February 2015

Understanding the Assessment and Reduction of Vulnerability to Climate Change in African Cities:

A Focus on Low-Income and Informal Settlements

David Dodman,[1] Katarina Soltesova,
David Satterthwaite and Cecilia Tacoli

International Institute for Environment and Development (IIED)

with contributions from
Chris Jack, University of Cape Town

[1] Corresponding author: david.dodman@iied.org

Foreword

The analyses and conclusions contained in this document are the sole responsibility of the authors. They do not necessarily reflect the opinion of the Agence Française de Développement or its partner institutions.

Table of Contents

List of figures

List of tables

1. Urban risk in Africa: the scope of the challenge

1.1. Introduction

Climate change adaptation is a major challenge facing urban areas in low- and middle-income countries. This is particularly important in a context of rapid urbanization, inadequate infrastructure, and limited financial and technical capacity of local governments. Some cities have begun the process of vulnerability assessment and adaptation planning, but these approaches have often been based on the use of complex and expensive scientific and technical 'top down' analyses (with substantive challenges for scaling-up and scaling-out), and have failed to take adequate account of the most vulnerable groups. There is, therefore, a need for a more thorough understanding of the particular impacts of climate change on low-income urban households and communities, the ways in which these impacts translate into vulnerability, and the types of responses that are already used by these groups to minimize risk and build resilience. Following from this, there is a need to analyze the ways in which community organizations seek to influence the activities of city authorities, and to understand the actions that city governments are taking (or not) to reduce the negative effects of climate change on all residents, but particularly those who are most vulnerable.

A focus on African cities is important for several reasons. Firstly, Africa's urban population is increasing rapidly: it is expected to grow from 288 million in 2000 to 552 million in 2020, which represents an increase from 35.6 to 42.2 percent of the continent's population (UN Population Division, 2011). Secondly, a large proportion (30-50%) of this urban population lives in informal and illegal settlements (Bicknell *et al.*, 2009) which are particularly vulnerable to climate change. As defined by the Intergovernmental Panel on Climate Change (IPCC, 2007), and as adopted by many authors in the field, vulnerability is a function of exposure, sensitivity and adaptive capacity. While entire cities may be exposed to some of the impacts of climate change (e.g. rising average temperatures), low-income groups frequently live in areas that are more frequently exposed to other hazards such as flooding (Douglas *et al.*, 2008). These areas tend to lack hazard-reducing infrastructure (e.g. drainage infrastructure), while informal settlements may receive less state provision of assistance in the event of a disaster. The physical, social, human and financial assets of these low-income groups are particularly vulnerable to both incremental changes in climate and extreme weather events (Moser and Stein, 2010). Low-income residents are also susceptible to less direct impacts of climate change, such as reduced availability of freshwater supplies that may particularly affect poorer groups, and increases in food prices due to climate change–related weather events (Dodman and Satterthwaite, 2008). Assessing vulnerability in African cities therefore inevitably requires a focus on low-income groups. Thirdly, this African urban population is of particular concern to AFD, which allocates a large amount of its financings to the 'infrastructure and urban

development' sector in the Africa region – between 2005 and 2009, 33% of such financing was dedicated to 'infrastructure and urban development' and 15% to 'water and sanitation', compared with 9% to 'agriculture and food security'.

Yet there is a particular need to develop better approaches and frameworks for understanding the complex and multi-faceted nature of urban risk and resilience (Dodman *et al.*, 2013). Although specific vulnerability assessments have been developed and utilized by international agencies (e.g. UN Habitat, the World Bank) and city governments (e.g. Durban, London) these have tended not to focus explicitly on understanding the nature of vulnerability for low-income urban residents and for cities as a whole (conversely, see Moser and Stein (2010) for an approach that does incorporate these dimensions). They have also tended not to engage directly with low-income urban communities as a means of identifying the needs and the perspectives of the poorest urban dwellers, and they have tended to focus primarily on extreme events rather than on ongoing and/or incremental changes. Key issues are likely to include assessing the differences between 'vulnerability to climate change' and more general 'vulnerability'; identifying appropriate means for measuring exposure, sensitivity and adaptive capacity as key elements of vulnerability (particularly in the context of informal settlements, where both meteorological and socio-economic data are scarce); and investigating the processes and mechanisms that shape exposure, sensitivity and adaptive capacity both at the city-wide scale and at the community-scale.

There is also a need to focus specifically on the vulnerability of low-income and informal neighbourhoods in African cities, and on the differential vulnerability of residents living in these locations. Informal systems of land provision are an essential mechanism for low-income urban residents to have access to shelter, and often have high levels of social acceptability (Rakodi and Leduka, 2004). They provide a significant proportion of the continent's urban residents with shelter. Official UN Habitat figures for 2001 suggested that 71.9 percent of sub-Saharan Africa's urban population lived in slums (UN Habitat, 2003), although later estimates are generally seen as unreliable due to changing criteria of what constitutes an informal settlement. Nevertheless, it is generally acknowledged that in many African cities, more than half live in informal settlements, and in some cities (including Dar es Salaam) it is said to be 70 to 80 percent. Yet these populations remain legally, socially, and economically marginalized and 'pathologized' (Kamete, 2012).

This research paper addresses these issues in several ways. Firstly, it is based on in-depth fieldwork conducted by research institutions in three African cities – Accra, Dakar and Kampala – which was integrated with the deep practical experiences of organizations with long histories of engaging with risk and resilience in low-income and informal settlements. Secondly, it builds on this knowledge and experience to identify the key elements of a framework for understanding the nature of vulnerability in African cities,

particularly as this relates both to the underlying drivers (such as poverty and political marginalization) as well as more immediate causes (including poorly constructed shelter on land that is exposed to hazards). Thirdly, it uses this as the basis for assessing and analyzing relevant approaches to reduce vulnerability and strengthen resilience, with lessons for civil society organizations, local and national governments, and international development partners.

1.2. Objectives of the study

This research paper addresses two main issues. The first is to strengthen understanding of the environmental, socio-economic, cultural, institutional and political factors that shape vulnerability to climate change in sub-Saharan African cities, with a particular focus on informal settlements. This involved addressing the following questions for the three case studies of Old Fadama (Accra, Ghana), Pikine (Dakar, Senegal) and Natete (Kampala, Uganda). The following research questions address the ways in which the vulnerability of individuals, households and communities shapes urban vulnerability as a whole; they also contribute to assessing the opportunities and barriers for reducing vulnerability through actions by a range of stakeholders at different scales.

- *What are the main environmental hazards associated with climate variability and change that affect each of the case study locations or are likely to do so in the near future?* This element of the research focused on exposure to climate-related impacts. It draws on scientific data produced from downscaled Global Circulation Models (GCMs), secondary data from national/city level on climate-related events and their impacts, and primary data pertaining to local experiences in low-income urban settlements.
- *What are the impacts of these hazards on the lives and livelihoods of low-income households and communities?* As explained above, low-income households represent a large proportion of the urban population in African cities and are particularly vulnerable to climate change. Because of this, the research placed significant focus on understanding the nature of this vulnerability in greater detail.
- *What are the mechanisms used by individuals, households, communities, cities and national governments to reduce vulnerability and to prepare for future climate impacts?* This question brings together issues facing local communities with the programmes and strategies that are carried out by local and national authorities. Responding to this involved reviewing initiatives that are currently used both at community and at city level, assessing the ways in which these interventions affect different groups within the city, and identifying potential mechanisms for improving the efficacy of these.
- *What are the drivers and obstacles to the adoption of responses developed and/or needed by communities, and to their implementation at larger scales (including at*

the scale of the city or municipality) when appropriate? Following this analysis, the type of support needed not only from city authorities but also from national governments, international donors and global agreements in order to foster adaptation by and/or to the benefit of low-income groups is examined.

- *How does the impact of climate change on cities contribute to the vulnerability of particular neighbourhoods, and how do individual and neighbourhood characteristics shape the vulnerability of the city as a whole?* The framing of this question highlights the relationships between different neighbourhoods within cities, and recognizes that cities function as complex inter-dependent systems. This means that even if some parts of a city are less likely to be directly affected by climate-related hazards, they may still be indirectly affected through effects on employees, production systems or networked infrastructure located elsewhere.

The second objective of the paper is to build on this understanding of vulnerability to describe a framework for analyzing climate change-related vulnerability that is relevant for city authorities and for donor agencies when considering risk reduction, urban development, and infrastructure projects and programmes. There is a growing body of literature both on the vulnerability of low-income urban settlements (e.g. Bicknell *et al.*, 2009; Hardoy and Pandiella, 2009), and on strategies for building resilience at the scale of the city (e.g. Roberts, 2010; ISET, 2011). However, there is a distinct absence of literature on existing and prospective strategies (at global, national, municipal and/or community levels) to respond to climate variability and change affecting low-income households and communities. In addition, much of the literature on vulnerability privileges its social and economic dimensions (in other words, the elements of sensitivity and adaptive capacity), with much less research on exposure to environmental hazards. This research will address both of these gaps, by incorporating a strong perspective on the impacts of environmental hazards and the appropriate mechanisms to reduce these. By doing so, it will help to meet the needs of professionals and practitioners – at the community, city, national and global scales – who are designing and implementing projects for building urban resilience.

1.3. Case study locations

The research on which this paper is based was carried out in specific informal settlements in three African cities: Old Fadama (Accra, Ghana), Pikine (Dakar, Senegal) and Natete (Kampala, Uganda). The case studies were chosen firstly because of their appropriateness for studying the vulnerability and resilience of low-income urban settlements. All three case study cities are exposed to a range of hazards, and have a variety of economic, social and political characteristics that contribute to vulnerability. This includes rapid population growth over the last 50 years, much of which has occurred within low-income and informal settlements. Secondly, they represent an appropriate range of experiences within Africa: the choice of these three locations covers West Africa (Accra and Dakar) and East

Africa (Kampala); coastal cities (Accra and Dakar) and inland cities (Kampala); and Anglophone (Accra and Kampala) and Francophone (Dakar) contexts. Thirdly, these locations have firmly established and highly regarded researchers and/or civil society organizations that were able to provide a strong basis for engaging in this work. In Accra, the work was conducted in association with the Institute for Local Government Studies; in Dakar with ENDA Tiers Monde; and in Kampala with Makerere University.

These locations also represent cities with significant strategic focus for the *Agence Française de Développement* (AFD). Accra has already benefited from AFD financing for an integrated urban development project (25 million euros), as well as for a public transportation project with a BRTS line (20 million euros). In that context, AFD wishes to further develop its partnership with the city of Accra. Dakar has received AFD financing through projects aiming at broadening the access to drinking water (6.25 million euros), improving traffic flows and limiting congestion within the agglomeration (9.8 million euros). The city is particularly important for the AFD's present and future interventions in Senegal. In the case of Kampala, there has been AFD funding for the water and sanitation sector (i.e. *Project for the Development of Collective Sanitation Infrastructure in the Deprived Districts of Kampala,* 3.8 million euros; *Financing of the National Water and Sewerage Corporation*, 9.5 million euros; *Financing of the Master Plan for Drinking Water Infrastructure in Kampala*, 64 million euros), which gave AFD the opportunity to build a strong partnership with the city.

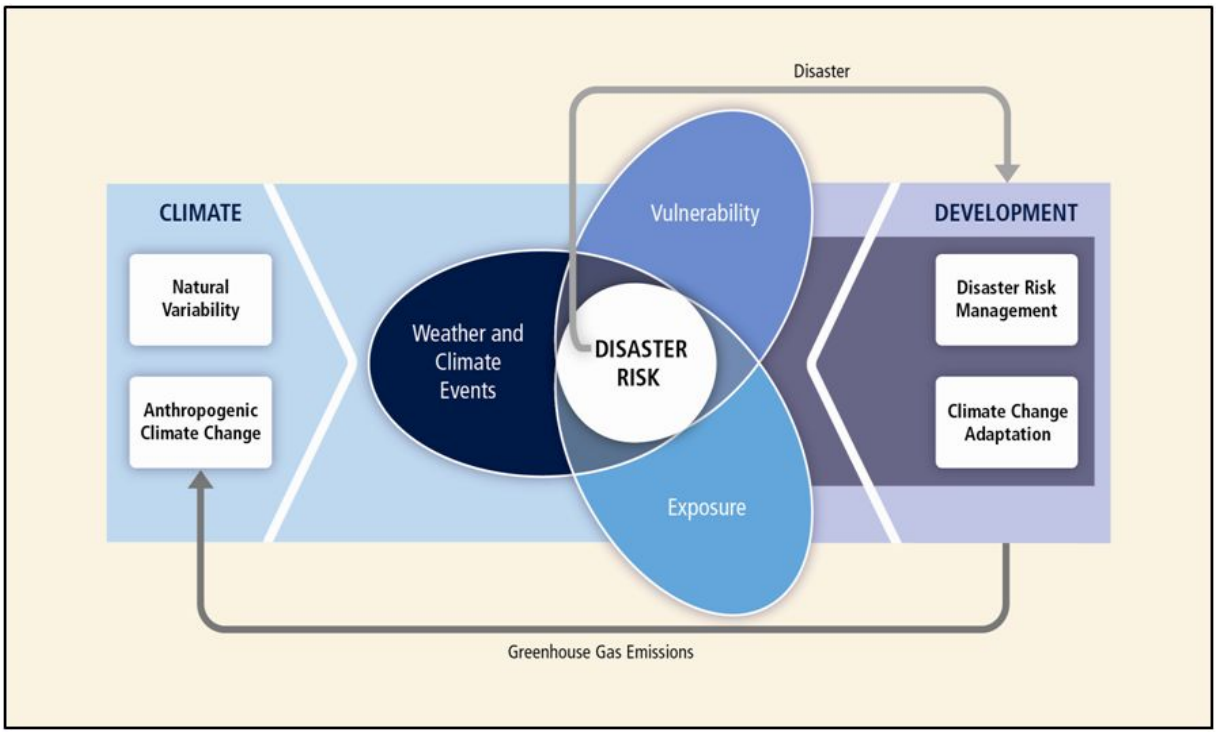
1.4. Vulnerability: conceptual and methodological approaches

The concept of vulnerability is deceptively simple, but has been used and elaborated in a range of ways in relation to climate variability and change. At the simplest and most applicable level, the term vulnerability is used to demonstrate that negative effects of climate shocks and stresses resulting from climatic variability or change are an outcome of both the physical nature of these shocks and stresses and the underlying conditions of a human or natural system that cause it to suffer harm. It derives from a growing understanding in the field of disaster studies in the 1980s and 1990s that the term 'natural' disaster was inappropriate, as human and social features shape the consequences of any hazard that may be experienced (Cannon, 2000; Blaikie *et al.*, 1994). Specifically in relation to climate change, the IPCC Fourth Assessment Report (2007) defined vulnerability as follows:

> "Vulnerability is the degree to which a system is susceptible to, and 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 change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2007)

Subsequently, the IPCC *Special Report on Extreme Events* (IPCC, 2012) has provided an expanded model for assessing disaster risk and vulnerability in the context of climate change (Figure 1). This model highlights the interaction of vulnerability, exposure and weather/climate events in a wider context of changing climate and development pressures. Adaptation measures are seen as interventions and processes aiming to reduce both the vulnerability and exposure of human societies and natural ecosystems.

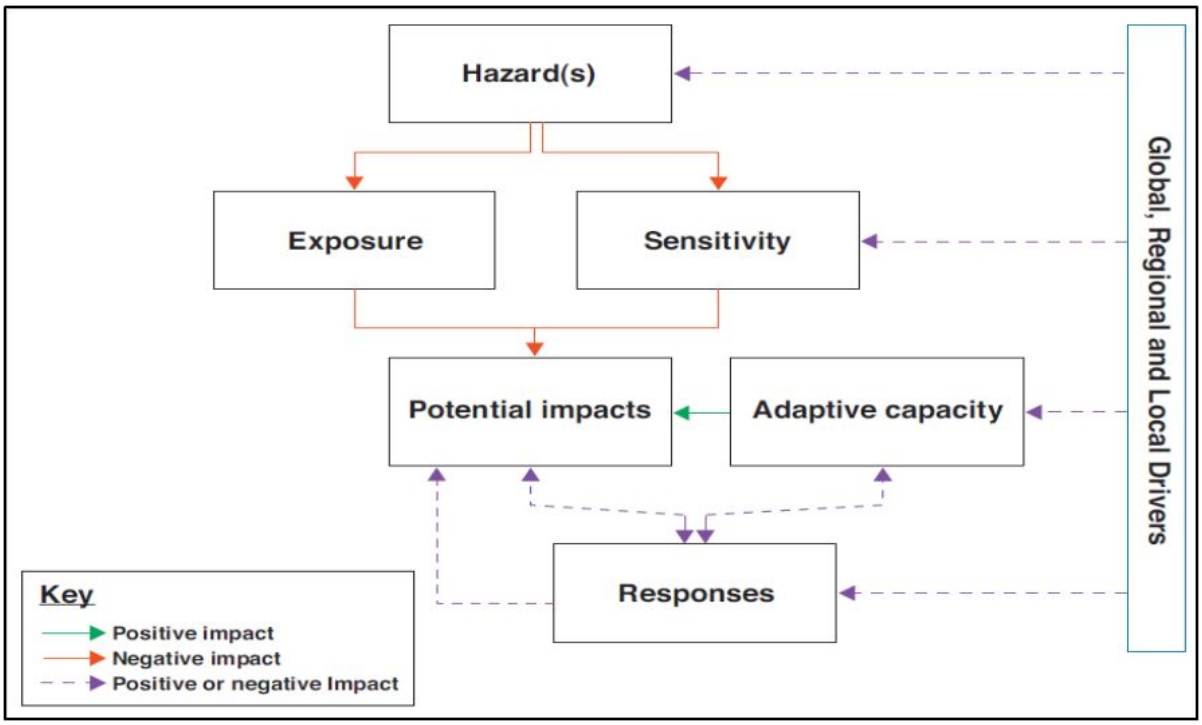
Figure 1. Vulnerability and risk in the IPCC Special Report on Extreme Events



Source: IPCC, 2012.

Other authors have examined the nature of vulnerability in a specifically urban context. In a review of different lineages of research on urban vulnerability, Romero-Lankao and Qin (2011) modify the IPCC (2007) definition and apply it to the urban system and its ability to cope (Figure 2). This model is an outcome of their analysis of several different approaches to understanding vulnerability: from a focus on natural hazards (which start with the impact of a particular event), to political ecology approaches (which highlight the inherent vulnerability of a system as an outcome of development and governance failures), to a focus on resilience (which sees vulnerability as being determined by inter-relationships between socio-economic, technical and environmental subsystems).

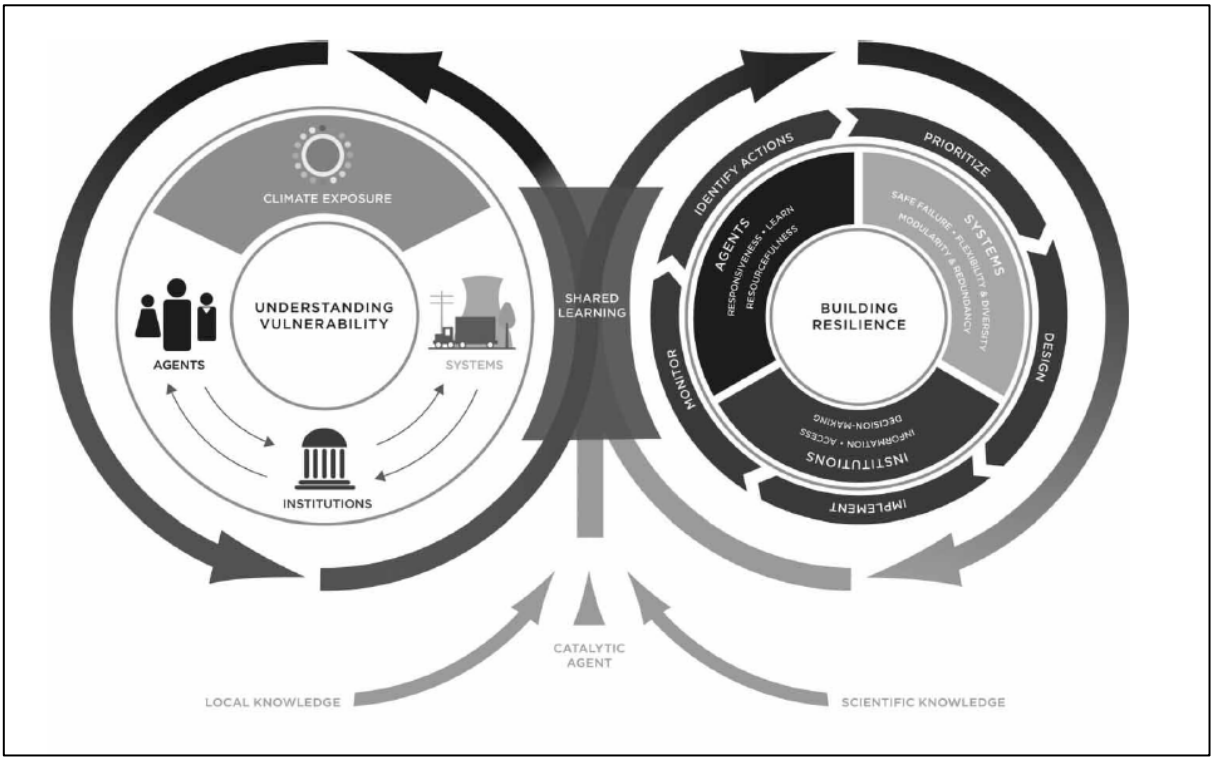
Figure 2. A conceptual framework of urban vulnerability to global climate and environmental change



Source: Romero-Lankao and Qin, 2011.

