extreme weather events will be experienced to a greater extent in urban areas compared to the surrounding landscape. The changing climate might also exaggerate the negative effects of urbanisation experienced, such as increased urban temperatures and flooding (Semadeni-Davies *et al.,* 2008). This occurrence of floods risks infrastructure in urban areas as the floods may lead to destruction of housing and service infrastructure. There is also contamination of water sources (Musacchio *et al.,* 2021),especially in urban areas that experience water shortages such as Chitungwiza, Budiriro and Epworth (Kudumba, 2022), which can cause cholera, typhoid and other water borne diseases.

RESEARCH METHODOLOGY

This chapter is based on a desktop study where a literature review was gathered from different scholarly articles in the form of journal articles, books and secondary government reports. Thematic and textual analysis of different tools was used in this study. Climatic existing experiences, case study and documents were used as archival methods. The information used was taken from different parts of the world because climate concepts, debates and ideas are more based on both developed countries and developing countries.

RESULTS AND DISCUSSION

In Africa, he most unsettling aspect of climate change from the perspective of many scholars (Corfee-Morlot *et al.,* 2011; Ranger *et al.,* 2011; Romero-Lankao and Dodman, 2011; Satterthwaite *et al.,* 2009) relates to the potentially catastrophic impacts it will have on the human and socio-ecological systems of cities. Earlier empirical studies of climate change (IPCC, 2001; Tol *et al.,* 2000; Mintzer, 1992) have focused more on its causes which have been largely attributed to human activities.

According to the IPCC (2007), the warming of the global climate is now overwhelmingly beyond dispute (despite the doubts expressed by a body of climate change sceptics) and several long-term changes in the world's climate are currently witnessed in many parts of the world. The environmental impact of global warming will be manifested in the form of various types of severe weather events (Romero Lankao, 2008; Simon and Fragkias, 2008). Impacts will be reinforced more by the local contextual conditions of places (characteristics of topography and location, quality of urban planning, urban services and infrastructure) than by the average global change (Hein *et al.,* 2008; Simon and Fragkias, 2008). Several of the recent climatic disasters involving severe disruptions to urban systems exemplify the extent to which the impacts of climate change will bear on humankind (Moser *et al.,* 2010; Bulkeley and Betsil, 2003).

Technology can help Africa cope with climate change. Above all other concerns, climate change is becoming the defining challenge of the 21st-century generation, especially in Africa. Predictions suggest that African nations, which are least responsible for climate change, are those most vulnerable to its effects. The most important climate change impacts for cities have been identified in many studies (Huq *et al.,* 2007; Parry, 2007; Wilby, 2007) as sea-level rise, flooding, problems of water availability and resources, human health problems, shortage of energy and damage to city infrastructure and the ecosystem. While these may not be the only climate change impacts for cities, this review will focus only on this limited range, since they have tended to receive wider acceptance. Limiting the review to these impacts only will facilitate a better understanding of what response actions cities in developing countries ought to prioritise, given the scarcity of municipal resources.

In Africa, CBA is an approach based on human rights and represents a new field in development and climate change studies. CBA refers to "a community-led process, based on communities' priorities, needs, knowledge, and capacities", whose objective is to "empower people to plan for and cope with the impacts of climate change" (Reid *et al.*, 2009:13). CBA involves governance, power structures, changes, and uncertainty, while simultaneously considering issues of poverty, vulnerability, and the inequitable distribution of and access to resources. Two key factors dominate CBA; which comprise a community, and where this community is (Reid and Schipper, 2014). Community refers to anyone

or any group of individuals affected by the impacts of climate change hence, is working with or without external interventions to cope with these impacts. As for the place, its scope determines the scale of a community and the extent of this community's vulnerability. CBA also identifies the adaptation priorities by relying on community-based and bottom-up tools. For example, the community-based vulnerability assessment (CBVA), developed by Smit and Wandel (2006), deploys the tools of CBA to identify and document the conditions and risks of communities and any challenges related to adaptation approaches.

The Secretariat of the Convention on Biological Diversity (2009) defines EbA as "the sustainable use of biodiversity and ecosystem services into an overall adaptation strategy that can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity". EbA research and practice typically include: i) coastal defence through coastal vegetation maintenance and/or restoration; ii) sustainable management of wetland floodplains; iii) natural conservation and restoration of vegetation and forests; and/or iv) healthy and diverse agroforestry systems (Munroe *et al.*, 2011). EbA ensures participatory decision-making and flexible management at multiple geographical scales and combines the best available science and local experiential knowledge of CBA (Andrade *et al.*, 2011). Perhaps that is why over 60% of EbA projects employ CBA initiatives (Doswald, *et al.*, 2014). Like CBA, EbA is a relatively new concept, spearheaded by environmental and biological conservation experts who embrace multidisciplinary, participatory and culturally appropriate approaches (Andrade, *et al.*, 2011). Furthermore, EbA and CBA seem to be complementary: while EbA underscores reversibility and biodegradability simultaneously with increasing the resilience of ecosystems and humans, CBA identifies people and communities at risk and empowers them to take part in decision-making (Girot, Ehrhart and Oglethorpe, 2012). Thus, EbA projects rely on local communities and ecosystems and rank long-term, low-cost, and no-regret adaptation interventions.