A framework for urban resilience planning developed by Tyler and Moench (2012) assesses urban vulnerability – and hence the potential for resilience – as an outcome of the relationship between systems (infrastructure and ecosystems), social agents and institutions (Figure 3). They propose the use of shared learning as an approach to strengthen the relationships between these components and as the basis for effective adaptation planning through intentional decision making. Resilient systems are seen as being flexible, functionally diverse, redundant and supporting safe failure. Agents include both people and organizations that depend on and manage those systems. They are seen as responsive, resourceful and possessing a capacity to learn. Institutions link systems and agents, and patterns of exposure to climate change. They structure human behaviour and exchange in social and economic interactions (rights and entitlements) and support decision making, learning, and application of new knowledge.

Figure 3. Framework for urban climate resilience



Source: Tyler and Moench, 2012.

The political ecology of risk model (Cannon, personal communication) incorporates climate pressure into the pressure and release model (PAR) used in political economy studies of disaster risk (Blaikie *et al.*, 1994), and stresses the political dimensions of vulnerability that arise over time and across scales. In this model, local environmental and socio-economic conditions result from development patterns shaped by structural forces at a multiplicity of scales. As the nature of hazards alters as a result of climate change, vulnerability to climate hazards further accumulates through pathways of mal-development. The approach emphasizes a view of vulnerability as encompassed within a multiplicity of scales.

1.5. Climate adaptation and development in African cities

What these approaches to risk and vulnerability have in common is an appreciation of the importance of the specific nature of the context being investigated. Rather than attempting to identify specific tools to describe vulnerability, they highlight the underlying principles that must be incorporated within any tools that are used. The exact tools that are chosen can then reflect the contextual situation being examined. This section addresses the distinct nature of African urban development that makes a focus on climate change adaptation in the cities of the continent appropriate; the relationship between urban

development and climate change adaptation; and the way in which global climate change policy and finance shape urban adaptation responses.

The distinct nature of African urban development trends and patterns

While there are significant differences between African cities – and indeed between the three cities examined in this report – there are certain broad similarities that indicate the relevance of developing approaches for understanding vulnerability in African urban areas. These can broadly be placed in three main categories: the physical changes in the climate; the key sectors that are at risk of disruption; and the underlying drivers of vulnerability. While none of these three categories is unique to African cities, the way in which the three intersect with each other points to a distinctly African urban challenge in responding to climate change.

In comparison with other regions of the world, climatological data for Africa are relatively limited, and projections of future climates have high levels of uncertainty (as seen in Section 3.2). For coastal cities, sea-level rise is a major threat, particularly given the higher projections of this in the IPCC Fifth Assessment Report – while only 1 percent of the continent's land area lies in the Low Elevation Coastal Zone, this is home to 12 percent of the continent's urban population (McGranahan *et al.*, 2007). The other major threats include increased frequency and/or intensity of droughts; increased frequency and/or intensity of flooding; increased frequency and/or severity of heat waves; and desertification (CLUVA, 2013). Recent research on 'climate departures' highlights the particularly rapid changes in climate that are expected in low-latitudes (Mora *et al.*, 2013), and that will affect African cities including Lagos and Nairobi (Washington Post, 9 October 2013).

There is also a growing recognition of the key urban sectors that will be affected by climate change. The more obvious impacts are on existing – and frequently poorly constructed or maintained – infrastructure, including housing, roads, coastal protection and drainage systems. However, there is an increased recognition of the importance of other networked infrastructure, and an acceptance that negative impacts on electricity production and distribution systems and telecommunications networks will have far-reaching implications for urban economic productivity. Still further removed – but of potentially significant importance – are the consequences of climate change in interrupting food supply systems, water availability in river basins and aquifers that supply cities, and supply chains providing raw materials and components for urban industries.

The third key feature is related to the underlying drivers of vulnerability, which in turn are largely shaped by the demographic, social and economic context. While Africa is the least urbanized continent, it is urbanizing rapidly – the proportion of its population living in towns and cities grew from 14.4 percent in 1950 to 35.6 percent in 2000, and is expected

to grow further to 57.7 percent in 2050. In terms of absolute numbers, this represents a growth from 33.0 million in 1950 to 288.4 million in 2000, and a projected growth to 1.3 billion in 2050 (UN-DESA, 2012). While this rapid urbanization may not be as 'explosive' as is often depicted (Potts, 2012), much of it will be taking place in small and medium-sized urban centres, with rapid spatial expansion of urban centres into previously undeveloped land, and under the jurisdiction of local authorities with limited technical and financial capacity to support the development of plans and infrastructure that can reduce risk. These are locations where already very high proportions of the population are living in informal settlements – and the informal sector is likely to retain its importance for providing housing in the absence of affordable alternatives for many of these new urban residents.

Taken together, therefore, the commonalities in the anticipated impacts of climate change (in terms of severity, if not in terms of the precise nature of these), the low level of development of many urban sectors which renders them susceptible to harm, and the demographic situation of rapid urbanization means that there is a conceptual and practical value in assessing the effects of climate change collectively for African cities.

Climate change adaptation and urban development

The impacts of climate change in urban Africa – and efforts taken to address these impacts – will also take place within a specific developmental context and in relation to existing efforts and programmes to support economic and social development. Adaptation to climate change will have to engage with urban development efforts. Indeed, addressing the infrastructure and development deficits will be a critical part of building resilience in African cities. However, responding to climate change will also require specific additional elements. Firstly, climate change will require new and additional investments in specific risk-reducing infrastructure to protect life and property. Secondly, climate change will require that infrastructure and investment projects are designed not only to withstand likely future climatic regimes, but also to cope with the uncertainties surrounding projections of these. Specifically in relation to this uncertainty, urban institutions and systems of governance will need to develop their abilities to learn and to respond rapidly to new conditions – rather than relying on systems and procedures developed in a more constant climate.

Urban climate responses and global climate change policy and finance

Decisions at the national and global level are also shaping the financial context within which climate change responses will take place in African cities. Recent decisions taken at the United Nations Framework Convention on Climate Change (UNFCCC) have highlighted the need for substantial global funding to address climate change. However, the majority of this still appears to be targeted at mitigation efforts. Where funds are

available for adaptation, these are primarily targeted at national governments – which have often been blind to the need for specific interventions to address the needs of low-income urban residents. Even the most innovative of global funds, the Adaptation Fund (which is directly resourced through a levy on Clean Development Mechanism transactions, and which is governed by a Board predominantly from the global south), has limited capacity for granting funds to sub-sovereign entities (Smith *et al.*, 2014). These funds have been critiqued for being:

- Inadequate, that is containing insufficient funds to meet the scale of adaptation needs;
- Unaccountable, that is not responding to local needs or priorities; and
- Inaccessible, that is they cannot be accessed directly by local organizations or local governments who will need to act to reduce climate-related risks.

Future funding for urban adaptation should respond to these needs by allowing greater priority-setting at the local level in response to local priorities and by developing new mechanisms for local access and accountability (for a discussion of these issues see Smith *et al.*, 2014; Satterthwaite, 2013).

2. Key sources of data and their application

2.1. Conceptual and methodological framework

The approach taken to vulnerability in this research draws on insights from the different models described in the previous section. In relation to exposure to hazards, it uses in-depth material from the three case study locations to identify the hazards that are experienced most frequently in these low-income settlements. In relation to the way these hazards affect individuals, households and communities, it examines the social, economic and political factors that shape lives and livelihoods in these areas, and examines the ways in which these shape the effects that hazards have on people.

The research methodology is based on a case study approach, with a strong participatory element. The underlying epistemological principle for the research is that 'scientific' knowledge produced by universities and formal research institutions and 'local' knowledge based on the experience and insights of citizens and communities are equally important for understanding vulnerability. The methodological approach has been developed in association with local partners, but is based primarily on the collection of primary qualitative data, and the analysis of secondary quantitative data.

Within each city, collection of empirical data focused on one or more low-income or informal settlements, based on scoping work and the insights of local partners. The cities have different structures of urban governance, which shaped the scope of each case study. In some cases, the responsibility for basic services (many of which have considerable implications for vulnerability and adaptation) rests with the city government; in other cases these responsibilities are held by communes or municipalities that function at a smaller scale. The study focused on the unit of local government that has greatest relevance in each particular case study location. Where appropriate, links were drawn to other decision-making bodies.

Specific methods for carrying out the research included:

- Climatological analysis, examining past trends and utilizing downscaled Global Circulation Models (GCMs) for future projections (see Appendix 4).
- Documentary analysis: reviewing existing papers, reports and publications from city authorities, national agencies and civil society organizations that are relevant to vulnerability (e.g. demographic and social surveys, National Communications to the UNFCCC, reports under the Hyogo Framework for Action).
- Key informant interviews: with community leaders, NGO representatives, city and national government officials (with responsibility for sectors including infrastructure and services, the environment, and disaster management), and

officials from bilateral agencies (including AFD, both in local offices and in the Head Office).

- Focus groups and interviews: with residents of selected low-income communities.
- Information gathering and awareness-raising workshops: at least two workshops in low-income communities, and at least one for stakeholders at the level of the city/municipality. These formed a key element of the framework for reducing vulnerability by creating a structured platform for the exchange of information about vulnerability and ideas for addressing this.

A research plan for implementing these methods was developed in association with local partners. In practice, documentary analysis and key informant interviews informed the selection of specific settlements for detailed research and helped to shape the content of focus groups and interviews. Learning workshops were used to share and receive feedback on preliminary findings, and as a means of linking local experiences and priorities with potential interventions and strategies at the scale of the city.

2.2. Qualitative and quantitative sources of data on urban vulnerability

How best to understand risk and vulnerability in cities generally depends on the existing information base. "When a city government has complete information about all households, buildings, neighbourhoods and enterprises within its jurisdiction and all these have basic infrastructure and services, these can provide the basis for mapping disaster risk… especially if there are accurate, detailed, location-specific records of the impacts of extreme weather and other events that caused accidental deaths and injuries" (Satterthwaite, 2011: 6). However, most urban centres in low- and middle-income nations do not have such an information base, particularly in regard to informal settlements. Very few have recent or satisfactory census information on which to draw, and national statistical offices usually fail or are unable to provide local government with the census data for their jurisdiction in a form that allows their use in identifying risk and vulnerability. Furthermore, the great range of hazards and the changing nature and scale of hazards and vulnerabilities in urban areas and complex interconnections between them makes it highly problematic to compare risks across urban areas and to label certain cities or regions within cities at being more 'at risk' than others (Dodman *et al.*, 2013).

With this in mind, the following sections examine some of the key sources that may be available at different scales – from the city to the household – and discusses the use of these in contributing to an understanding of vulnerability that is particularly relevant for poor and marginalized groups. These sources, and the additional primary data used in this paper, are both quantitative and qualitative in nature. While these may not generate data that are directly comparable between cities, the shared underlying approach provides a basis for understanding that is widely applicable. Indeed, the very strength of

enumerations as a means of quantitative data collection is that these do not rely on a sample, but rather survey the entire community – and the quality of the data is ensured because the data collectors and respondents have shaped the instruments that are used locally.

Collection and interpretation of qualitative data by community partners was an important element in research methodology. A focus on case studies meant that a common set of conditions of vulnerability was identified across the cities. By means of analytical logic (rather than statistical logic), such data allow for a degree of abstraction. This is different from analysis of quantitative data, the expectation of which is that it is representative of a population and that it affords generalizable findings.

Finally, it is important to note that by focusing on vulnerability in informal settlements within the three case cities, the findings are not intended to isolate specific areas from the wider city. As outlined above, such areas operate within greater urban systems whereby they are connected to development processes, spatial change and/or institutional arrangements by multiple feedbacks. Outcomes of systemic changes as often seen as unintended, but such feedback (outcomes) across different scales can equally be conceived of as extra-local and time-delayed.

2.2.1. Data on factors shaping vulnerability at the scale of the city

Understanding the climate context

Global and regional climate models have become progressively more sophisticated and more useful for indicating the likely future climatic conditions in given locations. However, challenges with down-scaling these models to the level of individual cities remain high, particularly for data-poor countries and regions. Although meteorological data for city-level historic weather variability (and climate trends) may be available in these contexts, the degree of computational capacity and technical skills required are rarely accessible to city governments. In addition, qualitative data capturing the experience and impacts of past urban weather events are rare. In-depth qualitative material in the form of archival records of media coverage, oral history studies or systematic reviews of grey sources from development or humanitarian agencies which could provide information about urban areas remain limited or virtually non-existent.

Understanding the range of possible impacts resulting from projected climate changes in has high levels of inherent uncertainty. This is visible in uses of conventional sensitivity analysis which assess projected impacts of future climate changes on key city sectors (e.g. economic base; food and biomass; housing and settlement; water, sanitation and drainage; electricity; energy; transport; telecommunications). Its limitations are apparent when a need arises to integrate city-scale information which would sensibly reflect the variation in and interconnectedness of local impacts.

Innovative urban planners have long recognized the potential for urban design and planning to help manage temperature and air quality in cities, and a detailed understanding of local climatic conditions is an important prerequisite for this (Hebbert and Jankovic, 2013). However, for most cities in low- and middle-income countries, existing climate and weather data are insufficient for assessing vulnerability (see sections 3.2. and 7.4). Nonetheless, a focus on vulnerability allows for a set of broad hypotheses about the likely impacts of climate change on urban populations.

Table 1. Examples of likely impacts on urban populations from climate change

Projected changes	**Examples of likely impacts**	**Impacts on low-income groups**
Changes in simple extremes		
▪ Higher (and increasing) maximum temperatures, more hot days and heat waves over nearly all land areas	▪ Rise in mortality and illness from heat stress with greatest impacts among particularly vulnerable groups – infants and young children, the elderly, expectant mothers, those with certain chronic diseases	▪ Concentrations of low-income populations often in heat-islands with very high densities, lack of open space and little ventilation; vulnerable groups within the low income population less able to take measures to avoid or reduce impacts
▪ Higher (increasing) minimum temperatures: fewer cold days, frost days and cold waves over nearly all land areas	▪ Decreased cold-related human morbidity and mortality ▪ Extended range and activity of some disease vectors – including mosquito- and tick-borne diseases – with infants and young children often at greatest risk	▪ Many of the settlements with concentrations of low-income groups without public health measures to control or remove disease vectors and without health care systems that provide needed responses
▪ More intense precipitation events and riverine floods	▪ Increased flood, landslide, avalanche and mud-slide damage resulting in injury and loss of life, loss of property and damage to infrastructure ▪ Increased flood run-off often brings contamination to water supplies and outbreaks of water-borne diseases	▪ Low-income groups usually concentrated on sites most at risk of flooding in poor quality housing less able to withstand flooding in settlements lacking risk-reducing infrastructure and whose homes and possessions are unprotected by insurance

Changes in complex extremes		
▪ Increased summer drying over mid-latitude continental interiors and associated risk of drought	▪ Decreased water resource quantity and quality ▪ Increased risk of forest/bush fire ▪ Decreased crop yields and higher food prices	▪ Low-income groups often facing more water constraints and more vulnerable to food price rises
▪ Increased tropical cyclone peak wind intensities and mean and peak precipitation intensities	▪ Increased risk to human life and damage to property and infrastructure; risk of infectious disease epidemics ▪ Increased coastal erosion and damage to coastal ecosystems and coral reefs	▪ The characteristics of so many informal settlements noted above being on sites most at risk, having poor quality housing and lacking risk-reducing infrastructure
▪ Intensified droughts and floods associated with El Niño events in many different regions	▪ Decreased agriculture and range-land productivity in drought-prone and flood-prone regions	▪ Impact on food prices
Changes in the mean		
▪ Air pollution		
▪ Water availability	▪ Reduced water availability ▪ Impact on agriculture	▪ Low-income areas getting the worst supplies
▪ Sea-level rise	▪ Coastal erosion, land loss, more floods from storm surges	▪ Often low-income settlements in some of the areas most at risk
▪ Higher average temperature	▪ Disease vector range spreading, worsening air quality, higher water demand and water loss	

Source: Authors.

The relevance of the development context

Urban areas around the world generate an increasing volume of quantitative data, which are collected by and available from local authorities, government agencies, development banks, international organizations, universities and other sources. Data collected through national censuses, demographic and health surveys (DHSs), sectoral surveys or for specific projects can reflect the provision and deficiencies in basic services and risk-reducing infrastructure, including housing quality, coverage and effectiveness of storm and surface drains, emergency drainage and public health. In turn, this can contribute to an understanding of the broader quality of the living environment, which is an important baseline for understanding vulnerability and resilience to climate-related shocks and stresses (Schensul and Dodman, 2013; Mulyana *et al.*, 2013). A variety of indicators can be identified within existing – and possible future – census questionnaires that can contribute to the understanding of patterns of vulnerability. For example, nearly all

censuses in developing countries ask about housing materials, number of rooms, structure type, access to water and access to energy for cooking and lighting. In addition, information on housing characteristics such as the materials for walls and floors and the presence of pit latrines or unimproved toilets can be an important indicator of the likely consequences of flooding for a particular household (Guzmán *et al.*, 2013).

Although there are inherent limitations in such data – such as selected scale and extent (geography), fragmentation (sectors) and diversity in methodology (irregular frequency of collection) – these data sets can be an important asset for city governments who champion a proactive approach to climate vulnerability. They can contribute to an effective baseline for vulnerability assessments, and can highlight areas where particular focus needs to be placed not only on reducing exposure to hazards, but also on strengthening the adaptive capacity of households and communities. At the same time, and as discussed below, it needs to be recognized that these sources of data are inherently more reliable in covering information in more organized (and more formal) parts of the city – and relying on them too strongly is likely to conceal the conditions and priorities for informal and other low-income settlements.

Urban institutions and vulnerability

A complex and dynamic web of institutions underpins urban climate vulnerability and resilience. An effective assessment of vulnerability needs to account for institutional variables including levels of political commitment, real capacity of local governments to reduce risk, the clarity of policy directions, and the characteristics of projects undertaken by city partners. Institutional frameworks and constellations of actors may change frequently, while many of the crucial features of such dynamics are not captured within the format and time-frames of policy documents and project appraisals. Reviews and analysis of formal documentation, supplemented by additional qualitative data, can provide important clues about the potential for formal and informal urban institutions to sustain engagement with local communities and develop adequate and timely means to support processes aimed at addressing the multiple root-causes and diverse manifestations of vulnerability.

Taken together, the climate, development and institutional contexts provide an important basis for understanding the vulnerability of cities to future shocks and stresses arising from climate variability and change (Table 2). This type of data can be obtained from a range of sources; in the best cases, multiple sources – from official statistics to global databases to newspaper reports – can be consulted to provide a more reliable depiction of the particular situation. However, for many cities in low- and middle-income countries, specific data of this type are either not collected, difficult to obtain or unreliable. This, in itself, may be an indication of vulnerability, as without effective information it will be

difficult or impossible to make appropriate decisions about how to manage change most effectively.

Tables 2-4 illustrate the type of data indicative of pathways of vulnerability present at different spatial and institutional scales. The tables were developed with the aim to serve as common methodological basis for data collection by the three research teams.

Table 2. Issues and data shaping vulnerability at the scale of the city

Thematic issue	Specific issues/questions	Data sources
General city context	▪ City location, relevant geographic and meteorological characteristics ▪ Population and demographic information	▪ Official government reports and documentation ▪ Published scientific literature ▪ Newspaper reports ▪ Disaster databases (e.g. Desinventar) ▪ Key informants (including governments, universities, NGOs) ▪ Meteorological data ▪ Epidemiological reports
Climate context	▪ Current and historic climate trends and variability (mean temperatures, hot/cold days, wind speeds, rainfall patterns) ▪ Experience and impacts of extreme weather events in past 20-30 years ▪ Projected changes in future climate, with assessment of uncertainty ▪ Projected impacts of future climate changes on key city sectors (economic base; food and biomass; housing and settlement; water, sanitation and drainage; electricity; energy; transport; telecommunications)	
Development context of relevance to climate change vulnerability and resilience	▪ Housing quality ▪ Provision for risk-reducing infrastructure and services ▪ Development deficits: basic infrastructure and services (storm and surface drains, roads, emergency services)	
Environmental health context relevant to climate change vulnerability	▪ Key environmental health risks ▪ Past evidence of impacts of climate variability on disease prevalence (e.g. relationship between temperature or rainfall and water-borne/water-washed diseases) ▪ Potential future climate impacts (e.g. new disease vectors) ▪ Proportion of population particularly vulnerable to climate-related health risks (e.g. infants, elderly, those with chronic diseases)	
Institutional context of relevance to climate change resilience	▪ Capacity of city/local government to reduce risk ▪ Stated commitment of elected or appointed officials to reduce risk ▪ Public investments that are relevant to reducing risk (including through addressing development deficits) ▪ Presence of plans or strategies to reduce risk ▪ External support for climate change activities	

Source: Authors.

2.2.2. Data on factors shaping vulnerability at the scale of informal settlements

The general characteristics of informal settlements within an urban area are a significant factor shaping the overall vulnerability of the town or city. They can help to provide general demographic and social information – including dependency ratios, unemployment rates, building materials and access to basic services – that will indicate how likely communities are to be negatively affected by climatic threats (Table 3). However, these informal settlements are frequently served particularly poorly by formal data sets. While data from national censuses or large demographic and health surveys (DHS) should be able to provide relevant aggregate data, in practice the coverage of these types of instruments in informal areas can be limited.

Datasets produced and maintained through NGO projects as well as data collated for academic research may help to enrich the picture through providing selected and generalizable insights about the driving mechanisms of exposure, sensitivity and adapting capacity. Good examples of these types of community surveys are the enumerations undertaken by federations of the urban poor associated with Slum and Shack Dwellers International (SDI) that provide detailed, community-verified information about all the households within particular settlements, and often across multiple settlements within the same city (discussed in more detail in Section 2.4).

Table 3. Issues and data shaping vulnerability in all informal settlements in a city

Thematic issue	Specific issues/questions	Data sources
Demographic characteristics of informal settlements	▪ Dependency ratio ▪ Percentage of households with single female heads ▪ Percentage of households with family member with chronic illness	▪ Census/DHS data ▪ Surveys ▪ Previous reports
Economic characteristics of informal settlements	▪ Unemployment rates (official and estimates) ▪ Percentage of households with single female heads	
Physical characteristics of informal settlements	▪ Sources of water (formal and other measures) ▪ Building characteristics (e.g. floor, wall, ceiling type)	

Source: Authors.

2.2.3. Data on factors shaping vulnerability in specific informal settlements

More specifically, designing effective interventions to strengthen the resilience of some of the lowest-income and most marginalized individuals, households and communities requires in-depth knowledge on the drivers of vulnerability in specific informal settlements. Qualitative data in specific informal settlements can be collected through

focus group discussions, thematic surveys and individual semi-structured interviews,[2] and can provide important insights into the lived experiences of hazards, local actors' perceptions of risk and their rationalization of relationships between the social and biophysical constituents of a city. Qualitative, highly disaggregated data highlight variations in sensitivity and adaptive capacity through improving evidence of provision, access and affordability of basic services, and deepening understanding of the assets and capacities that people can use to respond to threats. Focus group discussions can complement local survey data by allowing issues that are common concerns or widespread priorities to emerge. Qualitative data can also uncover the subtle mechanisms related to extensive risk and factors driving accumulation of vulnerability – aspects which are rarely captured in official or international statistics (e.g. local environmental health, fire hazard, heat island effects) (GNDR, 2013).

When used to examine exposure to climate-related hazards, participatory assessment tools are well-suited to reconstruct past climate-related events, assess their frequency and relative severity as well as highlight change in local patterns (Table 4). Embedded in distinct social, economic and environmental conditions, local-level qualitative data can provide important insights into variations in injury, death, loss, damage, adverse impact on livelihoods or time lost in preparation, response and recovery. Simple quantification of data prioritized by local residents can highlight the local significance of issues such as houses deserted because of weather-related events (as seen in Pikine), the share of household budgets spent on house repair (as seen in Old Fadama), or the amount of time dedicated to risk reduction instead of income-generating activities (also seen in Old Fadama).

Local-level data are also more effective than large official datasets at capturing information about adaptive capacity and strengthening knowledge of mechanisms facilitating local action. The elements that constitute local adaptive capacity – including strength of social networks, membership in community organizations, organizational emergence and linkages with other local institutions in the domain of civil society or the state – are best understood through data that are locally collected and collectively analyzed, even though wider power relations may pose a challenge to such endeavours. Matched by institutional and policy analysis, such data allow for greater insights about the dynamic nature of adaptive capacity at city level. It also enables a closer examination of the ways in which local champions position themselves in the broader institutional setting, and of mechanisms which facilitate effective mobilization of local groups. This type of participatory data collection and analysis can also be much more sensitive to concerns for

[2] Both such surveys and interviews are likely to capture data from a non-representative sample population.

social and environmental justice. The most sophisticated examples of this process are community enumerations (described in more detail in Section 2.4).

Members of the research teams in Ghana, Senegal and Uganda emphasized that the richness of personal and group experiences of hazards and urban risks means that it is important to take these into account in understanding the nature of vulnerability – and identifying the most appropriate means of responding to this. Such engagement enables external researchers and communities to seek ways of working alongside and supporting community responses. While acknowledging that participatory research methodologies are difficult to implement in practice, it is strongly believed that sustained engagement between researchers and local community groups, formal and informal leaders and opinion makers will contribute to more valid data being collected, which in turn will encourage more effective use of results and findings to build resilience.

Table 4. Issues and data shaping vulnerability in specific informal settlements

Thematic issue	Specific issues/questions	Data sources
Exposure to climate-related hazards	▪ Climate-related events that have affected the community in the past ▪ Frequency and severity of these events ▪ Changing patterns of events	▪ Group discussions: targeted to include different sets of people within communities (e.g. women, youth) ▪ Semi-structured interviews (undertaken and analyzed in collaboration with community partners) ▪ Specific tools to facilitate these include: - Hazard calendars (long-term and annual) - Diagramming techniques to indicate frequency and severity - Community hazard and environmental resource mapping
Consequences of climate-related hazards	▪ People injured and deaths ▪ Area affected by hazards ▪ Damage caused to homes ▪ Effects on livelihoods ▪ Effects on time (to prepare for, respond to, and deal with consequences)	
Sensitivity of individuals and community to hazards	▪ Water sources and safety ▪ Presence/absence of risk-reducing infrastructure (sanitation, drainage, garbage collection) ▪ Food and food security (sources, factors disrupting food supplies) ▪ Tenure rights ▪ Presence/absence of warnings of impending events	
Adaptive capacity of individuals and communities	▪ Strength of social networks ▪ Presence of/membership in community organizations ▪ Supportiveness of local institutions (civil society/state) ▪ Awareness of threats (climate-related hazards, climate change) ▪ Training in hazards/responses ▪ Time available/taken to prepare and respond ▪ Capacity to cope (managing but not changing risk)/to adapt (reducing risk)	

Source: Authors.

2.3. Managing research in different geographical and institutional contexts

Factors shaping vulnerability in low-income and informal urban settlements are strongly influenced by the local context. The data available for assessing vulnerability also vary greatly from place to place, which means that research approaches to understand vulnerability – and to provide an appropriate evidence base for building resilience – also need to reflect the geographical context. In addition, there is a growing recognition that local research institutions are often best positioned to understand local complexities, engage with an appropriate range of stakeholders, and ensure that research findings have lasting policy influence. Locally-situated research institutions may also be proficient at

engaging with local media outlets that can help to disseminate findings and generate broader impact through facilitating the communication of research results to policy makers.

These issues mean that efforts to conduct vulnerability research in different contexts cannot be prescriptive and rely on the use of similar data sets; nor can they assume that research institutions will have similar organizational priorities or capacities. Rather, multi-country research projects must be flexible and adaptable to local circumstances. This is not only a pragmatic approach: the use of a range of approaches may also help to yield deeper understanding about vulnerability in the specific locations and more generally.

While recognizing this contextual specificity, there are also many benefits to be gained through comparative and cooperative research. These include the opportunities for mutual learning, both around specific thematic issues (e.g. the impacts of particular types of climate change on urban areas) and around methodological issues (e.g. sharing approaches to examine these issues). The findings from research can also be enriched through comparison with other case studies, which can help to identify more general lessons and those that are more likely to be limited to particular circumstances. Research partnerships can also strengthen the ability of southern institutions to access global funding to further their research agendas, as this is often allocated through consortia of institutions.

The specific approaches for this programme of research were developed through partnerships involving institutions in Ghana, Senegal and Uganda, with additional insights from researchers from Sierra Leone, Nigeria and Zambia. The discussions were coordinated by the International Institute for Environment and Development (IIED), a UK-based policy research institution with extensive experience working in partnership with research organizations in Asia, Africa and Latin America. This process of partnership ensured that the three research teams were subscribing to the same jointly-formulated ethos, and were using the same generally accepted conceptual frameworks. However, it also provided sufficient flexibility for the details of the research approaches to be developed in each particular location.

The research process in each of the three locations was therefore shaped by the local partners' organizational histories, remits and relationship with local community partners. In Natete and Old Fadama, the process of assessing vulnerability the complemented long-term engagement of communities with the respective National Slum Dwellers Federations. In Natete, the team was led by an academic partner. This resulted in greater attention paid to contextualization of field data within a changing institutional context (at both the national and municipal level). In Pikine, the team's past experience in participatory adaptation programmes in rural areas led towards a focus on awareness raising about local impacts of climate change and greater concern for recent changes in availability of natural resources within rapidly urbanizing peri-urban areas.

All three of the team leading organizations acknowledged the importance of active engagement in local development processes and community mobilization. Each has been able to pursue this goal through different channels. This practical consideration has methodological implications: organizational histories and wider relationships with local communities influence how they undertake vulnerability assessments as well how they utilize findings and possible opportunities created by the research process. Furthermore, even if the partner organizations have a long history of engagement in participatory development, genuine participatory research is difficult to achieve if driven by demand.

2.3.1. Research context in Pikine

The research in Pikine (Dakar region, Senegal) was coordinated by a team from Enda-Energy who built on the NGO's sustained collaboration with community groups in Pikine. The team partnered with three community-based organizations (CBOs)[3] all of which have a history of engagement with local development processes and of community mobilization. The partner CBOs, the Goorgoorlu Youth Association and the ASC Darou Salam Association, have a long record of collaboration with municipal and national authorities and NGOs on projects in sanitation and health. They also intervene in risk reduction by coordinating neighbourhood emergency response and managing community drainage. The third partner, the local student association, traditionally coordinates neighbourhood-level social events and clean-up campaigns. Two residential neighbourhoods (*quartiers*) were selected by the partners: Missreh and Darou-Salam. Both are located in the *Commune d'Arrondissement* Diamaguène Sicap-Mbao of Pikine. Both of these residential areas are prone to flooding on a short-term, mid-term (up to 4 months per year) and permanent basis.

The Enda-Energy core research team undertook 15 interviews with key informants, including local community leaders (*chefs de quartier*), the local authority (Djamaguaye Sicap Mbao city hall), medical services (Medecin Chef de Centre de Santé Khadimou Rassoul), the agency for major infrastructure works (APIX), and NGO staff working in the area (Enda-RUP; Eau-Vie-Environement).

A four-day training workshop was conducted with ten members from the local partner organizations with the aim of finalizing the design of research tools and raising awareness about climate change. Five journalists from Pikine community radios joined in parts of the workshop dedicated to building capacity for effective communication of climate related risks and communication of research results to local policy makers.

---

[3] The Association des jeunes « Goorgoorlu », the Association de Sport et Culture « ASC Darou Salam », and the Coordination des élèves et étudiants de Diamaguène-Sicap Mbao (CEEDSIM).

A total of eight focus groups were conducted, four in each study location. Discussions were held separately with groups of women and men, each counting approximately 12 to 15 participants. Discussions focused on subjects related to historic weather events and trends in the availability and quality of local bio-physical resources including water, soil or vegetation. Finally, 40 household interviews with local residents were undertaken by members of local community associations. The respondents selected in the two neighbourhoods included both lower- and upper-class residents of houses exposed to flooding, landlords and tenants, and household heads, both male and female.

2.3.2. Research context in Natete

In Natete (Kampala, Uganda), the research was led by a team of academic staff and students from Makerere University Department of Geography, Geoinformatics and Climate Sciences. To undertake field assessment, the team collaborated with the Uganda National Slum Dwellers Federation (UNSDF) and their partner NGO, AcTogether. The team selected three zones in Kampala's Natete Parish as highly relevant for field assessment: the Kajumbi, Nanfuka and Central A zones of Nateete. The selected case locations are flood-prone areas combining low-income housing and light industry. No research on environmental hazards and climate change vulnerability had previously been undertaken in any of these locations. Focus group discussions were used as a central data collection tool, bringing together community leaders, elders, local residents and non-resident business people. On average, 10 representatives from each zone participated in the discussions. A total of 60 individual follow-up interviews were undertaken with members of households living in the areas.

2.3.3. Research context in Old Fadama

Research in Old Fadama, the largest informal settlement in Accra (Ghana), was led by the Institute for Local Government Studies (ILGS) in collaboration with the Ghana Federation of the Urban Poor (GHAFUP) and their support NGO, People's Dialogue (PD). The research location is adjacent to the Korle Lagoon and is exposed to periodic flooding. A focus group discussion was organized with 13 representatives from GHAFUP, the Old Fadama Development Association, vendors of cooked food, the Kayayei Youth Association, scrap metal dealers and the Sisala Youth Association. A household survey capturing one hundred (100) households was chosen based on a total of 34,000 households reported in a community-led enumeration report by People's Dialogue.

2.4. Enumerations: a way to understand vulnerability and to build adaptive capacity

Residents of low-income and informal settlements have long recognized that the absence of official information about their neighbourhoods is a substantial impediment to achieving greater security of tenure, better livelihoods and improved protection from

natural hazards. Equally, where official information is gathered, it may be incomplete or inaccurate, or may be used to justify evictions or other actions that have negative consequences for the residents of these areas.

In response to this, federations of the urban poor operating in cities in Africa, Asia and Latin America have developed a process of community-managed surveys or enumerations, which they use to provide the information base for action and negotiation. These enumerations differ from censuses or other government surveys in several important ways (Karanja, 2010):

1. They involve the grassroots organizations formed by those living in the settlements, who also have central roles in identifying the questions that are asked.
2. They cover all households, thereby ensuring that all residents know about the purpose of the enumeration and how they can be involved in subsequent processes and activities.
3. The data from the enumerations are returned to households and neighbourhood organizations for verification.

Because of their particular characteristics, these enumerations meet several needs: they provide information in a context where this is difficult or expensive to obtain without community involvement; they help to organize community members into groups who can then address other important issues (including community savings and land acquisition); and they may also help to change the attitudes and approaches of governments and international agencies by demonstrating the capacities of urban residents to provide the necessary information for upgrading and housing development (Mitlin and Satterthwaite, 2007). Because of their universal coverage, they can help to broker agreements within settlements that ensure that the needs of all inhabitants are met (Karanja, 2010).

In recent years, enumerations have become more sophisticated. They can involve settlement profiles and mapping exercises (sometimes including GISs), household surveys (which gather detailed data about every household), and vacant land surveys (which are a proactive approach to finding suitable land in the city for the resettlement of specific groups) (Patel *et al.*, 2012). They have contributed to the development of community partnerships with government to support upgrading in Uganda (Makau *et al.*, 2012); have been used to facilitate cluster upgrading and improved sanitation in Joe Slovo, an informal settlement in Cape Town (Baptist and Bolnick, 2012); and have helped to create a national land information programme (the Community Land Information Programme (CLIP)) in Namibia (Muller and Mbanga, 2012). In the specific context of this study, enumerations in Old Fadama conducted in 2004, 2006-2007 and 2009 have increased the residents' confidence and empowered them in their engagement with the city government. Simultaneously, the information has influenced local government policy – moving this

away from forced evictions and towards participatory relocations and rehabilitation (Farouk and Owusu, 2012).

The principles of enumerations are difficult to replicate in externally-driven activities. But the universal coverage and community-driven nature of these approaches means that they have the potential to provide substantial data on past experiences of hazards, which can then be used for more effective design and implementation of activities to build resilience.

2.5. Using mapping techniques to capture exposure and vulnerability

Urban organizations are increasingly incorporating spatial mapping and geographical information systems (GISs) into their analysis and programming at community level (see Livengood and Kunte (2012) for a detailed example). Multiple mapping tools have become accessible through open user-friendly software and low-cost technology. However, while the sophistication of mapping tools increases, the possibilities of its use expand and volumes of data grow, what varies are the implications and value of GIS-based spatial mapping for local communities and other local actors. All three of the partner organizations included mapping (using GIS tools) in the research process, and each team had a strong interest in collecting geo-referenced data and using this to represent local conditions. However, the spatial and statistical analysis of such geo-referenced local data is lagging behind – and is an issue that requires more attention by research partners and donor organizations.

More traditional ‘dynamic mapping‘ was used in Pikine to examine changes in the availability and spatial distribution of local biophysical resources, changes in land use and the relationship between processes of urban change and emerging environmental risks. Two maps of Diamaguène Sicap-Mbao were traced and populated based on information gathered in discussions with local residents and historical records available to the student volunteers. The exercise allowed for a discussion of changes between 1980 and 2012, focusing on the use and quality of water resources, retrenchment of agricultural land, the presence and use of gardens and fruit trees, as well the processes linking a multiplicity of arrangements of land ownership with resulting socio-economic diversity, variation in housing quality and provision of basic services (i.e. middle-class private and public cooperative housing, informal settlement).

2.6. Capturing dynamic processes

In their own ways, all three teams came to realize the importance of a focus on dynamic processes, and the ways in which these shape the experiences of residents of low-income and informal settlements. Both the underlying drivers of vulnerability and the proximate causes of vulnerability vary over time – sometimes in predictable or cyclical ways,

sometimes in a less predictable manner. For example, inadequate financial resources can be a driver of vulnerability – but they can vary according to the time of the month or the income-earning opportunities available at a particular time. If a particular hazard event is experienced at the same time as financial assets are depleted, then overall vulnerability is compounded.

In Kampala, the team highlighted change taking place in the institutional environment and the city's economy. The wider structural context is characterized by shifting institutional dynamics and responsibilities. Under such conditions, means of engagement between relevant formal institutions and communities are evolving at a slow pace, but new opportunities may arise with growing importance attributed to urban environmental planning. The ways in which these institutional dynamics evolve over time therefore strongly influences the vulnerability of low-income groups.

In Pikine, the research identified a number of parallel issues evolving over time, including changes in land use, natural resource base and type of response by local communities. The occurrence of flood events was traced over the past 25 years, with special emphasis on changes in land use and urbanization that have led to a change in the nature of local urban flooding since the late 1990s. Through mapping of changes which have occurred over the past 30 years in the local natural resource base, the discussions in Pikine displayed a broad awareness among local residents of the multiple causes contributing to local flooding and the associated environmental crisis.

Focusing on the processes and changes in the development of local coping strategies, the research highlighted connections between local organizational dynamics and the types of spatial interventions that were practiced. Early physical interventions in the neighbourhoods were undertaken by and on behalf of individual households and focused on localized sand-filling of low-lying land (street sections, courtyards). In the past five years, local CBOs have periodically mobilized to ensure that a network of temporary drainage canals is excavated in order to reduce the adverse impacts of summer flooding. Increased organization of local risk-reducing interventions is paralleled by the local residents' mounting dissatisfaction and distrust of actions taken by formal authorities. These actions include mismanagement of emergency response, resettlement, mixed messages inherent in neighbourhood restructuring initiatives, and ambiguity in socio-spatial relations resulting from the construction of inner-city water retention ponds.

3. Thematic analysis of vulnerability

3.1. Understanding urban risk

There is a wide range of physical, biological, technological and chemical hazards within urban areas that can cause or contribute to risk and vulnerability.[4] However, the way in which these hazards are addressed – in particular through the presence of basic protective infrastructure and the quality and capacity of local governance – can result in urban environments being associated either with extremely low or very high risk. Risk in urban areas can be understood as being intensive (the outcome of major disasters)[5] or extensive (the risk of premature death, injury, impoverishment, and destruction of buildings and infrastructure from all events that are not classified as 'major' disasters). Intensive and extensive risks occur at different scales, from the household to the community to the district and the city, although the impact from disasters (including those that are associated with climate variability and change) is mostly felt at the individual or household level.

Understanding the nature and scale of risk in cities in low-income cities therefore requires dealing with incomplete data about cities and even more incomplete data about the risks faced by low-income groups or groups in particular districts (for instance, the population in a particular informal settlement that lacks provision for infrastructure and services and is on a floodplain). An interest in risk needs to combine an understanding of 'every-day' risk (for instance, from inadequate provision for water and sanitation or particular diseases such as malaria) to risks that are common but not every day (for instance, seasonal such as the monsoon rains) to risks that are occasional (above average intensity cyclone/rainfall that comes every few years) and very occasional (for instance, earthquakes). There are also the complications of adding climate change to understandings of risk and vulnerability, especially when climate change impacts are changing and in the uncertainty as to the particulars of climate change in each location.

The importance of future climate change in shaping urban risk is increasingly recognized. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007 (Wilbanks *et al.*, 2007) contained a single chapter on 'Industry, Settlement and Society', which concluded that vulnerabilities to climate change depend considerably on specific contexts, with these being particularly severe in certain 'high-risk' locations. The Fifth Assessment Report, to be published in 2014, contains a greater

[4] This section is based largely on Dodman *et al.* (2013).

[5] For a disaster to be recorded in EM-DAT, the most widely used international database, at least one of four criteria must be fulfilled: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; or call for international assistance.

focus on urban areas, examining them from the perspective of impacts, adaptation and vulnerability to climate change, as well as their role in climate change mitigation. Various other high-profile reports have also addressed the links between climate change and urban risk in considerable detail, including the UN Habitat (2011) Global Report on Human Settlements (*Cities and Climate Change*) and the First Assessment Report on Cities and Climate Change (ARC3) (Rosenzweig *et al.,* 2011). Taken together, it can be concluded that there is an increasing recognition that climate change will affect a range of sectors, including water supply, ecosystems, food supplies, coastal systems and health, all of which are highly relevant in urban areas (Dodman *et al.,* 2013).

3.2. Climate trends and projections

Making detailed projections for future climatic trends is challenging, given the inherent uncertainty around future global greenhouse gas emissions (as the driver of climate change), around the ways in which the resulting atmospheric concentrations of greenhouse gases will influence global temperatures, and around the local consequences of these. This difficulty is compounded in many locations in Africa because of poor past climate records, meaning it can be difficult to identify climate trends in recent decades – an issue affecting the discussions of Accra's and Kampala's climates below. The information in this section is based on weather station observations to describe recent observed trends, and downscaled Global Circulation Model (GCM) projections of future climates (see Appendix 4 for a description of the methodology used). Its main value is in identifying possible trends rather than making detailed predictions, and in highlighting the need for responses to climate change to recognize the inherent uncertainties involved in making projections of future climates.[6]

Climate trends and projections for Dakar

The climate data available for Dakar itself are not sufficiently reliable for identifying trends or making projections, therefore data for the nearby location of Thies (approximately 50 km east of Dakar) have been used instead. Given the regional topography of the region, this data should be fairly representative of Dakar, with the only caveat being that Dakar lies on the coast whereas Thies is inland – which may mean that Thies is drier and less vulnerable to heavy rainfall events produced by the warm coastal waters.