CLIMATE CHANGE IN AFRICA AND ZIMBABWE

Climate change is a reality in Africa. There are prolonged and intensified droughts in eastern Africa, unprecedented floods in western Africa, depletion of rain forests in equatorial Africa, and an increase in ocean

acidity around Africa's southern coast. Vastly altered weather patterns and climate extremes threaten agricultural production and food security, health, water and energy security which, in turn, undermine Africa's ability to grow and develop. Climate and environmentally related disasters which threaten human security can induce forced migration and produce competition among communities and nations for water and basic needs resources, with potentially negative consequences for political stability and conflict resolution. As climate change becomes increasingly acknowledged as a key driver of global, regional and local-scale impacts that exacerbate the vulnerability of human systems, the question of how to conduct 'climate compatible development' within urban systems has become more pressing. This is because the planet is currently mid-way through the second global wave of urbanisation, which is proceeding on a scale and at a historically unprecedented rate. Moreover, this second wave of urbanisation is largely taking place within the slums and informal settlements of developing-world cities in Africa and Asia where multiple pressures combine with climate change impacts to exacerbate pre-existing vulnerabilities and inequalities.

In Zimbabwe, climate change impacts cannot be neatly separated from other pressures that have a bearing on the viability of poor urban African household budgets. Planning and undertaking climate compatible development in African cities must accommodate this reality, accounting for a broader set of interconnected vulnerabilities and development priorities. At the heart of this challenge lies the question of how to balance and find synergies between immediate development priorities and building the longer-term climate resilience and sustainability of African cities. This challenge is particularly pronounced in the context of slums and informal settlements within African cities where there are high levels of contingency, fluidity and immediacy. In this regard, the African Centre for Cities (ACC) and the Climate and Development Knowledge Network (CDKN) are primarily concerned with how to support and facilitate development in African cities that address the realities and particular challenges associated with informality and inequality, while integrating climate change and long-term sustainability considerations.

EFFECTS OF CLIMATE CHANGE IN AFRICA

Although for the large part, developed countries are culpable for climate change and have contributed most to total global emissions, it is poorer countries that will suffer catastrophic impacts in the long term. Small

island developing states (SIDS) such as Cape Verde, Seychelles and Mauritius, and African mega deltas such as the Nile Delta in Egypt, Niger Delta, the Kalahari and Okavango Deltas in Botswana, are particularly vulnerable (Black, 2001). Current projections of sea-level rise and increased tropical cyclone intensity, may make many of these small island states in Africa uninhabitable. The effects of climate change include an increased frequency of extreme weather events, rising sea levels, changes in precipitation patterns and droughts, increasing water shortages, the spread of tropical and vector-borne diseases and increased frequency and intensity of storms. Recurrent droughts are becoming commonplace in several parts of Africa with the impacts on the population increasing exponentially. Droughts have largely occurred in the Sahel and some parts of southern Africa. During the Sahelian drought of the early 1970s, about 300000 people and millions of animals died. Flooding, on the other hand, has also caused havoc, particularly in southern and eastern Africa. Floods in Mozambique in 2000 resulted in two million people being displaced with 350000 jobs lost, impacting the livelihoods of up to 1.5 million people (Nkomo *et al.*, 2006).

The effects of climate change will be felt most acutely by the vulnerable segments of the population (Centre for International Earth Science Information Network, 2009). The impact of climate change on livelihoods is manifested directly and indirectly, including loss of natural resources and changes in the viability of economic processes due to changes in global markets. Future climate change is expected to have considerable impacts on natural resource systems and changes in the natural environment, sustenance and livelihoods. These, in turn, can lead to instability and conflict often followed by displacements of people and changes in migration patterns. For example, the on-going conflict in Dafur relates to scarcity induced conflicts. Therefore, as hazards and disruptions associated with climate change grow in this century, so too may the likelihood of related population displacements (Hugo, 1996). Mass movements of people are projected to occur, especially from developing countries that cannot cope with recurrent droughts and associated food shortages and climate change-related migrations. Such population movements are likely to pose serious international security challenges in coming decades (Mitchel and Tanner, 2006). In sub-Saharan Africa, instances of climate-related conflicts have been noted. As most climate models predict a decline in precipitation in several dry-lands in sub-

Saharan Africa with consequent declines in biodiversity, there might be an increase in these scarcity-induced conflicts (Nkomo *et al.*, 2006).