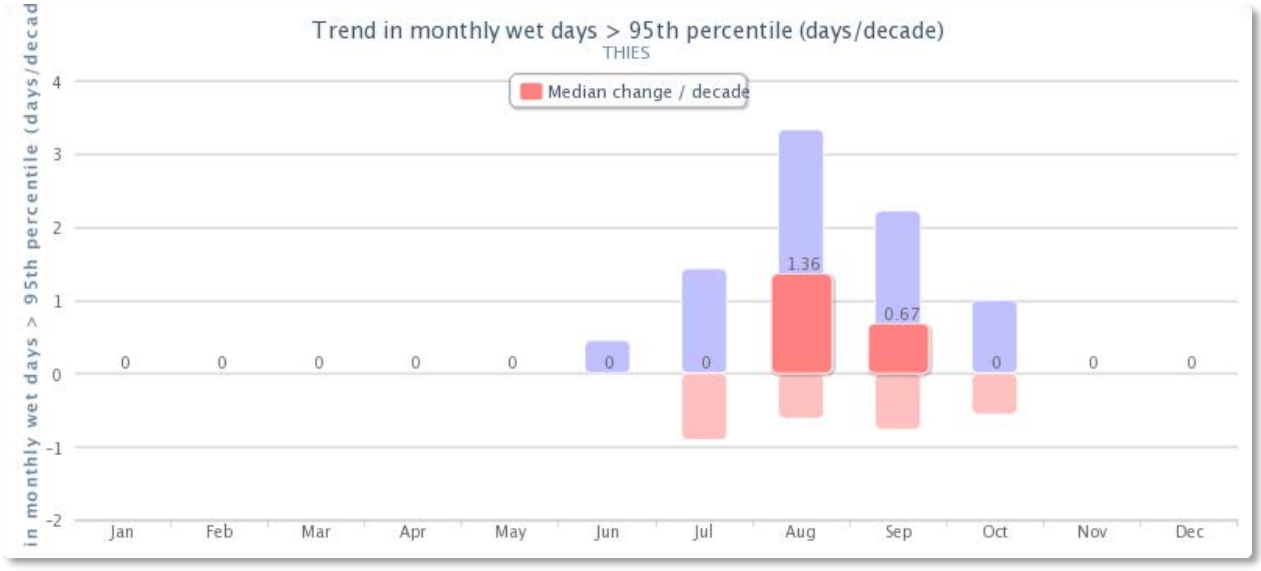
[6] Data presented in this section and the methodology described in Appendix 4 were produced by Chris Jack and colleagues at the Climate Systems Analysis Group (CSAG), University of Cape Town, using data available on the Climate Information Platform (http://cip.csag.uct.ac.za/).

Thies has a single rainy season extending from July to October, with peak rainfall and the heaviest rain events occurring in August, with maximum daily rainfall of about 70 mm. The average number of rainfall days exceeding the 95th daily rainfall percentile in August is 0.75 days per year or 7.5 days per decade. Historical trend analysis on the observed period (1981-2011) reveals a significant positive trend (increasing) in heavy rain events in August and September (Figure 4). The median trend is a 1.36 days per decade increase over the 30-year period, which is significant in the context of the 7.5 days per decade average for the period.

Future projections of days exceeding the 95th percentile of daily rainfall for the 2020-2040 period show some level of uncertainty for August but fairly strong agreement on positive change for July and September (Figure 5). It is possible that the downscaling method is not capturing the full extent of the increase in extremes in August, but it is also possible that the increased extremes are manifest in the 'shoulder' months (July and September) of the season. This second option aligns with an increase in total monthly rainfall in these two months (Figure 6).

There therefore seems to be fairly strong evidence pointing towards an increase in extreme rainfall events in Thies (and by proxy, Dakar). The historical trend analysis shows significant historical trends and the downscaled projections show weaker but consistent changes for the 2020-2040 period. It is possible that the downscaling method is underestimating these changes to some degree.

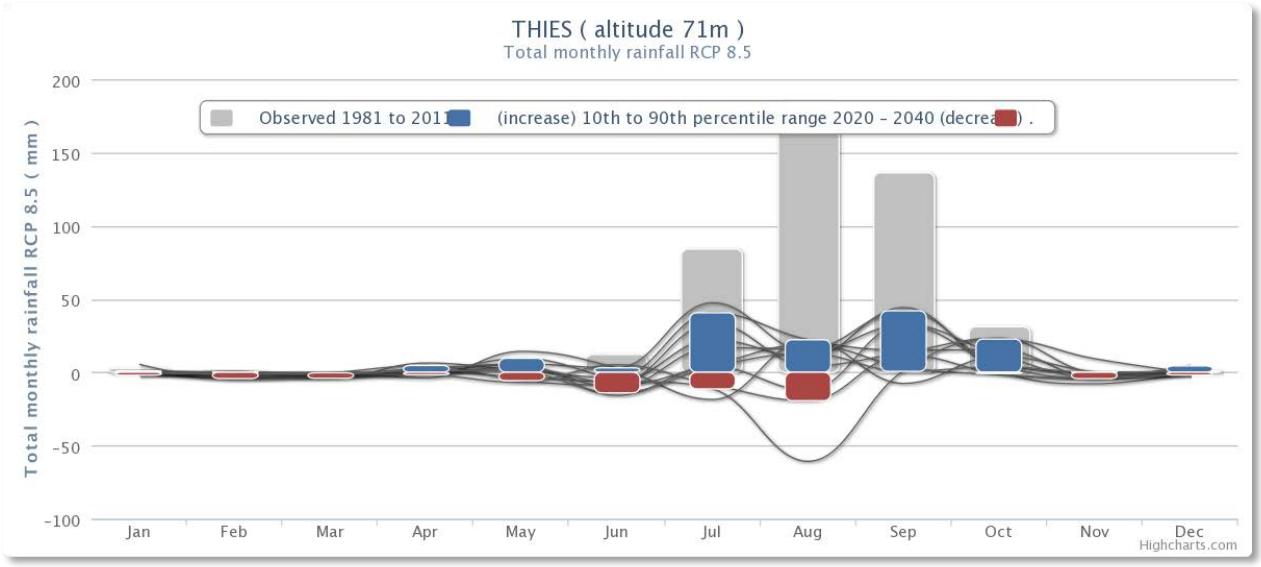
Figure 4. Dakar (Thies) – trend in monthly wet days



Description of Figure 4: Estimated trends in monthly count of days exceeding the 95th percentile of daily rainfall for the period 1981 to 2011. Wide red bars indicate median

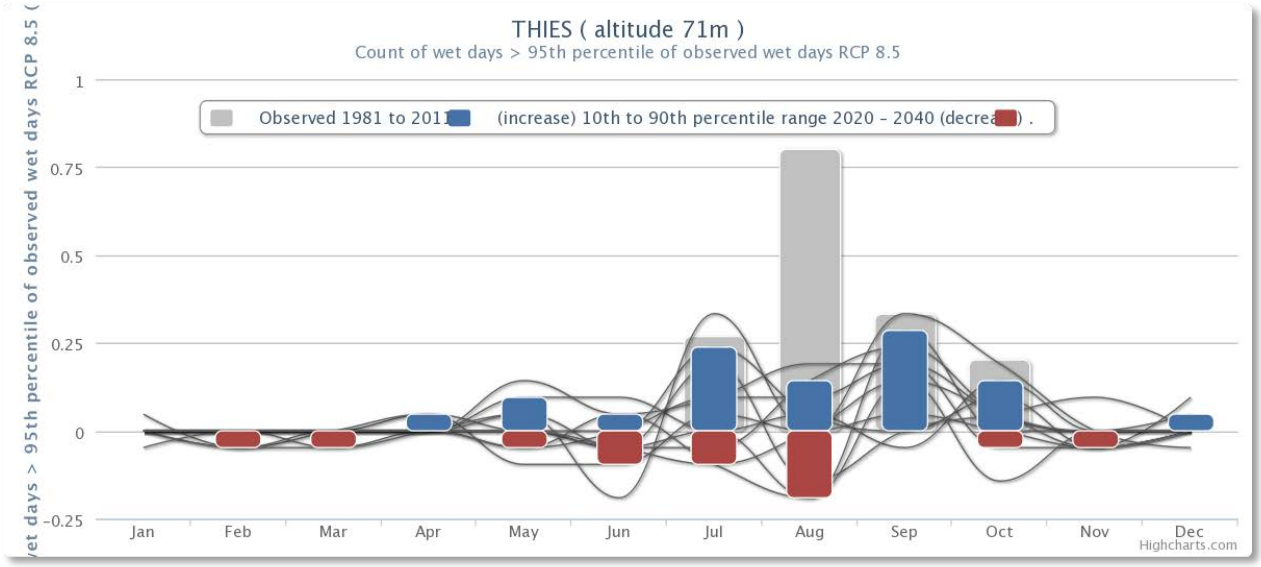
trend estimate. Narrow blue and pink bars indicate the 25th to 75th percentile range of trends.

Figure 5. Dakar (Thies) – total monthly rainfall



Description of Figure 5: Multi-model downscaled projected changes in total monthly rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean value.

Figure 6. Dakar (Thies) – count of wet days



Description of Figure 6: Multi-model downscaled projected changes in days per month exceeding the 95th percentile of observed daily rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean.

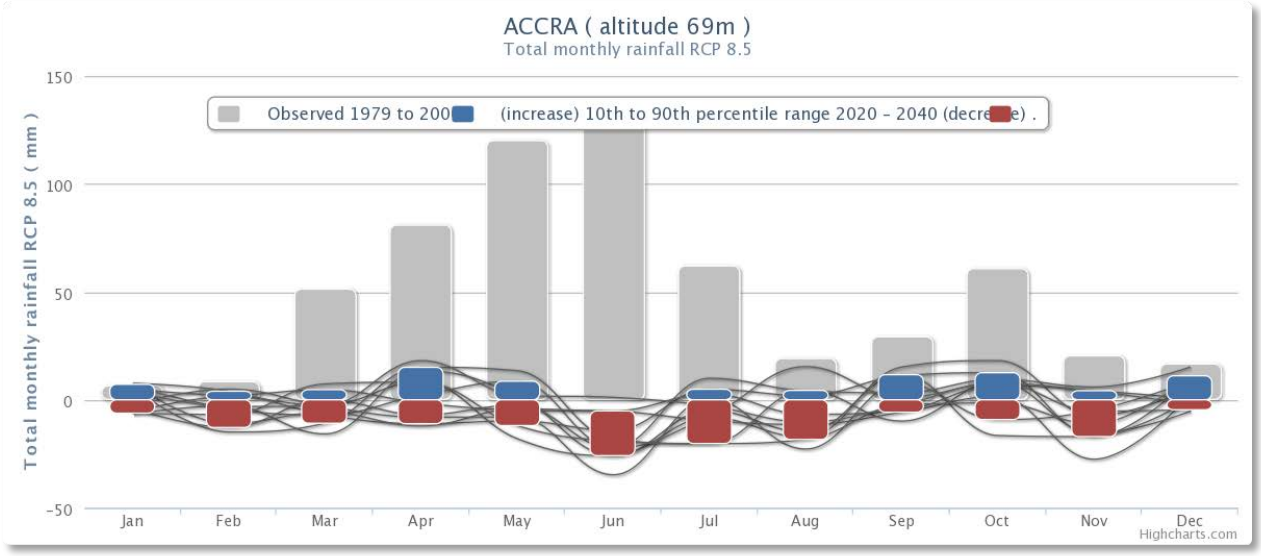
Climate trends and projections for Accra

At a latitude of 5.6°N, Accra experiences a classic double rainfall season with long rains extending from March to July and a shorter rainy season from September to November. The majority of heavy rainfall events occur in the long rainy season and in particular in the months of May and June with 2.2 and 2.5 days per annum exceeding 20 mm per day in each of these months respectively. However, the data record for Accra contains long periods of missing data and many intermediate missing values. While the data record extends from 1979 to 2000, in reality only 12 years of data are valid, making it difficult to calculate robust statistics of historical trends. The results presented are the best that can be produced with this level of missing data.

Downscaled projections of total monthly rainfall show high disagreement between models and hence high uncertainty. Only June shows some degree of agreement on a slight decrease in total monthly rainfall (Figure 7). Similarly, downscaled projections of the number of days exceeding 20 mm per day are very uncertain. The only reasonably confident messages are a possible decrease in these heavy rain days in June and a possible increase in the short rainy season (September and October). Changes in the short rainy season may be significant, however, as currently this season does not experience many heavy rain day events (Figure 8).

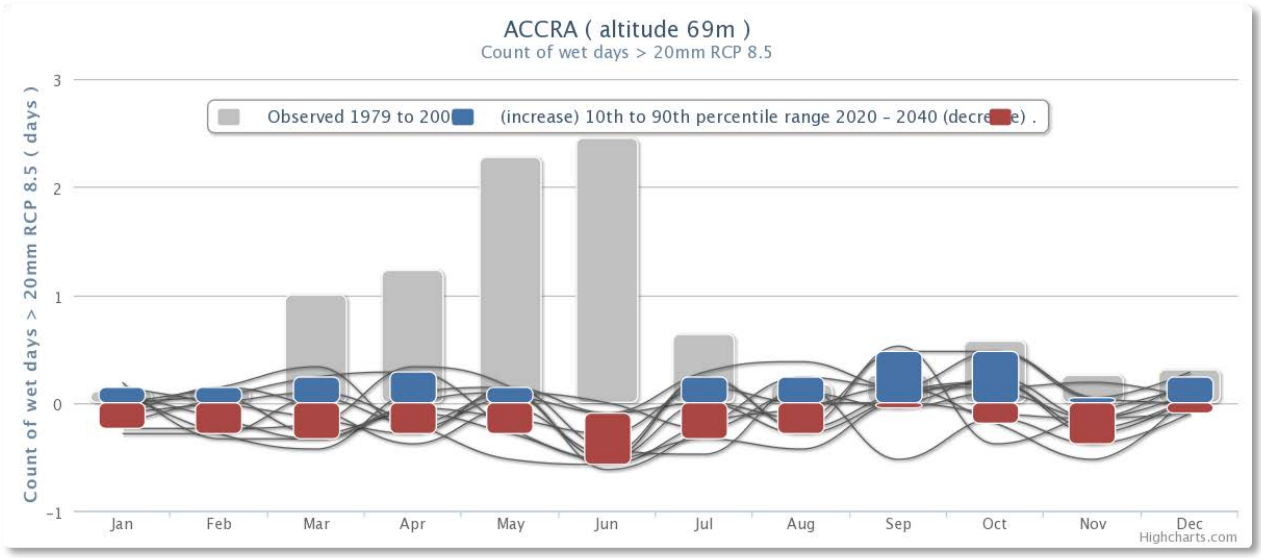
Once again, it is possible that the downscaling methodology is not capturing increases in daily extreme rainfall events and is therefore underestimating these increases. However, regardless of this possible limitation, GCM projections for this region of West Africa generally produce high levels of uncertainty because of the complexity of the West African climate including the West African monsoon rainfall system.

Figure 7. Accra – total monthly rainfall



Description of Figure 7: Multi-model downscaled projected changes total monthly rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean.

Figure 8. Accra – count of wet days



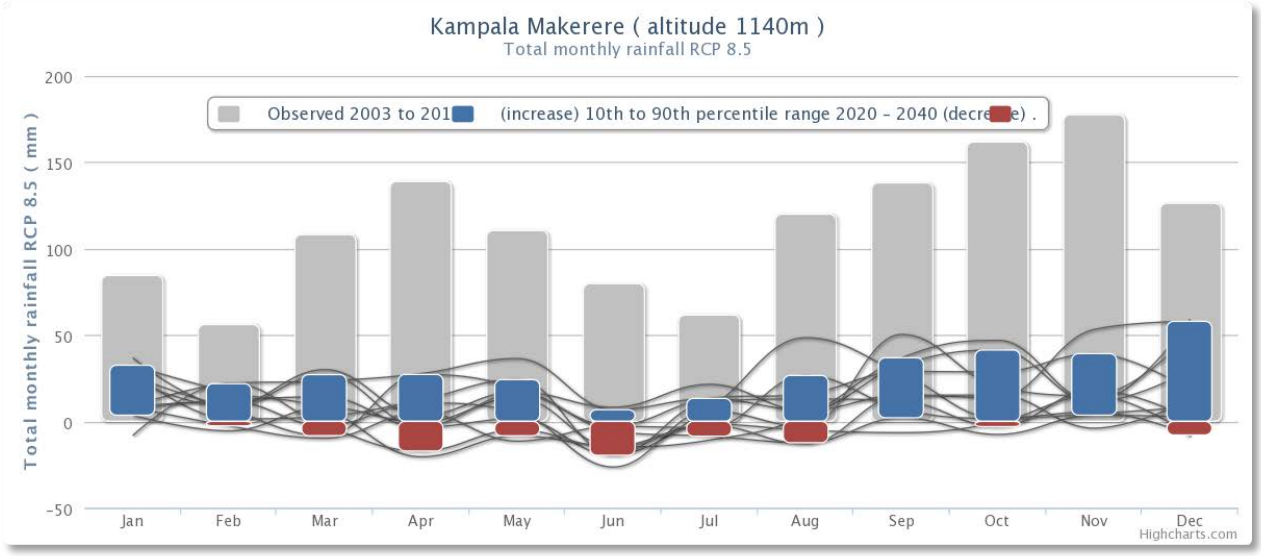
Description of Figure 8: Multi-model downscaled projected changes in days per month exceeding 20 mm daily rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean.

Climate trends and projections for Kampala

Lying almost on the equator, Kampala displays a classic tropical climate with two rainy seasons. However, the two seasons are separated by a relatively dry period in July resulting in essentially one long wet season extending from March through to December/January. The wettest month of the observed period was November and this is also the month with the highest number of extreme rainfall days (18 days per decade). However, the data record for Kampala extends only from 2003 to 2012, which is too short for the production of robust trend statistics.

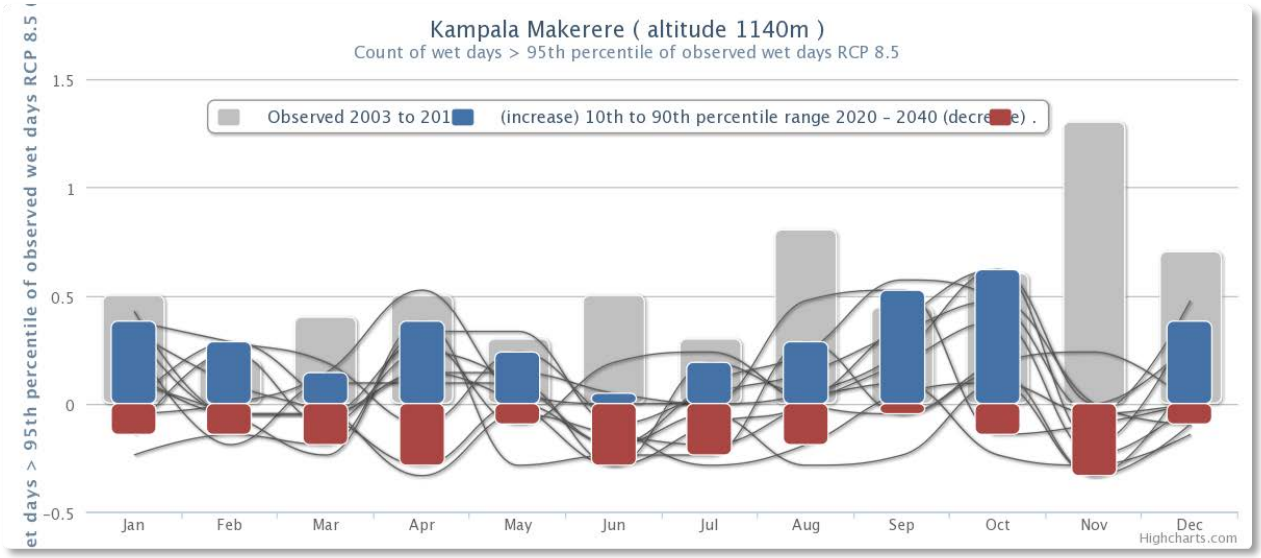
In relation to future patterns, downscaled projections of total monthly rainfall show fairly strong agreement on increased rainfall throughout the year with changes on the order of 20% increase (Figure 9). Downscaled projections of heavy rainfall events (exceeding daily 95th percentile value) show some interesting possible changes (Figure 10): there seems to be some agreement between the models on a decrease in heavy rainfall events in November, the month that has experienced the highest frequency of such events in the observed period. On the other hand, the models seem to agree on an increase in such events in the two prior months of September and October suggesting a shift in seasonality of heavy rainfall events in the future. For the remainder of the year, the projected changes in heavy rainfall events are fairly uncertain with strong disagreement across the suite of models downscaled.

Figure 9. Kampala Makerere – total monthly rainfall



Description of Figure 9: Multi-model downscaled projected changes total monthly rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean.

Figure 10. Kampala Makerere – count of wet days

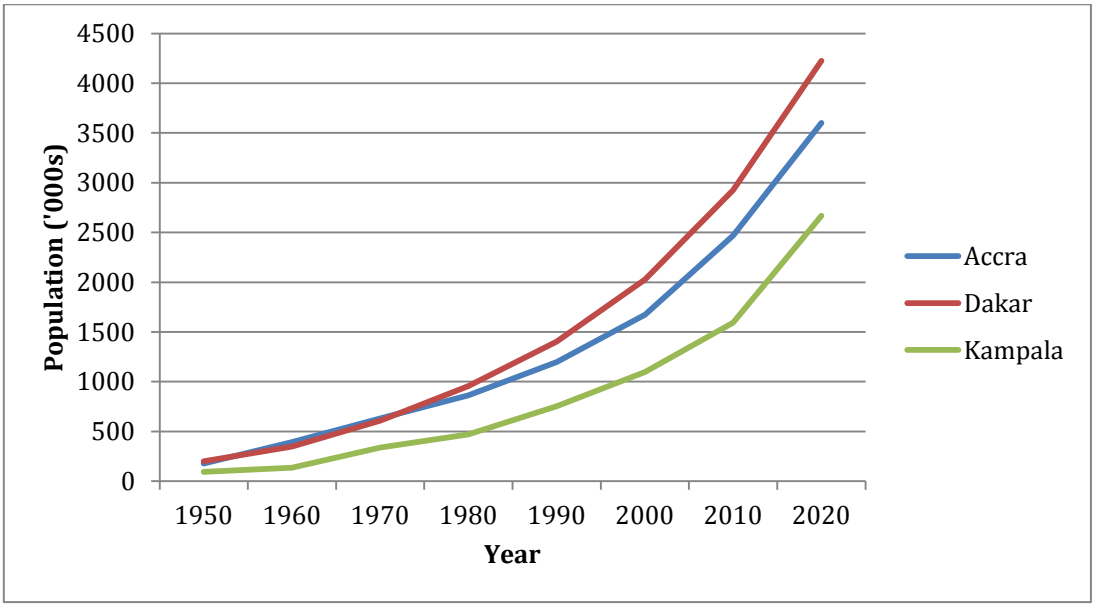


Description of Figure 10: Multi-model downscaled projected changes in days per month exceeding the 95th percentile of observed daily rainfall (lines). Blue bars indicate 90th percentile of multi-model range. Red bars indicate the 10th percentile of multi-model range. Grey bars show the observed climatological mean.

3.3. Exposure

Recent reviews of disasters in urban areas (IFRC, 2010; UNISDR, 2009, 2011) suggest a rapid growth in the number of disasters in urban areas, with most of these being associated with extreme weather, including heavy winds and rains, floods, landslides and fires. They also suggest that the number of locations where such disasters are happening is expanding geographically. Although the factors that underpin these vary, as do their relative importance, in most instances they are linked to increases in the urban population in informal settlements, increases in run-off due to urban growth and poor land-use and watershed management, and chronic underinvestment in drainage. As described above, climate change will shape patterns of exposure to particular hazards in the three case study cities. At the same time, urban expansion and development are generating new patterns of hazard, exposure and vulnerability that did not exist before. All three cities have experienced rapid population growth over the last fifty years (Figure 11), with the result that a growing number of people are living in areas exposed to particular hazards. This illustrates a dynamic linkage between demographic change and climate-related vulnerability, in which population growth, distribution and composition affect the numbers of people exposed to climate-related hazards while simultaneously influencing the vulnerability of different individuals and groups.

Figure 11. Population Growth in Accra, Dakar and Kampala (1950-2020)



Source: UN Population Division, 2011.

3.3.1. Urban land markets and the location of informal settlements

The political economy of city development underpins the creation of vulnerability. Urban systems involve complex interactions of agents and institutions, many of which operate at scales beyond the local neighbourhood. Competition over urban land leads low income groups to occupy areas with high exposure to hazards. Land use and ownership in such areas is further exposed to rapid changes when they become targets of urban actors with greater resources. Resulting arrangements have both direct and indirect impacts on the vulnerability of households living in such neighbourhoods.

This situation is highly obvious in Kampala's Natete Parish. The high-density settlement comprises residential areas and light industry. Despite inadequate infrastructure, it is an economically vibrant area, steadily increasing its contribution to Kampala's economy.

Increasingly, private developers looking to invest within the growing industrial zone have found land within Natete's flood-prone areas inexpensive and therefore highly attractive for further industrial development. But incremental industrial expansion and associated land transfer are not free of conflict. Owners and investors in small-scale industries possess sufficient resources to reclaim low-lying land. Yet, by in-filling land, they transfer flood risk onto low-income residents who occupy residential parcels. Likewise, local road networks used by residents are highly affected by redirected flooding. Local economic development is thus coupled with increased pressure on local residents. For some, their vulnerability further increases with rising costs of individual anti-flood interventions. For others, the choice to relocate from the area engenders additional costs and loss of social networks.

In Pikine, development processes at metropolitan scale modified local patterns of exposure to flood hazard and altered conditions of physical vulnerability. Construction of a toll highway between Dakar and Diamniadio, leading through some of the most topographically diverse and flood-prone neighbourhoods, has resulted in a disruption of existing water flows and areas of infiltration, thus influencing the locations in which flooding takes place. While a number of small water retention basins were constructed as part of the major transport infrastructure project, these have shown little potential to ensure a reasonable degree of control over the hydro-physical processes at the scale of distinct wards. More houses are temporarily or permanently inundated every year, and as a result many have been deserted by their former residents. Transformed into unofficial waste dumping sites, such growing zones noticeably intensify stress in the surrounding residential areas.

3.3.2. The direct and indirect effects of housing quality on vulnerability

Housing quality has significant direct and indirect impacts on the vulnerability of households residing in hazard-prone neighbourhoods. Living in poorly built houses

magnifies chances of exposure, which consequently compromises health and physical safety and substantially increases living costs as well as psychological distress. Risk is frequently shaped by building materials, type and size of a dwelling, which in turn are influenced by tenure security and households' financial capacity. Insecure tenure will compromise building quality, plot size and accessibility within entire settlements. Household expenses attributable to climate variability and change, such as those associated with repeated damage and seasonal house maintenance, have the potential to overwhelm family budgets.

In Old Fadama, although 86% of residents suffer from regular flooding and where recurrent flooding results in major loss and damage of property, the hazard ranked as most critical is fire. This is comparable to the situation in other cities where official records of fire are limited as they are often classified as small or mid-size events that are too localized and the financial costs of which are difficult to ascertain (Pharoah, 2009; IFRC, 2010). Risk of fire outbreaks is associated with the choice of construction material, density of the built environment, and damage to local electricity wiring (often as a result of high winds and flooding). Two reasons underpin local residents' prioritization of fire hazard: the predominance of wood as a construction material and the lack of access roads to secure emergency assistance. A survey undertaken in 2012 in the settlement showed that three quarters of respondents chose wood over sandcrete,[7] with the lower cost of wood being a significant factor in the decisions made by the households. Those who chose sandcrete gave reasons such as protection against fire outbreak and durability; a form of building resilience against hazards. At the same time, tenure rights have a great bearing on the choice of building type, materials used and investment in community infrastructure. Repeated eviction notices served by city authorities deter house owners from investing into a transformation of the area. Local morphology, which is likewise shaped by tenure insecurity, further contributes to vulnerability to fire hazard: one quarter of Old Fadama's residents have no access road leading to their houses and in emergency situations will receive little external assistance.

Up to 80% of the households interviewed in Old Fadama occupy single-room structures. Owners of the properties account for 77% of the households. Yet despite the relatively small size of the dwellings, a significant 7.5% of household income is spent on housing maintenance. Among the activities undertaken are changing of roofing sheets and rubber roofs (done by 42% of households), repairing wooden walls, cementing the floor, replacing doors and windows, painting and plastering wall cracks. Some 4% of the households do not do any maintenance work on their houses at all throughout the year, because the houses are either new or are rented properties. The source of funds for this

[7] Sandcrete is a building material made of cement and sand.

maintenance work is mainly personal savings (identified by 51% of households), although other sources include savings groups, remittances, family members and landlords.

Housing quality is particularly poor in rental dormitories, which rank among the most crowded and least maintained of buildings. Many are provided for female head-porters, the *kaya yei*, who remain a widely marginalized group in urban areas. The sub-standard quality of housing exposes the female tenants to a range of health risks and escalates their vulnerability to environmental hazards: during flood events, the tenants' choice is between sleepless nights in flooded rooms or profound discomfort when sharing rooms with male tenants.

In Pikine, the majority of houses are built with permanent materials. In some areas, the choice of permanent building material was made as a perceived means of reducing the risk of eviction. However, the cost of house repairs and maintenance significantly increases the vulnerability of Pikine's poor households. Frequently up to 16-member households occupy large houses with more than five rooms. Households are predominantly headed by men in retirement age and the responsibility of bearing the additional costs of recurring house maintenance costs lies on a small number of economically active individuals. Expenditure required for house maintenance includes the cost of labour and material to sand-fill internal courtyards and streets, raise doors, windows, roofs. Additional routine expenses are dedicated to the operation of water pumps for drying the interior of houses as well as fixing of electrical wiring damaged by severe wind. Failure to do so exposes countless households to poorly ventilated, overheated and mouldy indoor environments, severely exacerbating health risks.

Kampala's informal housing system provides both suppliers and consumers with a degree of control over the design and use of housing with minimum cost and official interference, but it is nonetheless highly problematic in terms of its utility and durability. In Natete, the average household of seven members occupies two to three rooms. Most houses are built with permanent materials of burnt bricks and cement screed floors, but iron sheet roofs provide limited insulation capacity. However, the need for frequent repairs as a result of periodic and intensifying flooding is seen as economically unsustainable, and has forced many to abandon their houses.

3.3.3. Interactions between local exposure to hazards and solid waste management

The challenges posed by waste management are consistently highlighted as critical across all three of the studied urban locations. Despite decades of piloting innovative municipal projects, deficient waste infrastructure and management systems have failed to reverse or reduce pressure caused by unsafe environmental conditions. In residential settlements, large volumes of solid waste clog drains and water channels and further reduce the infiltration capacity of built land, a situation compounded by the impermeable surfaces

existing around residential quarters. Flash floods caused by increased surface runoff can endanger residents living in houses constructed in materials with low durability. Temporary pools of stagnant water create conditions favourable to breeding of malarial mosquitoes, and an increase in malaria cases has been reported in all three case studies. In contexts where volumes of liquid and solid waste overwhelm the processing capacity of local infrastructure and ecosystems, the pollution of the local environment (including sources of drinking water) critically amplifies health risks.

A large majority of households in Old Fadama (94%) dispose of their waste by paying for house-to-house collection. Collection is overseen by community leaders and managed by their subsidiaries, while the Old Fadama Development Association employs additional door-to-door collectors. No services are provided by local authorities, and the bins that are occasionally donated to the community are seen as insufficient in number and size. On average 10 Ghana cedis (approximately US$5) is paid per month for refuse disposal, a cost which leaves some households with no choice but to opt out of collection on a temporary or permanent basis and revert to using a dump site within reach of the settlement. The quality of the service is irregular, and waste collectors are blamed for disposing of rubbish in the nearby Korley Lagoon.

In Natete, a municipal system of waste collection is likewise irregular and defective. Local waste is routinely deposited directly into the drainage channel or on its banks. While communities have been advised to deposit garbage at pre-determined pick-up points along the main road, irregular collection schedules have resulted in conflict between local residents and those living close to the collection points. Improving solid waste management has been a challenging issue at the scale of the city despite the support of the World Bank. US$8-10 million has been invested in this sector since 1996, designated for the establishment of a landfill, purchasing of vehicles and sensitization of communities about waste management and the potential of recycling. These interventions were paralleled by numerous pilot projects implemented by civil society organizations. The challenge of scaling up these pilot activities persists as programmes are subject to changing donor priorities.

Failed past projects focused on private sector waste management within cities in the Dakar region, and have left a sectoral vacuum only sporadically filled by fragmented interventions. In the last decade, the sanitary situation has been aggravated in flood-prone neighbourhoods as countless deserted houses have been left to subside and transformed into waste deposit sites. In some cases, it was hoped that waste could provide material to infill low lying properties, but long-term flooding of many of such land parcels has made similar attempts futile. Nevertheless, a practice of waste-sealing abandoned buildings proliferates and testifies to a growing need for local waste management solutions. Deserted and polluted spaces within the immediate proximity of inhabited houses have highly undesirable impacts on health and personal safety: ground water contamination,

bad odours and the breeding of flies and insects are perceived as caused directly by such sites while localized criminality and new habitats for stray dogs and snakes are highlighted as new threats.

3.3.4. Exposure of key public facilities

The vulnerability of residents of low-income and informal settlements is shaped not only by their individual circumstances, but also by the provision (or lack of provision) of a range of public goods and services. Where the facilities associated with providing these are also susceptible to damage as a result of climate variability or change, vulnerability can be compounded.

In Pikine's Diamaguene Sicap Mbao ward, the existing seven public schools face yearly inundations shortly before the start of the new academic year. Temporary enrolment in private schools elsewhere involves tuition and travel costs which are a heavy burden on families during periods when household budgets are already stressed by increased expenditure on food and medicine. Difficult decisions often need to be taken at the start of the academic year when school facilities are used to temporarily shelter evacuees. Across Pikine, numerous schools have been flooded and fell into disuse once owners of the surrounding houses raised the street level, inadvertently transforming school yards into water collection basins. A number of health facilities likewise suffer from months of disuse. Residents of Old Fadama rely on health facilities outside the settlement, but road flooding complicates access and increases the costs of the services.

In Diamaguene Sicap Mbao, regular flooding of the ward's four markets has far-reaching consequences for vendors and customers alike. The situation is aggravated by the fact that one of its markets had been closed to clear the way for the new toll-highway. The presence of local markets is an important component of local economies and significantly shapes the economic opportunities of urban low-income residents. Access to nearby and affordable food markets is also essential, as relocation of commercial market activity increases transport costs and complicates poor people's access to reduced-price produce (Tacoli, 2013). Besides its impact on food prices, temporary relocation of commercial activity onto streets within surrounding neighbourhoods triggers conflict over the use and management of street space.

Sports and games spaces are likewise frequently made unusable through flooding and subsequent waste dumping. Management of such facilities is a hot issue for well-established and highly organized youth groups, who use leisure spaces as channels for ascertaining their status and role vis-à-vis the local authorities (Baller 2007; Simone 2004a). Possible conflict and resulting distrust between these actors carries negative implications for cooperation and new institutional arrangements geared to strengthen local adaptive capacity.

3.4. Sensitivity of the case study locations

Sensitivity, or susceptibility to harm when exposed, is an element of vulnerability which emphasizes a differential in the impacts of hazards. Sensitivity is frequently linked with access to financial resources, health, support provided by social networks, or access to meaningful information allowing individuals, families and groups to make informed decisions. Sensitivity increases through recurrent stress and it is conceptually at the base of thinking about the accumulation of vulnerability in the context of slow onset disasters and cascading disaster effects. This growing evidence of accumulated risk helps to undermine the traditional hazard-oriented assumption that sees disasters as purely 'natural' phenomena (Cannon, 2000).

3.4.1. Income generation patterns and economic features of informal settlements

Income poverty is not the sole cause of vulnerability, but within highly monetized urban economies, opportunities for income-generation are an important factor in the choice of individual and collective pathways for vulnerability reduction. Attributes such as household structure, the nature of the settlement and its position relative to the city's production centres, business zones and markets shape the residents' relative capacity to muster the financial resources required for life, as well as to bridge periods of emergency and extended stress.

Natete is an economically vibrant area, with 70% of its residents being economically active. Most of these are relatively young and are employed in the informal sector, with jobs ranging from home-based activities to trading, services and market vending. Other occupations include working as mechanics, builders, charcoal sellers, car cleaners, carpenters, kiosks, phone sellers and chargers. The 16% who are employed in the formal sector include workers in education, telecommunication services and industry. More recently, new employment opportunities have emerged in small- to medium-scale industries specialized in metal works, furniture production, oil and petroleum products, and most prominently food processing (particularly milling grain for flour). The increasing presence of small- and medium-sized industries in Natete Parish is paralleled by growth in private and public sector driven industrial parks located in the city centre and extending into the city's periphery. Along with workers from other parts of the city, Natete's present as well as former residents have been able to draw benefits from such new opportunities. Nevertheless, as discussed above, a more negative balance accrues for those whose houses have been exposed to the additional risks produced by the construction of the new industries. The case of Natete's changing nature is a reminder of the need to understand local vulnerability as a dynamic condition, perpetually mutating as it is shaped by processes of economic development and spatial change at city scale.

Another perspective which emphasizes links between urban economies and local vulnerability is the conceptualization of housing as a productive asset. Diversification of

household income is frequently managed through home-based economic activities and room letting. Particularly among low-income households, a large share of household income may be procured through renting, both as the provision of low-cost accommodations and for commercial purposes. Investment in house improvement is frequently aimed at creating additional rentable space and informal rental markets are an important resource for low-income urban dwellers. Of course, tenants are unable to make use of this opportunity, which removes a significant potential source of income from them. In Natete, owners of houses with two or three rooms frequently rent one or two of them at an average of 50,000 shillings (US$20) per month. In Pikine, constructing an additional story is a sign of economic and social achievement but also an ultimate investment. Such income is compromised when mobility increases during flooding periods and short-term rental agreements are sought predominantly by tenants with fewer resources such as new city entrants and low-income earners.

Nevertheless, not all income-generating activity is compromised in emergencies – indeed, certain economic ventures are designed to draw benefit from crisis situations as they rely on marginal opportunities presented temporarily within particular contexts. In Old Fadama, a majority of its residents rely on jobs outside of the settlement. The main occupations include manual labour (23%), sale of scrap (15%) and food vending (10%). Other occupations include driving, sale of dirty or residual oil, and farming. Those employed as scrap dealers often see their houses flooded and wares carried away by flood water but new commercial opportunities are opened by dealing in goods from flood-damaged shops, homes and machines. Food vending too can be highly sensitive to or flexibly accommodating of crisis situations. Highly sensitive to local stress are those who live in the settlement or prepare food relying on facilities such as kitchens, tools, storage or markets located within the affected areas. Their option is to limit bulk purchases of raw foodstuffs or increase their costs by renting storage outside of the settlements. On the other hand, those who are able to provide the service despite having to make additional investments are able to make higher sales over shorter periods. During times of crisis, their clientele grows, including those individuals and families who have lost their cooking and storage facilities and have seen food prices rise to a level where home food preparation fails to be an economically viable option.

In Pikine, large polynuclear households often comprise few economically active members. Making such households even more vulnerable are increasingly more frequent arrangements whereby young men leave the parental house at the age of 18, modifying the ways in which they are co-responsible for other family members. Under such circumstances, women are under increased pressure to secure families through periods of crisis, combining commercial activity and social networks. Small commercial ventures are facilitated through saving schemes; most widespread has become night-time street vending of basic foodstuffs and low-cost readymade meals. Nevertheless, like many of

their customers, vendors are exposed to floods and their limited access to safe water increases the risk of food contamination (Tacoli, 2013).

3.4.2. Demographic variation and the nature of vulnerability

Where demographic data do exist, they may help in planning for vulnerability reduction through providing scenarios about the likely future population size and composition. Fertility rates, migration, age structure, and household size and composition are all demographic characteristics that shape future patterns of economic development, dependency ratios, the need for and sufficiency of educational provision, and other key components of development (Schensul and Dodman, 2013).

Individuals, household and communities are differentially exposed to hazards, and exhibit different patterns of vulnerability (IPCC, 2012). Income poverty alone is only one in a long list of characteristics contributing to vulnerability. Inequalities related to assets, education, disability, health, gender, age, class and ethnicity are characteristics which interact with distinct hazards in ways that create specific forms of vulnerability. Detailed demographic data are rarely available for informal settlements and many specific forms of vulnerability remain poorly understood (Dodman *et al.*, 2013) but locally undertaken enumerations reveal important differences among low-income settlements. Large variation in sensitivity exists among populations which are transient or stable, households of varying sizes and composition, and individuals of different ages and states of health.

Old Fadama is characterized by a youthful population of men and women, with the majority falling between the ages of 21 and 35 years. Single households constitute a third of the population, followed by three (23%) and two-member (17%) households, giving an average household size which is smaller than the metropolitan average of 3.2 members per household. Residents view large households as significantly more vulnerable compared to small ones, which are predominantly composed of one to two economically active adults. Keeping households small, children are routinely sent to live with grandparents and other family members in northern regions where they are cared for, with family members in the city sending remittances. Resources, including time, otherwise committed to a household's reproductive functions are thus reallocated to increase economic productivity. This may be seen to reduce short-term vulnerability, but may have longer-term implications for family and individual wellbeing.

Most of Old Fadama's residents have moved to the settlement for economic reasons and many are transient. Income levels among residents of Old Fadama are moderate, which is attributed to its strategic location in an economically vibrant environment opposite the Agbogbloshie market, one of the largest markets in the city, known for bulk breaking of foodstuffs and scrap selling. However, despite high employment rates in the settlement, a

large number of its residents are transient, significantly reducing the effort that local residents are willing to focus on vulnerability-reducing strategies.

In Pikine, the residential nature of the settlement and the socio-economic characteristics of households differ greatly from those of Old Fadama. Large (up to 16-member) and long-established (residing in the area for more than 30 years) households are much more common. Many formally depend on household heads who are no longer economically active; this structure renders local households significantly more sensitive to a range of direct and indirect stresses.

In Natete, neighbourhood-level demographic data show that female-headed households constitute about 12% of total households. Their most distinctive feature is that most live in rented tenements. Rental accommodations are generally of worse quality, more costly and less secure, with rental fees prone to change during periods of flooding. As female-managed and female-headed households generally count a higher number of dependent members (four on average) such uncertain tenure arrangements make these households significantly more vulnerable.

3.4.3. Inadequate sanitation and vulnerability

The importance of adequate sanitation in densely populated urban areas can hardly be overstated for individuals as well as larger urban systems. Restricted access to facilities, poor maintenance and defective infrastructure support have grave repercussions on the health of local residents. In low-income informal settlements, provision and servicing of facilities frequently depend on the private sector. The availability, quality and affordability of these facilities are therefore subject to short-term market strategies and economic goals pursued by external actors. The positive benefits of community-managed facilities have been highlighted in literature, but such cases remain limited and highly dependent on local capacity to organize as well as capacity to muster sustained political and financial support.

In Old Fadama, the bulk of sanitation facilities are owned and managed by the private sector. Data from neighbourhood enumerations show that houses in the settlement generally have no facilities such as bathrooms, toilets and kitchens. Only 10% of the surveyed households have private bathrooms, 3% have kitchens and 1% have running water, while none has a private toilet located in the home. The majority of residents thus rely on a total of 101 commercially-run public toilets and 153 bathrooms.

A mapping exercised undertaken in the settlement also indicates a strong correlation between the placement of sanitary facilities and the road network. Similar to the case of fire hazard, Old Fadama's densely built environment and lack of an adequate transport network results in a clustering of sanitary facilities along a number of main axes, leaving large areas in the vicinity of the lagoon under-serviced.