CONCLUSION AND RECOMMENDATIONS

Climate change is a global problem facing all nations. To realise cross-border and local solutions, all countries need to join in managing the effects of climate change on health. This daunting challenge requires a multidisciplinary approach that involves all sectors of government, NGOs, civil society, the private sector, media, various academic disciplines and innovative forms of international cooperation. African nations, their communities and all partners, cannot afford to be passive participants in the struggle against climate change. They should be creatively and meaningfully engaged with full participation over the long haul. Partners should play an active role in monitoring, discussing, advocating and assisting with the process of adaptation and mitigation. Each country should show leadership by putting in place appropriate public health systems to deal with adverse health outcomes, developing its capacity to monitor emerging health and health-related problems, improving the evidence base for policy-makers, planners and practitioners, implementing programmes and undertaking regular evaluations to assess and guide interventions. The scale of current and projected environmental changes necessitates a crucial role for central governments in Africa. However, benefits can be maximised and risks minimised if vulnerable populations are meaningfully involved in planning, implementation, monitoring and evaluation and coordinated responses to environmental change.

Urban planning and design are often cited as the key determinants to improving the resilience (coping ability) of built environments to reduce the increasing impacts of climate change. However, urban planning and design literature has hardly addressed climate change adaptation, particularly at the neighbourhood and district scales. From the perspective of environmental change, over decades, the primary focus of planning research has been on achieving sustainability, a branch that advocates for several strategies to reduce greenhouse gas emissions and facilitate climate change mitigation. The unavailability of climatic information in terms of precision, format and scale has created challenges for planning scholars wishing to advance climate change adaptation.

In particular, the information on climate change impacts on cities representing, as it does, complex interactions between human and natural systems is not sufficient. As a result, current adaptation planning includes only normative strategies from a hypothetical point of assessing risks and proving expert-driven adaptation actions. The process of developing such actions often overlooks two aspects: i) highlighting the theoretical and methodological links used in both planning and adaptation literature; and ii) assessing and prioritising the climatic problems and their solutions by incorporating local experiential knowledge.

Vegetation can, indeed, play an important role in moving the urban climate closer to a pre-development state. Urban green infrastructure (UGI) and NBS are fundamental concepts in this work with an emphasis on the role that nature can play in providing multiple services to the urban population. UGI is a concept that stems from planning, hence the focus is on the strategic role for integrating green spaces and their associated ecosystem services within urban planning at multiple scales. NBS are broad in its definition and scope, with a broad view on 'nature', and an emphasis on participatory processes in creation and management.

The issues have mostly focused on the way human activities are fast changing the composition and behaviour of the atmosphere and the extent of disruption which this may cause. Cities are singled out to play a very important role in dealing with climate change since, in addition to being the major source of GHGs, they have frequently been the major centres of the impact of the most severe climatic events. Coastal cities are specifically required to take urgent action because, even if all GHG emissions were to cease today, temperature and sea levels would continue to rise globally owing to the quantity of GHGs released into the earth's atmospheric system. Climate change impacts are predicted to be particularly adverse for many cities in the developing world, where millions of people will be severely affected in the course of this century. Urban planning is primarily called upon to play an important role in adapting cities to climate change impacts, and in mitigating GHG emissions. The role of urban planning is to be particularly critical in dealing with climate change since most municipal governments making urban planning decisions also have a great deal of influence over emission sources and the range of adaptation activities that take place.

Recent studies in African countries have examined ways in which populations have attempted to cope with recurrent droughts. Agriculture in these countries is heavily dependent on rainfall (as opposed to irrigation in more developed countries), rural populations there are particularly exposed to fluctuations in precipitation. The evidence is that drought occurs with sufficient frequency that some groups have adopted a range of adaptive strategies to cope with climatic risks, including particular temporary migration patterns. In western Sudan, for example, such migration strategies have included sending an older male member to Khartoum to seek wage labour when drought conditions occur. Similarly, the migration patterns of young people in northern Ethiopia appear to respond directly to patterns of drought. In dry rural areas, once drought becomes particularly severe and other adaptation options are exhausted, entire families and communities will move to places where relief is expected to be available. The international community in December 2009, at the Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC), agreed on a way forward to cut back on GHG emissions.

There is need to increase people's resilience to the impacts of climate change so that fewer people are forced to migrate. The breakdown of natural-resource-dependent livelihoods is likely to remain the premier driver of long-term migration during the next two to three decades. Climate change will exacerbate the situation unless vulnerable populations, particularly the poorest in Africa, are assisted in building climate-resilient livelihoods. This will require substantial investment in:

1. Adaptation measures, including water-wise irrigation systems, low/no-till agricultural practices, income diversification and disaster risk management.
2. Initiatives to help small farmers and other vulnerable groups to protect and promote agricultural production: simple, inexpensive actions such as setting up an effective system of meteorological alerts, improving agricultural extension services to increase yields and the establishment of independent networks of information exchange between and among communities across the region.
3. The empowerment of women and other marginalised social groups to overcome the additional barriers they face to adaptation.
4. Inclusive, transparent and accountable adaptation planning with the effective participation of especially vulnerable populations across the continent.