Frequent disruption in the daily operation of these facilities and high user-fees are a burden for local residents. During periods of flooding and high water levels, erratic opening times and frequent closure of the facilities increases stress. Pressure concentrated on only a handful of functioning facilities compels residents to dispose of excreta in the lagoon, further increasing health risk in the wider area. User fees are generally prohibitive and may rise during crisis periods. Furthermore, low investment in maintenance leads to frequent contamination of the lagoon and the surrounding residential areas.

In Pikine, a majority of households benefit from on-site sanitation in the form of simple or raised latrines. Access to facilities is much less problematic than it is in Old Fadama, but serious deficiencies exist in sludge management. In a majority of cases, private entrepreneurs operate fleets of vacuum trucks and provide emptying services to selected houses which can be accessed by road and where residents can afford the price of the service, approximately US$65 for a single use of the tanker. It is estimated that for most low-income households, only one-third to one-sixth of the current fee would represent an affordable service fee. Evaluating the economic sustainability of a proposed public-private waste transportation service, Green *et al.* (2011) found that at a subscription cost affordable to low-income residents, the feasibility of a functioning system is minimal. Unless existing transportation networks and car efficiency are improved and municipal dumping sites are managed appropriately, profit margins will remain unattractive for private entrepreneurs to make the service sustainable and affordable for a majority of households. Indeed, poor households in flood-prone areas resort to a more affordable technique of sludge disposal by hiring individual entrepreneurs who perform manual emptying of latrines. The technique consists of a transfer of sludge into holes excavated within an internal courtyard or at street level. Across Pikine, deficient sanitation has contributed to severe contamination of ground water and its consequent disuse. In low lying areas, high volumes of imported water and untreated liquid waste make an important contribution to the rising water table and resulting periodic flooding.

3.4.4. Public health

A wide range of factors contribute to the state of health of residents in informal settlements, including quality of living environment, housing quality, institutional arrangements, and patterns of social marginalization (Mitlin and Satterthwaite, 2012). Specifically in relation to climate, the main impacts on health at a regional scale are direct heat-related mortality and morbidity, and a climate-mediated change in the incidence of infectious diseases (Patz *et al.*, 2005). The urban heat island effect exacerbates heat waves in densely built urban environments, with residents of houses constructed with materials of high thermal conductivity suffering additional pressure. As urban areas and urban population grow, vulnerability to heat-related mortality is likely to increase in the future. A conservative estimate of the health burden of climate change in 2000, assessed the total

mortality due to anthropogenic climate change at a minimum of 150,000 people per year (WHO, 2002).

Flooding can lead to the contamination of water, living surfaces and indoor air pollution, and is associated with increase in biological pathogens which can be spread through air (such as TB), water and food (such as diarrhoeal diseases) and disease vectors (such as malaria and dengue). Malnutrition caused or exacerbated by prolonged or periodic food insecurity (which may also be a consequence of flooding) has wide-ranging and long-lasting effects with differential impact on diverse social groups. While fewer persons may be killed directly by floods, changes in malaria, malnutrition and diarrhoea have great aggregate disease burdens and are the cause of most premature deaths in relation to daily extensive risks (Dodman *et al.*, 2013).

Health risks related to the quality of the built environment and housing quality are high in densely populated poorly built houses, which are subject to regular flooding or fire hazard. In Old Fadama, the residents of crowded rental tenements, many of whom are socially marginalized female head porters, suffer from above average incidence of skin disease and chicken pox. Fires such as forest fires or fires in informal settlements can cause asthma, respiratory infection and other harm to people's respiratory systems (WHO, 2007).

Water quality generally deteriorates after floods and droughts. Residents in Old Fadama ranked cholera as the second most significant disease in the community. Some structural measures are taken to protect water sources, but there is no oversight of the quality of water stored and distributed by private vendors. In Pikine, residents stated that the incidences of dysentery, cholera, typhoid, schistosomiasis, skin disease and malaria are all increasing. Conversely, the fact that the water network in Natete Parish is well connected to Kampala's water distribution network reduces some of the public health threats that may arise as a result of climate change: connections are mainly set up on individual initiative and taps are outside the house to enable reselling to those without direct access.

Public health crises result in additional household expenses for medical care – whether this is direct payment to doctors, transportation to health centres or the cost of medicine. In a context where few individuals have health insurance and where health services are paid for out-of-pocket (be it in official health centres or traditional healers), such expenditure may have catastrophic consequences and further contribute to the accumulation of vulnerability. In addition, ill-health reduces the ability of individuals to generate income – which may result in a vicious spiral of worsening nutrition and wellbeing.

3.4.5. Urban food security

Food security is a substantial concern for all low-income households. Particularly in urban areas, food security is an outcome not only of the production of sufficient quantities, but

of effective distribution and storage networks, and of affordability to low-income residents. Access to and affordability of food are crucial factors shaping the vulnerability of low-income urban residents – both because climate variability and change can disrupt this, and because poor nutrition can increase susceptibility to hazards (Tacoli *et al.*, 2013). Low and irregular incomes are important factors that may contribute to food insecurity, but environmental hazards and inadequate housing and infrastructure also contribute to the extent of malnutrition. Greater weather variability and climate change will disproportionately affect low-income individuals and communities with the least capacity for adaptation as the cumulative impacts of extreme and localized disaster events will deepen food insecurity (IFRC, 2010).

The global economic crisis that started in 2008 has had a devastating impact on informal sector workers, with increased competition from workers laid-off from formal sector jobs and rising costs for food, fuel and transport. Although not the sole factor, insufficient income is a major cause of urban food insecurity. Poor urban households typically spend over half their earnings on food, and any decline in incomes that are already low is strongly felt. Recent research in eleven Southern African cities shows that four out of five urban households are food insecure (Frayne *et al*., 2010). In Pikine, more than one-third of poor households depend on short-term credit that they procure from extended family, neighbours and wider social networks. In most cases, borrowing takes place to secure daily food and it is much more necessary when food prices are increased.

Hazards resulting from urban environmental change, weather variability and climate change can also affect food security through reducing incomes. Floods reduce people's ability to travel to work, while disruptions in transport infrastructure increase food costs and difficulties accessing markets. Disruptions in people's ability to store food are unavoidable when entire neighbourhoods are flooded for extended periods of time. Inadequate access to clean water sources, and the extremely poor sanitation and waste collection experienced by the majority of residents of cities in Africa (as exemplified in the case studies in this report) are also major causes of high levels of severe diarrhoea, malnutrition and stunted growth. Individual persons' productivity decreases where water-borne diseases such as cholera, dysentery and skin infections become prevalent due to poor sanitation, and this increases malnutrition. In a vicious circle, ill health requires additional expenditure on medication – which can reduce the amount of money available for purchasing nutritious food.

A common coping response is reducing the quality and quantity of food and foregoing meals, while at the same time working longer hours. Food must be bought in small quantities and at higher prices. Women tend to work longer hours than men as they need to combine income-generating activities with care responsibilities, often with little help from men. In many cases they forego food to ensure that their children have enough. This clearly has long-term health consequences. In Pikine, women are increasingly

supplementing family income by taking up street vending jobs. This is made possible through day credits based on the traditional *bëccëk* system. Such commercial activities take place in the evening and night hours and while the value of such commitment is widely acknowledged by the family, the additional pressure exerted on the individual presents multiple downsides.

Low-income urban residents' access to food depends on both physical accessibility and financial affordability. Informal food vendors are the main source of food for the urban poor. Buying cooked food is often cheaper than cooking at home, and saves time. In Pikine, this practice – *tables de nuit* (night tables) – has more recently become the main source of food for many poor and flood-affected families. In Old Fadama, the absence of home cooking facilities and unreliable public kitchens make the purchase of street food virtually the only local option.

Yet when compared to formal markets (and supermarkets), local fresh markets and informal food vendors can be more flexible in responding to local needs and capacities. Small local shops and informal vendors build on long-term relationships and practices. They are able to compensate for higher prices by a willingness to grant credit to customers who are long-term clients or neighbours. As such, these arrangements signal increasing pressure on urban households at a time when food prices fluctuate in response to both national production and unstable global food prices. Consciousness about systemic changes over time and at scales beyond individual settlements is high among local residents and includes emphasis on risks associated with densification, rapid urbanization and the clearing of land for real-estate speculation. In Pikine, these have led to diminishing availability of fruit trees, worsening water quality, and decreased availability of fertile land within peri-urban areas.

4. Reducing vulnerability: lessons from case studies

4.1. Enhancing resilience through non-climate related activities

Many of the characteristics of resilient urban areas that limit the disaster and climate risks faced by urban residents and communities are not achieved through specific adaptation activities. The presence of effective and well-maintained networked infrastructure – water, sanitation, sewerage, storm drainage, electricity, telecommunications – can significantly reduce the urban residents' exposure to particular climate-related hazards. Effective water, sanitation and sewerage systems reduce the spread of water-borne and water-washed diseases – which may otherwise become more frequent as a result of rising temperatures. They also strengthen the resilience of individuals and households through reducing the burden of disease, and enhancing the ability to generate income. Similarly, access to electricity and telecommunications systems can strengthen urban livelihoods, enabling greater investment in dwellings that can reduce their susceptibility to particular hazards. They can also help individuals and households strengthen their knowledge about particular risks, and thereby enable more effective responses to be made. In addition, effective storm-water drainage and coastal protection infrastructure are essential for reducing exposure to flooding of different types. These non-climate related activities contribute to what has been termed 'accumulated resilience' – the stock of assets and capacities that exist in local communities and cities that reduce risk from a range of shocks and stresses. Of course, these are not in themselves sufficient to manage climate change, but they form an important basis without which specific interventions (including those referred to elsewhere in this section and report) are unlikely to achieve meaningful success.

The absence of basic infrastructure and services is a significant contributor to vulnerability, and addressing these deficiencies can help to build resilience. For example, the health burdens that are likely to arise as a result of climate change, including the spread of water-borne, water-washed and temperature-sensitive diseases can be reduced by the provision of adequate sanitation. There are virtually no domestic toilets and bathrooms in Old Fadama, with residents relying on 101 commercial public toilets and 153 public bathrooms. Many of these are located along the banks of the Korle Lagoon, and empty their content directly into this water body. Improving the quality of sanitation for Old Fadama – which may include both the provision of private facilities and the improvement treatment of human waste – would improve public health, reduce the time and costs for people to access sanitation, and thereby increase their adaptive capacity to deal with shocks and stresses.

In Kampala, the expansion of high-pressure water pipes connected to the city water supply system under the Local Government Development Programme (between 2001 and 2006) reduced disease outbreaks such as cholera and dysentery in low-income settlements. But

access to potable water is not even: some households in Natete have their own supplies, while others must purchase from households that do. This demonstrates that vulnerability is unevenly distributed even within a relatively small spatial area, as those relying on purchasing water will have to spend a larger proportion of their income to acquire this, and may be more tempted to make use of unsafe sources. Also in Kampala, increasing temperature and rainfall may make conditions more favourable for mosquitoes and the spread of malaria in the city. More general improvements to the public health infrastructure and better control of disease vectors are not specifically 'adaptation' activities but will reduce the potential for negative health effects as a result of climate change.

Poor management of solid waste also increases susceptibility to flooding. Residents of Old Fadama recognized that "the rubbish is washed away into gutters and chokes them". Conversely, when flooding takes place, this is worsened by the presence of garbage: "floods collect rubbish into the house and they smell". Improving solid waste management would therefore reduce both the frequency of flooding and the severity of the impacts when this does take place. Garbage blocking drainage channels was also identified as the major proximate cause of flooding in Natete, with drainage channels being poorly maintained. Improved solid waste management in all the case study locations would help to reduce the likelihood of flooding as a consequence of heavy rainfall.

The poor quality of housing also contributes to vulnerability. In Old Fadama, 83% of the surveyed respondents lived in houses with conditions assessed as being 'fair' to 'bad', with cracks and holes in the walls, leaking roofs, exposed foundations, decaying doors and inadequate windows. These housing conditions leave residents exposed to climate-related hazards, particularly flooding. Flooding destroys possessions and creates uncomfortable living conditions: one respondent commented that "my house becomes dirty and wet", while others have to spend nights standing up as there is nowhere to lie down. In addition, a considerable proportion of the residents' limited income is used on housing maintenance (an average of 7.5% across the surveyed households), reducing the funds available for other activities and priorities. Finally, managing the effects of flooding reduces time available for more productive activities: a focus group participant explained that "it takes all our energy and time to clear the water from our rooms and thus, it delays the time we should have gone out to work to make more money". Addressing the housing deficiencies in Old Fadama would therefore strengthen both the physical and economic conditions of residents, making them more resilient to climate-related hazards.

Housing in Kampala is also largely provided through informal mechanisms, with low-cost housing frequently being found in flood-prone areas. The structure of the houses is also inadequate for the climate: foundations are damaged through long-term saturation, and roofs constructed with corrugated iron sheets mean that houses become uncomfortably hot during hot days and uncomfortably cold during cold nights.

However, these housing problems take place in a broader context of tenure insecurity. While the formal survey in Old Fadama identified cost as a major impediment preventing residents from improving the quality of their houses, the focus groups made it clear that tenure rights also played a major role in this:

> "The government continuously gives us eviction notices, so we cannot make any investment in the community. If the government could upgrade the place, people of this community would have put up nice buildings."

More generally, it is increasingly recognized that initiatives on drainage, sanitation, water supply, garbage management, road infrastructure, urban and peri-urban agriculture, and health related projects can help to build the capacity of low-income urban residents to deal with climate variability and change. However, in Kampala it is noted that many of these have only been implemented on a pilot basis, which means that their spread is uneven throughout the city. The provision of key environmental infrastructure would reduce risk and contribute to building the resilience of the urban population – especially the urban poor – to climate risks.

4.2. The role of local institutions

Local institutions play an important role in enabling access to the types of resources that can build resilience. They can provide access to specific services that help in the event of exposure to hazards, including evacuation procedures and shelters. They can also contribute significantly in terms of enabling or restricting access to 'safe' land on which low-income urban residents can live.

The phrase 'people as infrastructure' (Simone, 2004b) has become frequently used to epitomize the activities of individuals, groups and networks linked through relations of reciprocity and aimed at creating conditions for economic opportunity. Social networks function as information channels, repositories of knowledge built and shared over time and across space, storehouses for skills, and vehicles for collective action within and beyond distinct communities. Some formal and informal constellations of actors are exclusively economic in focus, while others act as foundations for evolving cultural identities and political engagement. People's priorities and existing structural conditions determine the spectrum of contributions that social networks make toward reducing the vulnerability of low-income urban residents.

Also emphasized in literature on social networks is the temporality of such relationships: individuals simultaneously engage in parallel relationships, ranging from transient connections to highly organized long-term formations. But while some situations require flexibility and allow individuals to benefit from temporary social relationships, others depend on conditions of trust, created through interdependencies, shared identities, formal

agreements or long-term involvement. High residential mobility of individuals and households can disrupt trust. Migration is often cited among adaptation strategies, but depopulation and high mobility have undesirable implications for collective action (Wallace and Wallace, 2008). In fragmenting communities, individual households are more likely to depend on patronage and it becomes difficult to mobilize effective pressure and hold local authorities and elites accountable. Organizing physical interventions is challenging when material and labour depend on contributions from local residents. The same applies to non-structural interventions such as savings groups, many of which require long-term member commitment.

These institutions can be very informal in nature: in Kampala, social networks are used for families and households to support each other through remittances or provision of food (which may come from family members in rural areas), or for providing accommodations and household items after flooding. Local institutions can play a significant role in organizing collective action to reduce risks. In Natete, local leaders use an improved public address system to inform community members about activities including de-silting sections of the drainage channel at the onset of the rainy season. Gender-based social networks also exist in Natete that provide micro-credit and collateral, and also provide funds to members who have been affected by flooding. But for many, high residential mobility is a growing hindrance in sustaining such networks. Membership in the groups is pegged on whether one is belongs to the community. Distrust of prospective members is high. Keeping track of member obligations becomes difficult as mobility in the area increases and the local population becomes more heterogeneous and transient. This is particularly the case during the rainy period when many long-term residents flee flooding and new tenants move into temporarily available accommodations. While the national Voter's Register of 2011 estimates Natete's population at 15,000, many households have relocated and resources available through tightly coordinated and controlled networks are at risk of declining despite a growing need for mutual support.

While local institutions and organizations have the potential to contribute strongly to the reduction of risk, they are not always strong, visible or effective. In Old Fadama, the vast majority (95%) of the respondents were not aware of any institutions that could make decisions about and address the causes of flooding. While community networks do exist, these were seen to have a more social emphasis: a member of a focus group stated that "we get benefits from social networks for social gatherings (for weddings, funerals, etc.) but not for coming to the aid of flood victims". Many such groups are formed along ethnic or tribal lines, which ensures a degree of trust but it is equally seen as limiting their potential for expansion. Nonetheless, despite the exorbitant cost of social events, such occasions remain an important platform for individuals to both strengthen ties with other family members and to access new networks and opportunities beyond the boundaries of the community (Odeye-Finzi, 1985).

In Pikine's diverse neighbourhoods, women's saving groups are ethnically inclusive. Conventionally, revolving savings groups have been used by women to redistribute funds and support members in financing and organizing social functions and obligations, small business activities or bridging periods of emergency and shortage. More recently, as the pressure put on households increases, members have used *tontines* to not only redistribute cash but instead to circulate basic foodstuffs.

Pikine manifests a vibrant associative culture populated by associations dedicated to sports, culture, education or neighbourhood development. Many of these groups partner with local NGOs and local authorities and they are key mobilizers for preventative and emergency interventions. Neighbourhood organizations display strong local identities but their networks extend across the city, providing a dense infrastructure for intense information sharing and collective learning. Furthermore, since the mid-1990s, local residents have followed and many have participated in past development interventions which placed strong emphasis on community organization and local action. However, many such associations have had to confront a new challenge: since 2005, as many as one third of residents across multiple neighbourhoods have had to relocate due to flooding and severe wind storms. Displacement, increasing fragmentation of neighbourhoods and families, and lacking institutional support frameworks are a new challenge for local associations and city-wide social networks.

It is important to remember that these local institutions can also exhibit negative characteristics. People can be excluded from participation, or local organizations can be co-opted by more powerful elites (including government representatives and agencies). In general, however, local institutions can play an important role in reducing vulnerability through 'soft adaptation' – the knowledge, skills and cascading technologies that can contribute to not only to coping within communities but also to the planning and implementation of city-scale adaptation actions.

4.3. Working with institutions at different levels and scales

Local interventions take place within a policy and institutional framework that operates at a range of different scales. National policies can mandate whether local authorities conduct risk assessments or develop risk reduction plans; while national decisions affect the level of funding (and the autonomy over this) that is held at the local level. The ability of local organizations to engage across cities and countries is a significant factor in shaping their knowledge and their ability to influence policy decisions.

The institutional and governance frameworks can be complex and difficult for local organizations to engage with. In Kampala, the recent Kampala Capital City Authority Act gives the responsibility for local planning, resource allocation and implementation to five lower municipalities. These municipalities should have a substantial role to play in

addressing many of the factors contributing to vulnerability; but planning and implementation of development projects has remained centralized at the city level, and the municipalities lack the resources, power and authority to make meaningful improvements. At the same time, the risks associated with climate change are yet to be fully mainstreamed into the KCCA's planning and management framework.

In Accra, the Greater Accra Region (with a population of approximately 4 million in 2010) is divided into ten District, Municipal and Metropolitan Assemblies, each of which is administered by a chief executive (representing the central government) and which derives authority from an elected assembly. However, the division of responsibilities and resources between these different levels of government is not always clear or well understood. This complexity also exists in the governance of climate change risk: the Environmental Protection Agency is the focal point for the UN Framework Convention on Climate Change; the Ministry of Environment, Science and Technology hosts the National Climate Change Committee; while the National Development Planning Commission (NDPC) and the National Disaster Management Organization (NADMO) are facilitating initiatives to mainstream climate change and disaster risk reduction into national development. This broad set of actors means that it can be difficult for communities to identify and engage with the appropriate agency for the particular task of reducing climate risk. While NADMO has established disaster management committees at the national, regional and district levels, these are said not to be operating effectively. However, NADMO and the Accra Metropolitan Assembly members have visited Old Fadama to offer relief items after disaster events.

Working effectively with institutions at the national scale can also contribute to the reduction of risk in low-income and informal urban settlements. Uganda has produced a draft National Disaster Preparedness and Management Policy, which includes provision for community-level disaster preparedness committees. These have not yet been implemented in Natete, but have been launched on a pilot basis elsewhere in the city (including the disaster hotspot of Bwaise). At an even larger scale, UN agencies – particularly UN Habitat – can provide tools and strategies that can build resilience in communities. In Kampala, UN Habitat worked with the Kampala Capital City Authority to conduct a vulnerability assessment and to provide pilot interventions for enhancing resilience – although comprehensive tools to achieve this in low-income areas of the city are yet to be developed or implemented.

4.4. The potential and limits of specific types of risk-reducing interventions

Low-income and informal communities cannot wait for larger-scale structural responses that address the underlying drivers of vulnerability, but instead have to find ways to address the local manifestations of risk. These responses are usually small-scale in nature,

engage only with the direct experiences of hazards, and are frequently characterized as ‘coping’. Yet these actions play an important role, particularly in the absence of broader interventions by government institutions and service providers.

Structural interventions within houses are the most frequent of household responses aimed at reducing their physical vulnerability. Constructing barriers in doorways, raising verandas, floors and roofs have become an indispensable routine for households who face periodic flooding. Those living in temporary or rental accommodation have fewer means to influence the quality of housing and resort to small-scale modification of the living environment such as raising beds and valuables above flood level. Perceived and real security of tenure further shapes the volume and type of investment in the living environment. Redirecting storm water from houses through infilling of flat and low-lying areas around houses before or after construction are part of essential, and costly, investment in flood-prone areas. Coordination among house owners, local businesses, industries, and authorities involved in road construction is essential; incongruous or conflicting interventions often dislocate and intensify risk.

A wide range of coping strategies were identified in the different communities. During floods, people in Old Fadama would try to remove water from their rooms, or would go to a friend’s house (possibly outside the community) to sleep. After floods, they would unblock choked drains and construct passages to allow water to flow into the nearby lagoon. More proactive measures are taken before the onset of floods, including building walls around water sources (particularly wells), raising the foundations of water sources, and constructing gutters. Investment in such protection measures is done predominantly by private water providers and smaller-scale vendors who own and operate most of the existing connections. The operators of public toilet facilities also raise the foundations of these and build walls around them to protect them from floods. Upgrading is rarely the choice of community groups or individual households who, dissuaded by frequent eviction notices, refrain from major investments in the area. Action taken or foregone by different actors reflects their relative position within wider cultural structures and urban governance regimes.

In Natete, people use a similar range of coping methods, including redirecting storm water from houses and infilling low-lying areas before constructing houses, but these are implemented in a haphazard manner meaning that their net effect at the community level is negligible. Individuals construct barriers in their doorways and raise their verandas to prevent flood waters entering houses, but these are only temporary solutions as the increasing intensity of floods means that repairs have to be made frequently. The limitations to these local approaches were noted within focus groups in Natete. Addressing floods was seen to require structural solutions – including constructing better drainage networks, redesigning bridges and supporting the relocation of people who are most affected. Pilot activities have taken place across Kampala that can reduce some elements

of climate risk, including waste recycling, urban agriculture, improving drainage infrastructure, technologies for infiltration enhancement, community sensitization on disasters, and youth training programmes. Institutional adaptation within the KCCA and other municipalities will be required for these pilot activities to become more widespread, for example by supporting initiatives to create enabling regulations.

Neighbourhood-level outcomes and sustained benefits of physical interventions depend considerably on alignment between factors including sustained action by organized community groups, local leadership, flexible financial resources and strategic cooperation with local authorities. Over the past two decades, physical upgrading in Pikine progressed in an uneven fashion, largely associated with a controversial land titling programme. Active community organizations have, however, formed and proliferated across all neighbourhoods. In recent years they have held a pivotal role in mobilizing for and coordinating construction of local drainage canals and sand-filling of low lying areas. But resources available to local communities vary and increasingly more frequent are assemblages of incommensurable physical infrastructure systems with connections missing between adjacent areas. Apart are residents in cooperative and privately-owned housing estates who dispose of sufficient resources allowing them to commission constructions of underground drainage, connected to existing state-built trunk infrastructure. In contrast, poorer neighbourhoods have developed systems of temporary open drainage networks, functional for approximately 3-5 months per year. These reduce damage and shorten periods of emergency in periodically flooded neighbourhoods. Over the past five years, such networks have expanded to connect neighbourhoods, aiming to reach locations suitable for discharge.

An important added value of such initiatives is the reinforcement and extension of organizational and personal networks beyond distinct neighbourhoods and across the whole city. Additionally, community associations have used such interventions to engage in local political processes, voicing demands for more inclusive local development planning, as well as demanding that government emergency response be complemented by risk reduction interventions. It is, however, important to acknowledge the opportunity costs inherent in community engagement. Community-based physical interventions or political engagement requires significant time dedication and thus shortens the time available for income generation.

Other approaches to reduce risk that can involve both local communities and government institutions can include ecosystem-based adaptation strategies. In and around Kampala these options may include urban forestry, hilltop afforestation and enhancing green surfaces. These types of approaches have the potential to generate a wide range of co-benefits, including improved water quality, health benefits, reduction of the urban heat island and the creation of livelihood opportunities for low-income groups. As yet, however, the potential of these has not been realized in any of the case study locations.

There is a growing recognition that specific risk-reducing interventions will be most effective if they can be used as the basis for broader political engagement by low-income residents that encourages and supports the broader processes of risk reduction by city authorities. Similarly, it is noted that city authorities should play an enabling role, by taking decisions and implementing programmes that strengthen the ability of low-income groups to make improvements on their own. The precise balance between these sets of activities will vary from city to city, but all African cities are likely to require considerable amounts of both. The implications of this analysis will be explored further in the following section.

5. Conclusion: implications for understanding and reducing vulnerability

The case studies presented in this report support the opening observation that climate change is a major challenge facing urban areas in low- and middle-income countries. It will place an additional layer of stress on individuals, households and communities that already exist in a perilous state. It will have directly negative effects on the livelihoods and wellbeing of many people in towns and cities in Africa, and will prevent some poor households from moving out of poverty. This concluding section synthesizes the insights provided by the research into how vulnerability can best be conceptualized, identifies some of the key lessons that the research provides for research into vulnerability in the urban context, and then draws out the implications of this for adaptation practice – whether this is carried out by civil society organizations, local governments, national governments and their agencies, or international development partners.

5.1. Conceptualizing vulnerability

The underlying drivers of vulnerability are strongly associated with socio-spatial processes which localize access to and condition the affordability of basic infrastructure and services, housing quality, food security, capacity to generate sufficient income, and ability to access safety networks. Where access to information channels and inclusion in decision-making is facilitated, social networks and local institutions have a higher capacity to coordinate local action and negotiate their engagement in urban development processes. Where this is not the case, they face fragmentation and high opportunity costs associated with mobilization.

Approaches to vulnerability frequently mirror debates about the relative importance and interaction between wider socio-economic structures and agency. The research presented in this report makes it clear that both approaches are needed for a better understanding of differentiated urban vulnerability and for the development of capacities to respond to existing and emergent shocks and stresses. Individual and community characteristics certainly contribute to vulnerability – but so do manifestations of the political economy across cities, regions, states and international networks. This is particularly the case when examining exposure to climate-related hazards. A structural perspective is important in diagnosing the root causes leading to conditions contributing to local vulnerability such as the relative location of low-income informal settlements, their positioning within networks of transport infrastructure, the availability of protective and risk-reducing infrastructure, access to healthcare, or low-income residents' exposure to hazards through distinct pathways of income generation. The political marginalization of these groups likewise hampers vulnerability reduction as decisions over major planning interventions take place without the involvement of most residents and frequently jeopardize existing local-level

initiatives. Examples outlined through the analysis of case studies include unease over side effects arising from the construction of Dakar's new toll highway or changes in Kampala's institutional structures and resulting ruptures in channels of representation.

An agent-based approach allows for an understanding of urban vulnerability via the multiplicity of experiences, perspectives, motivations and capacities of distinct actors. It focuses attention on factors which motivate choices and render decisions achievable or – at least – makes them worthwhile efforts. Such focus also acknowledges the distinctiveness of social interactions permeating each city and sheds additional light on pathways through which local conditions of vulnerability emerge and the multiple steps through which they come to be addressed. What has been tangentially addressed in this study but requires future attention is a perspective on urban vulnerability (specifically the vulnerability of low-income settlements and their residents) with a focus which encompasses extra-local networks, emergent processes of city-wide community mobilization for vulnerability reduction, and intra-/inter- urban linkages. Hints for such lines of enquiry permeate the empirical material of the case studies. They are a signal that while low-income informal settlements demonstrate a shared pool of vulnerability characteristics, when taken as a unit of analysis they require a conceptual opening to account for interactions within a broader socio-spatial (and ecological) system. Addressing the challenge offers an opportunity to better address the changing dynamics of exposure within, across and beyond the city; an aspect which is particularly salient in view of the complexity of climate-related impacts.

5.2. Lessons for vulnerability research

5.2.1. Methodological guidelines and toolkits for analyzing urban vulnerability

In recent years, a growing number of cities, academic institutions and international organizations have developed detailed methodological frameworks for assessing climate change–related vulnerability, a selection of which are listed in the box. These are usually framed as logical mechanisms that will aid in creating objective measures of vulnerability.

Selected methodological guidelines and toolkits for analyzing urban vulnerability:

UN Habitat, *Planning for Climate Change*
guide: http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3530
toolkit: http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3529

UN Habitat, *Developing Local Climate Change Plans*
http://www.unhabitat.org/downloads/docs/11424_1_594548.pdf

Mercy Corps, *Community-Based Vulnerability Assessments* (Indonesia)
http://acccrnindonesia.files.wordpress.com/2011/01/urban-bulletin-vol-91.pdf

LDC Expert Group, *National Adaptation Plan Process*
http://unfccc.int/resource/docs/publications/publication_ldc_napp_2013.pdf

Provia Guidance on Assessing Vulnerability, Impacts and Adaptation to Climate Change
http://undp-alm.org/sites/default/files/provia-guidance-nov2013-summary.pdf
http://undp-alm.org/sites/default/files/downloads/provia-guidance-nov2013.pdf

UNEP, *IEA Training Manual: Climate Change Vulnerability and Impact Assessment in Cities*
http://www.unep.org/geo/pdfs/IEA-Climate-Change-VIA-City.pdf

Parikh, J., G. Sandal, P. Jindal (2014), *Vulnerability profiling of cities: a framework for climate-resilient urban development in India*, Asian Cities Climate Resilience Working Paper – forthcoming online.

Sharma, D., F. Singh, R. Singh (2013), *Urban Climate Resilience: a review of the methodologies adopted under the ACCCRN initiative in Indian cities*, Asian Cities Climate Resilience Working Paper No. 5 - http://pubs.iied.org/10650IIED.html

IRADE, *Climate Resilient Urban Development: Vulnerability profiles of 20 Indian cities*, Executive Summary at http://irade.org/Executive%20Summary_RF.pdf

Being a subtle, yet deeply political process, undertaking a vulnerability assessment means that the contexts in which these are used, the ways in which inputs are sought, and the priorities of the institutions and individuals implementing them will result in significant differences in the outputs that are generated. The experiences with individuals and community groups in low-income and informal settlements in Ghana, Senegal and Uganda have highlighted the following central lesson: it is of outmost importance to engage with local grassroots organizations in setting the terms under which these frameworks are developed and utilized.

Many of the guidelines and toolkits listed could be applied in urban centres in low- and middle-income countries – but it would be more appropriate to commence vulnerability assessments with a process of engagement to identify the priorities for the assessment. The specific frameworks (including those listed) can then provide direction on the key climate-related issues that require consideration, and the specific tools that they present can be used and adopted to engage with particular local climate-related issues.

When developing and undertaking vulnerability assessments, it is important that the soliciting and selection of data and information remain the focus as different approaches to gathering and using data will lead to a range of operational choices and solutions. Key principles that should be considered in this regard include:

- contextual relevance: based on the local social, economic and environmental characteristics);
- participation: ensuring that the perspectives of those who live and work in areas affected by climate-related risk, particularly residents of low-income and informal settlements, are adequately considered;
- political awareness: recognizing that the costs and benefits of environmental and climate-related decisions are unevenly distributed, and that local power relations can play a considerable role in determining who 'wins' and who 'loses' and whose realities are captured through data; and
- recognition of urban dynamics: incorporating an awareness that urban systems are shaped by a range of local, regional and global forces, and that responses to environmental and climate threats cannot be assessed and addressed within narrowly defined geographic and institutional boundaries.

Such principles will guide the assessment of local capacities, which provides key information about the ability of stakeholders to sustain local interventions and develop ownership of processes – an input highly relevant in decisions regarding maintenance and long-term operations. Likewise, assessment of risk reducing interventions such as resettlement or ecosystem-based adaptation projects will become recognized as political-economic processes. While the general approach to improving informal settlements in many African cities has evolved from relocation to *in situ* upgrading, climate change may shape the hazard environment in such a way that relocation does indeed become necessary. If this is the case, the principles above – of context, participation, political awareness and recognition of urban systems (including the systems used by low-income residents to generate livelihoods) – become all the more important. Similarly, conservation of ecosystems has often been undertaken at the expense of land availability for low-income groups – and while the value of ecosystem-based adaptation is increasingly recognized (Doswald *et al.*, 2014; Jeans *et al.*, 2014; Lwasa, 2013), for this to be effective in urban centres in Africa will require a more substantial engagement around the politics of access to land and the benefits achieved from environmental services.

Beyond key principles, a framework for analyzing climate change–related vulnerability will consider the following elements:

a) the likely changes in climate based on the best available scientific data (as described in Section 3.2) – recognizing that this may have significant shortcomings;
b) possible impact pathways, taking into account the ways in which particular changes in climate (e.g. total amounts of rainfall, intensity of rainfall, temperature increases, sea-level rise) will result in particular negative consequences (e.g. increased frequency or intensity of flooding, damage to networked infrastructure, reduced availability or increased cost of food, spread of disease);
c) the overall effects of these impacts on the ability of urban systems to function – particularly the urban systems that support life and economic activity (electricity generation and distribution, water supply, storm water drainage, transportation);
d) the underlying drivers of vulnerability for particular neighbourhoods in the city, taking into account both the spatial distribution of climate impacts and the social and economic characteristics of particular communities that shape their sensitivity and adaptive capacity; and
e) factors making particular individuals or groups of individuals more likely to be negatively affected by these changes; these include gender, age, health status and (dis)ability.

This framework highlights the three key elements of vulnerability to climate change – exposure, sensitivity and adaptive capacity – and therefore provides a holistic basis on which to understand this and build responses. It also highlights the needs for the use of different types of data – both quantitative and qualitative – as a means of building up this detailed picture.

5.2.2. Framing, soliciting and assessing data

Formal sources of data obtained at the scale of the city can help to identify the drivers of vulnerability at the city-scale, or the broad characteristics of the city's informal settlements. However, these often lack the level of coverage or detail needed to understand the ways in which particular sub-groups are currently affected or are likely to be affected in the future. For example, the experiences of tenants and landlords, of the formally employed and informally employed, of women and men, of children and the elderly are likely to be different – and this will be difficult to capture in large-scale surveys. More detailed approaches – using extensive community-collected quantitative data (for example through enumerations) and using qualitative data (for example through focus groups) have the potential to unearth some of these smaller differences. These can help to address some of the key questions on vulnerability raised by Hardoy and Pandiella (2009):

- Who lives or works in the locations most exposed to hazards related to the direct or indirect impacts of climate change (e.g. on sites at risk of flooding or landslides)?
- Who lives or works in locations lacking the infrastructure that reduces risk (e.g. from serious floods, where settlements lack drains)?
- Who lacks knowledge, capacity and opportunities to take immediate short-term measures to limit impacts (e.g. to move family members and assets before a flood hits)?
- Whose homes and neighbourhoods face greatest risks when impacts occur (e.g. homes of poorer quality provide less protection for inhabitants and their possessions/physical assets and hence there is more loss, often including death and serious injury)?
- Who is least able to cope with impacts (illness, injury, death, loss of property, loss of income, lack of insurance or relation to government to get compensation)?
- Who is least able to adapt to avoid impacts (e.g. by building better homes, getting government to install needed infrastructure and provide needed disaster preparedness, moving to a safer place)?

As discussed in Section 2.3 (addressing issues pertaining to research within different demographical and institutional contexts), data available for assessing vulnerability vary greatly from place to place and the availability/quality of some data will depend on the timing of the assessment. There is also a growing recognition of the value of local research institutions which are often best positioned to understand local complexities, engage with an appropriate range of stakeholders, and ensure that research findings have lasting policy influence. Data on past climates and projections for future climate regimes can be more difficult to obtain for low-income urban centres. However, this is a vital part of the picture for understanding climate vulnerability. A changing risk context may shape the adaptation priorities – for example from *in situ* upgrading to community-planned and managed relocations to areas less exposed to particular hazards that may become more frequent or more intense. In their own ways, the different case studies attempted to engage with climatic data: whether from formal sources or from community recollections. The latter approach can be extremely helpful, as it exists alongside a process of awareness raising and priority-setting. However, in many urban centres with more transient populations it may be less achievable.

5.3. Implications for adaptation practice

The way in which vulnerability is conceptualized and analyzed has important implications for the ways in which various actors – from households to international organizations – respond to the challenges of climate change. The framework suggested above will help to identify some of the key entry points for action in any particular location.

One element that will be essential in supporting adaptation practice is ensuring the availability of funds to support more resilient communities and cities. Only a small proportion of the funds committed under UNFCCC 'fast-track' financing have actually been disbursed; only a small proportion of these have been allocated to adaptation (despite a commitment to 'balance' between mitigation and adaptation); and an even smaller proportion have been directly accessible to sub-national levels of government or to civil society (Ciplet *et al.*, 2012). In contrast, locally controlled funds have been shown to be effective for development activities in low-income neighbourhoods, including small-scale infrastructural improvements that reduce the harmful effectives of climate variability and change (Mitlin, 2013).

At the local level, the understandings of vulnerability explored in this report highlight the importance of housing quality, solid waste management, sanitation, public health and food security as key drivers of vulnerability for low-income urban residents. Approaches to vulnerability reduction therefore need to operate in the distinct sphere of strengthening the resilience and adaptive capacity of residents of low-income urban areas through engaging with these basic development concerns alongside working directly to reduce exposure to hazards.

At the city scale, there is a key role for engaging with urban land markets to enable low-income groups – whose presence and actions are essential for the function of urban systems and city economies – to have access to safe locations for shelter. This type of outcome can only be accomplished with the engagement of more engaged and committed institutions, particularly local government institutions that are willing to engage with low-income and informal communities.

Finally, at the global scale there is a need for greater support for urban adaptation, including the adequate resourcing of both local governments and local communities to invest in building resilience. The existing financial mechanisms – both 'formal' climate finance (under the UN Framework Convention on Climate Change) and less formal funding from aid agencies and NGOs – have been slow to develop pathways for money to reach marginalized and low-income groups in urban centres. But these funds must be accompanied by commitments from actors at different scales to continue engaging both with the local drivers that make residents of low-income and informal neighbourhoods susceptible to harm; the structural drivers that result in the marginalization of particular groups in urban societies; and the global drivers of anthropogenic climate change caused by greenhouse gas emissions.

Appendices

Appendix 1. Case summary: Old Fadama (Accra, Ghana)

The case study of Old Fadama, Accra, Ghana was based on the recognition that vulnerability to climate change takes place in a context of rapid urbanization, inadequate infrastructure, and limited financial and technical capacity of local governments. This means that groups that are already marginalized – because of low-incomes or living in informal settlements – are particularly vulnerable. The research in Old Fadama analyzed the nature of risk in this large informal settlement, examined the ways in which community organizations seek to influence the activities of city authorities, and sought to understand the actions that city governments are taking to reduce the negative impacts of climate change particularly on those who are most vulnerable. The report contributes to the development of a framework for understanding the nature of vulnerability in urban centres in Ghana, while simultaneously assessing and analyzing relevant approaches that can be used to reduce vulnerability.

Old Fadama is located on low-lying land along the Odaw River and the Korle Lagoon. The settlement was established by migrant workers and internally displaced persons predominantly from the northern part of Ghana. In 2012, Old Fadama had a population of 78,684. Single households formed the majority (29%), followed by households with three (23%) and two members (17%). It has a youthful population (76.9% below 35 years of age), and the population density is approximately 2,500 persons per hectare.

A multi-faceted data gathering technique was used. Structured questionnaires were administered to one hundred households to gather detailed information about the household-level characteristics (including socio-economic features) that contribute to vulnerability. A focus group discussion, involving 15 residents from all zones and livelihood groups, was organized to understand the actions that individuals, households, the community and the city authorities are taking to reduce the negative impacts of climate change. These data sources were complemented by previous community enumerations conducted by People's Dialogue, one of the partners in this programme of work.

These enumerations indicate a high employment rate of 96%, with 85% of the employed population engaged in the informal sector. Most employment is located outside the settlement and income levels at Old Fadama can partly be attributed to its strategic location in an economically vibrant environment, located opposite the Agbogbloshie market. There are relatively high levels of illiteracy, with 44% of respondents being unable to read or write. Housing quality is poor and 34% of residents live in group-shared rooms – a form of living arrangement that with the inadequacies in provision for water and sanitation makes residents susceptible to communicable diseases. There are virtually no

domestic toilets and bathrooms, but residents can count a total of 101 public toilets and 153 commercial bathrooms. There is no formal arrangement for solid waste collection and disposal, with liquid and solid waste frequently being discarded into the nearby Korle Lagoon. Access to and quality of water is also a key determinant of vulnerability because of the direct bearing that it has on the health of the population.

Specifically in relation to vulnerability to climate-related hazards, poor housing conditions coupled with a lack of basic social and economic infrastructure and services means that residents frequently experience the impacts of flooding, excessive heat and fire outbreaks. Although not directly related to climate change, the outbreak of fire is considered to be the most frequently occurring and the most destructive hazard. Most of the areas in Accra that have suffered from previous flood events lie within the major valleys and lagoon outlets. Flood mapping in Old Fadama revealed water marks ranging from 50 cm to 1.1 m on 59% of the walls of respondents' houses. A quarter of the households interviewed lacked access roads around their houses making timely rescue efforts very difficult in the event of severe flooding and other hazards such as fire outbreak.

Housing type and building materials are particularly important in shaping the vulnerability of residents of Old Fadama. The standard practice of building in wood rather than in more permanent materials is attributed to both a lack of financial means and a general fear of eviction (meaning that the monetary value of investing in improved shelter would be lost). A cross tabulation between housing maintenance and expenditure revealed that a significant 7.5% of household income is spent on housing maintenance. The prevalence of single-room structures (more than 77% of households occupy these) and single occupancy rental accommodations in the community further shapes the residents' vulnerability and exposure to certain climatic and health hazards. In particular, the lack of sanitation facilities in homes (not a single one of the 100 households surveyed has a toilet in their home), and the unreliable operations of public facilities by private entrepreneurs increases the sensitivity of local residents, particularly of women.

Flooding has resulted in the destruction or loss of property for 68% of the surveyed respondents, although there is evidence that some occupations (for example street food vending) allow sufficient flexibility for individuals to earn profit during periods of emergency. No municipal or state institutions specializing in disaster/risk management were identified as collaborating with community groups in the community – about 95% of the households interviewed did not know of any institution, individual or group that makes decisions with respect to flood/fire prevention or early warning systems in the community. State-mandated institutions and city authorities only intervene in emergency situations when assistance is provided to disaster victims by means of relief items.

Appendix 2. Case summary: Natete Parish (Kampala, Uganda)

This report reviews the demographic, climatic, administrative and institutional context of Kampala, and how this contributes to the vulnerability of low-income urban residents. This forms the basis for a literature review of the characteristics of low-income informal settlements contributing to vulnerability, and a specific case study of three zones of Natete Parish in the city.

Demographic and climatic context

Kampala has a population of about 1.7 million (2011 estimate), growing at an average annual rate of 3.7%. At the same time, national GDP growth has slowed from 7.5% in 2005 to 3.5% in 2011-2012. While a growing proportion of the urban population is characterized as middle class, the majority (60%) of Kampala's population is either lower-middle or low-income. Livelihood strategies range from formal jobs and formal jobs with irregular pay to informal jobs, the latter being important not only as a source of income to residents but also to the urban economy as a whole.

Rainfall varies between 1,200-2,000 mm annually, with more variable and extreme climatic conditions predicted as a result of climate change. Extreme weather events have contributed to recent flooding, with substantial events in 2005 and 2007. In 2007, the Eastern region of Uganda received the heaviest rainfall in 35 years, resulting in significant drops in crop yields and destruction of infrastructure. In Kampala, flooding is becoming increasingly common, with detrimental effects on urban infrastructure including transportation systems, and on low-quality housing in low-income settlements.

Administrative and institutional context

The most recent political, institutional and administrative transition shaping Kampala has been the recentralization of the city's administration and management under the Kampala Capital City Authority (KCCA) Act. Previously the responsibility of municipal governments, infrastructure installation, procurement, planning and project implementation – which were previously the responsibility of municipal governments – have now been centralized at the KCCA level. The focus of urban development continues to be on spatial planning and 'traditional' sectors including markets, street lighting, garbage collection, revenue from commercial activities, property premiums, public transportation, health services and education services. Inadequate attention is paid to ecosystem services, energy and community welfare. A synthesis of KCCA policy documents and strategies indicates that despite projects being implemented in the city (e.g. through the UN Habitat Cities and Climate Change Initiative described below), climate change is not yet fully on the planning agenda.

Planning to reduce disaster risk in Kampala

KCCA in partnership with UN-Habitat's Cities and Climate Change Initiative undertook a vulnerability assessment followed by a number of pilot studies and interventions addressing climate change risks and resilience. In the light of recent political commitments to reduce climate-related risks, the expectation is that the new Authority will bridge issues of urban development, climate change and disaster risk reduction. Likewise, part of KCCA's institutional policy is cooperation with tertiary academic institutions and the development of new knowledge around innovation for urban development and resilience. Despite these efforts, comprehensive tools for climate resilience are yet to be developed.

A number of development initiatives which have been developed without an explicit focus on climate-related vulnerability may nonetheless make relevant contributions to reducing risk: these include the Kampala Urban Sanitation Project, Kampala Institutional and Infrastructure Development Project, and the Kampala Integrated Environmental Management Project (KIEMP). In particular, the 2001-2006 Local Government Development Programme installed secondary and tertiary drainage infrastructure in several neighbourhoods to improve surface runoff and reduce the risk of flooding. Several parishes in Kampala also acquired a considerable length of high-pressure water pipes connected to the city water supply system through this programme, which has helped to reduce outbreaks of cholera and dysentery in low-income settlements. Most projects and programmes of this type are addressing the development deficit rather than climate change risk – but, of course, many development-related needs are significant contributors to vulnerability. There has also been a shift from disaster response to disaster risk reduction focused on preparedness, recovery and knowledge generation. The national platform for disaster risk reduction provides coordination, analysis and advice on priority action, with membership from key government ministries, UN agencies, international NGOs and academia.

Informal settlements in Kampala

Informal settlements in Kampala are characterized by inadequate infrastructure and poor quality housing – an unsurprising situation given that the official housing deficit for the city is 100,000 units. The deficit is compounded by inadequate housing utilities including water, sanitation and energy. Economic activities in informal settlements include trade, services (charging phones, motor garages, laundry, internet cafes, mobile banking, transportation, rental housing), construction, education, health clinics, urban agriculture, waste resale and waste recycling. Extended social and safety networks provide a social infrastructure for mutual support in form of remittances or food flows within, between and beyond cities.

Many of the city's informal settlements are located on marginal land, usually the wetlands, meaning that flooding is a frequent and damaging hazard. Some coping methods have been devised such as redirecting storm water from houses and infilling of flat areas before housing construction, but as these are implemented in a haphazard manner the net effect is negligible.

Vulnerability in Natete Parish

Natete Parish is a low-income settlement situated in the western part of the city, in one of the low-lying areas of the south western drainage system of Kampala. The settlement is economically vibrant, with a mixture of residential and light industry developments. While contributing to economic activity, the presence of industry can also cause conflicts over access to land.

Natete's population is estimated at 15,000, although numerous households have chosen to relocate since 2008. The average household has six members, with about 12% of households being female-headed. These female-headed households mainly occupy rented tenements, which may also contribute to their vulnerability. Houses in the settlement are built with permanent materials of burnt bricks, cement screed floors and iron sheet roofs. They have two to three rooms, of which one/two are generally used for rental, hence generating income.

Natete is well connected to the Kampala water distribution network, but its quality is locally compromised by pipe breakage. Sanitation and drainage facilities are of poor quality: the area has one main drainage channel which receives storm water from the surrounding hills and is poorly maintained. The actions of industrial developers to protect their own properties from flooding can also worsen the flooding of residential properties. Community roads are poorly maintained, and garbage collection is inefficient owing to the intermittent and irregular collection schedules. Specifically in relation to climatic hazards, no early warning system is in place to mobilize local people in case of impending emergency.

Local residents make use of family and local social networks in order to reduce their sensitivity to climate and environmental hazards. A number of women's micro credit groups operate in the area providing collateral in form of property and emergency finance for flood-affected members. High residential mobility however threatens the sustainability of these groups. Physical interventions to houses are frequent to reduce exposure to flooding, and include barriers in doorways, raised verandas, doors, floors and roofs – but these modifications may be unaffordable for many households. Other interventions to reduce risk are identified by residents of the area, including construction of drainage channels, redesigning a local bridge, providing additional risk-reducing infrastructure and services, and implementing ecosystem-based adaptation activities.

Appendix 3. Case summary: Pikine (Dakar, Senegal)

The research in Pikine was undertaken by a team from ENDA Energy, a programme of ENDA Tiers Monde specializing in access to sustainable energy, adaptation to climate change and environmental governance. The team identified two neighbourhoods for case study research in Diamaguene Sicap Mbao, one of the 16 *communes d'arrondissement* in the city of Pikine. The core research team undertook 15 interviews with key informants, while 40 households were interviewed by community researchers. Eight focus groups were conducted, with four in each study location: these discussions were held separately with groups of women and men, each counting approximately 12 to 15 participants. In addition, a four-day training workshop was conducted with 10 members from local partner organizations and local journalists, with the intention both of finalizing the research tools to be used, and raising awareness about climate change more generally.

Two types of mapping were conducted: a dynamic community mapping and an institutional mapping. Dynamic mapping was used to identify the boundaries of the unit of analysis (Diamaguene-Sicap Mbao *commune d'arrondissement*), available biophysical resources and their spatial/geographical distribution both in the past and present. The institutional capacity mapping on the other hand was conducted to identify various institutions (both formal and informal), skills and assets within research area. This was to explore the existing capacities within the community and how they are used.

Environmental and climatic issues in Pikine

Dakar and Pikine are located in the Sahel region, and therefore experience low levels of rainfall (between 100 and 500 mm per annum) and an average temperature of 30°C. Apart from increased levels of precipitation and more severe storm events, the region is expected to suffer from intensified wind storms and rising temperatures as a consequence of climate change.

The geomorphology of Pikine consists predominantly of a dune system and low-lying areas – the *Niayes* – characterized by a high water table. This land was formerly used for farming, but over the past 40 years has been urbanized, and suffers from increased incidents of flooding. Pikine's coastal zones are increasingly subject to coastal erosion, attributed both to sea-level rise as well as the removal of beach sand as a consequence of a decade-long construction boom.

One of the approaches chosen as a lens for understanding local vulnerability was to examine the changes between 1970 and 2012 in the availability and quality of local natural resources. Degradation in water and soil quality, and the gradual decline in green spaces were identified as key issues by members of the research team – but were not perceived of as such by members of local community-based organizations. Between 1970 and 1980, water was considered to be abundant and of good quality, and was available

from a large number of traditional drinking water wells. These conditions deteriorated by 1990 and current surface as well as ground water are deemed highly polluted. Similarly, while parts of the neighbourhood Darou Salam had been used for vegetable and fruit farming until about 15 years ago, at present there is only one agricultural zone left in the area. These changes impact local food security, income generation and the infiltration capacity of the soil.

Demography and economy of Pikine

Over the past 15 years, Pikine's population is estimated to have doubled from approximately 786,000 (in 1998) to approximately 1.6 million in 2012 (ANSD, 2010). While the national average urban household size is 9 members, a sample of Pikine's households (both in informal and formal areas) showed that there may be up to 17 members per housing unit. Large households are generally headed by older men while young men increasingly tend to leave the family house and rent rooms within the local area.

A majority of Pikine's population before 1960 consisted of residents evicted from Dakar. The zone included agricultural land and industrial sites. During the 1970s and 1980s, these peri-urban zones accommodated a majority of rural migrants seeking alternative livelihoods during prolonged periods of drought. From 1985, new neighbourhoods developed consisting of cooperative and private housing as well as informal settlements. A number of informal settlements were included in redevelopment and land titling project supported by GTZ and a designated agency, Fondation Droit à la Ville.

The majority of housing in Pikine is built with permanent materials, yet the quality of the cement used for self-built housing is considered poor. While some basic infrastructure for liquid waste and drainage exists in regularized neighbourhoods, the provision is poor in informal settlements. Some 90% of households in informal parts of Pikine rely on in-house pit latrines. Only 40% of waste water is systematically treated at the level of the Dakar region. Limited access to settlements means that solid waste collection is irregular, and that waste is frequently disposed of in flood-damaged and abandoned houses.

The Pikine City Hall reported an employment rate of 27.4% in 2007. Informal employment in commerce, artisanal production and the provision of transportation services constitutes the major source of livelihood for local residents; while both formal and informal employment opportunities are available in Pikine's industrial zone. A number of major markets are located in Pikine allowing for dynamic commercial links with businesses located in the Dakar region and the rest of the country, including the central market of Thiaroye (diverse products), the Syndicat (fruit and vegetables), Pikine fish market and the Mbao fair (livestock). Urban agriculture is practiced within the

wetland areas of the Niayes, while artisanal and industrial fishing provide further livelihood options and women are increasingly engaged in small-scale commerce.

Households in Pikine spend more than half of their expenditure on food, and a further 40% on electricity, water, cooking fuel, transport and communication costs (ANSD, 2008). More than half of households stated that they have received support from family or neighbours in the form of financial assistance or food, and more than half of households had access to credit. Traditional women's savings groups are the most frequent form of mutual support, providing access to finance, food or household items.

The impacts of disasters

Based on the timelines discussed during focus groups, the first substantial flooding in areas of Pikine took place in 1989, and resulted in numerous households having to relocate. In 1999, a second large flood emergency occurred, but flooding has only been an annual occurrence since 2005. The patterns of flooding are influenced by barriers such as newly constructed roads (including a major toll highway) and sand filling of streets by individual households. Apart from flood events, intense wind storms have also led a number of households to relocate. In addition to the cost of maintenance or relocation, households face psychological stress associated with families being divided in the process of relocation, which particularly affects the wellbeing of children (including their ability to attend school).

According to the *Assessment Report on Flooding in Dakar* (GoS, 2009), the peri-urban areas of Pikine and Guediawaye were the most affected in the region of Dakar: 44% of the population were affected (360,000 persons) in Pikine, and 7.2% (22,000 persons) in Guediawaye. In Pikine and Guediawaye, 30,000 houses and 130 schools were inundated. In these peri-urban areas, the estimated cost of the 2009 inundations is US$42 million in damage and US$40 million in loss of property. Between the first major flooding in 2005 and late 2009, a total of 3,350 houses were abandoned, with 1,500 of these having been abandoned since the summer of 2009. Local researchers counted 72 houses abandoned in the neighbourhood of Darou Salam, 200 in Sam-Sam Dimath and 17 in Missirah Diamaguène.

Social infrastructure such as schools, markets and health centres suffer from closures due to periodic flooding. Commercial activity is therefore frequently relocated onto street level, which creates conflict among local residents, pedestrians and the business community. Costs associated with flooding include the need to purchase materials for house maintenance, the cost of sand for infilling, the cost of medicine for people who have taken ill, and higher food prices. In response to increased living costs, household members may engage in alternative income generation such as small commerce. Women are increasingly involved in (night) street selling of hot foods and basic food stuffs.

In response to flooding, local youth and development associations carry out physical risk-reducing activities including the digging of temporary drainage canals. While street filling by individual families may reduce their own risk, this frequently results in the dislocation of flood waters into neighbouring areas. The cost of pumping of flood water (pumps and fuel) is co-financed through community contributions and local government allocations. Although it is generally believed that the sole solution to widespread flooding is state-built underground drainage, only a limited number of neighbourhoods in the vicinity of major transport routes have benefited from drainage systems connected to a major network. A large number of community organizations are active in the area, including women's groups, religious groups, savings groups, local communities specialized in the provision of basic services, and local youth associations. Numerous projects are undertaken by international NGOs.

Based on interviews undertaken with local government representatives, it is believed that there are no policies or national programmes aimed at addressing flooding in the area. City-wide and local development planning instruments are partially aimed at addressing local vulnerability. A strategic plan for Grand Dakar 2025 under the auspices of City of Dakar and the Dakar Regional Council with technical support from the Regional Development Agency, civil society organizations and research institutions aims for a sustainable development framework but offers a limited basis to address climate-related risk.

Appendix 4. Approach for assessing climate change trends and projections

The information presented in Section 3.2 is based on weather station observations of daily rainfall and temperature at the locations indicated. The raw data have been quality controlled to attempt to remove as many errors as possible, but some errors may remain undetected, although the impact of these errors should be small. The greatest problem with the station observations is long periods of missing data, which is of particular concern for the historical trend analysis. The trend analysis methodology provides an estimate of the uncertainty of the trend for each month of the year and these estimates should be seriously considered when drawing conclusions from the results.

The advantage of using weather station observations is that they generally represent the most consistent and unbiased time series of daily data for particular locations. Alternatives such as satellite and reanalysis products can introduce significant regional and weather system–specific errors that are difficult to account for. In addition, satellite-based products to not provide good estimates of near surface air temperature. Finally, satellite products generally only provide up to 15 years of data, which limits the robustness of historical trend analysis.

Trend analysis

The trend analysis used is that of the median of pairwise slopes (Hoaglin *et al.*, 1983). This method calculates the trend between every data point and every other data point in the series and uses the median of the resultant discrete distribution as the best estimate of the actual trend. The advantage of this method is that it is less vulnerable to being skewed by outliers at the ends of the time series. It also allows for an analysis of the spread of the distribution of trends, which is a good indication of the robustness of the trend. In the plots presented, the monthly statistics are grouped by month of the year and the resultant data series used to produce the median of pairwise slopes statistic. The result is an estimate of the trend of the monthly statistics for each month of the year. This allows trends to be explored as a function of seasonality, which often identifies features such as shifts in seasonal peaks and the onset and cessation of rainy periods.

It is important to note that the required observed period for trend analysis is 30 years. This is in order to ensure that trends are not too strongly influenced by decadal time scale variability or periodicity. This is quite a strong restriction and for the three cities in question, only Dakar (Thies) had sufficient data to produce a trend analysis.

Downscaled projections

The downscaled projections presented below have been produced by the SOMD (Self-Organizing Map Downscaling) method described in Hewitson and Crane (2006). This is an empirical downscaling method based on synoptic typing with stochastic variance. The

advantages of this method are that the predictor variables used to describe synoptic states are variables such as geo-potential height, upper air moisture and mid-level winds. These variables are generally well captured by GCM simulations of historical climates, whereas variables such as rainfall are generally poorly captured by GCM simulations as such variables are highly vulnerable to course scale parameterizations of rainfall processes as well as course representation of topography and land use in the GCMs.

The projections are based on the Representative Concentration Pathways (RCP) 8.5 scenario for the period 2020-2040. This RCP aligns itself with fairly high future emissions. The projections are presented as projected changes for the mean of the 2020-2040 period from the mean of the 1980-2000 period for each month of the year.

Urban flooding and climate

Flooding is a complex phenomenon and urban flooding even more complex. The approach taken here is simplistic. Flooding in a particular location is a function of a wide range of variables and parameters including river and catchment characteristics, upstream rainfall, antecedent soil moisture conditions, and local natural and manmade structures. However, for this brief analysis, only heavy rainfall events are explored either through a count of days in a month that experience greater than the 95^{th} percentile of the distribution of daily rainfall totals, or experience greater than 20 mm, depending on the quality of data available. While this is simplistic, it is indicative at least of the tendency towards more intense rainfall which is an important driver of flooding, especially in the urban context. A more complete analysis would explore the specific weather conditions leading up to historical flooding events in a particular urban area. This would provide key insights into the climate drivers of flooding and enable a more robust exploration of future risk.

Ensemble projections and uncertainty

The projections have been downscaled from 11 Coupled Model Intercomparison Project (CMIP) 5 GCMs. This is only a subset of the approximately 30 GCMs contributing to the CMIP5 archive. However, only these 11 models provide the daily synoptic data archives that are required for the SOMD downscaling methodology. It is unclear without further analysis for each location where these 11 models fall within the broader spectrum of models; however it is assumed that the spread represented is fairly similar to the full spread across all models.

Uncertainty is a complex subject and can be approached and dealt with in numerous ways. The approach taken here is the approach of model agreement. It is assumed that if downscaled projections across multiple models all show similar directions of change for the future then there is fairly high certainty. Conversely, strong disagreement indicates strong uncertainty. Clearly there are numerous questions and arguments surrounding this approach. It should not be assumed that strong model agreement indicates strong

probability of occurrence as all models could be simultaneously wrong. However, with no better alternative, model agreement remains the simplest approach to grasping uncertainty in multi-model projections.

Caveats and limitations

The SOMD downscaling method produces conservative downscaled time series in that all changes are a function of changes in the frequency of historically-identified synoptic climate states. The method cannot produce daily values that fall outside of the range of observed daily values for a particular location. This is common to most empirical downscaling methods. Given current understanding of a warmer climate and extreme rainfall in the tropics, it is therefore likely that the SOMD method does not represent the possible increase in magnitude of daily extreme events in the future.

The consequence is that future extremes greater than observed can only be captured if they are the result of multi-day synoptic sequences. Single-day extremes greater than observed cannot be produced. However, even if the magnitudes of the new extremes are not well-captured, an associated increase in frequency of observed extremes can be examined and provide a useful proxy measure.

Bibliography

ANSD (2008), *Situation économique et sociale dans la région de Dakar de l'année 2008*, Agence Nationale de la Statistique et la Démographie, Ministère de l'économie et des finances, Dakar.

ANSD (2010), *Estimation de la population du Sénégal*. Agence Nationale de la Statistique et de la démographie, Ministère de l'économie et des finances, Dakar.

Baller, S. (2007), "Transforming urban landscapes: soccer fields as sites of urban sociability in the agglomeration of Dakar", *African Identities*, 5(2), pp.217–230.

Baptist, C., J. Bolnick (2012), "Participatory enumerations, in situ upgrading and mega events: the 2009 survey in Joe Slovo, Cape Town", *Environment and Urbanization,* 24(1): 59-66.

Bicknell, J., D. Dodman, D. Satterthwaite (2009), *Adapting Cities to Climate Change*, Earthscan, London.

Blaikie, P., T. Cannon, I. Davis, B. Wisner (1994), *At Risk: natural hazards, people's vulnerability and disasters*, Routledge, London.

Cannon, T. (2000), *Vulnerability analysis and disasters*, Routledge, London.

Ciplet, D., S. Fields, K. Madden, M. Khan, T. Roberts (2012), *The eight unmet promises of fast-start climate finance*, IIED Briefing, November 2012. Available online: http://pubs.iied.org/pdfs/17141IIED.pdf

CLUVA (2013), *Climate change and vulnerability of African cities - Research briefs* (Addis Ababa, Dar Es Salaam, Douala, Ouagadougou, Saint-Louis), edited by P. Gasparini, A. Di Ruocco, A.M. Bruyas, AMRA S.c.ar.l., Naples. Climate change and Urban Vulnerability in Africa (CLUVA). [online URL:: bit.ly/1eY4SKr]

Dodman, D., D. Brown, K. Francis, J. Hardoy, C. Johnson, D. Satterthwaite (2013), *Understanding the nature and scale of urban risk in low- and middle-income countries and its implications for humanitarian preparedness, planning and response*, IIED Human Settlements Discussion Paper Series, Climate Change and Cities 4. [online URL: http://pubs.iied.org/10624IIED.html]

Dodman, D., D. Satterthwaite (2008), "Institutional Capacity, Climate Change Adaptation and the Urban Poor", *Institute for Development Studies Bulletin* 39(4): 67-74.

Doswald, N., R. Munroe, D. Roe, A. Giuliani, I. Castelli, J. Stephens, I. Möller, T. Spencer, B. Vira, H. Reid (2014), "Effectiveness of ecosystem-based approaches for

adaptation: review of the evidence base", *Climate and Development,* DOI: 10.1080/17565529.2013.867247.

Douglas, I., K. Alam, M. Maghenda, Y. Mcdonnell, L. Mclean, J. Campbell (2008), "Unjust waters: climate change, flooding and the urban poor in Africa", *Environment and Urbanization* 20(1): 187-205.

Farouk, B., M. Owusu (2012), "'If in doubt, count': the role of community-driven enumerations in blocking eviction in Old Fadama, Accra", *Environment and Urbanization* 24(1): 47-57.

Frayne, B. *et al.* (2010), *The State of Urban Food Insecurity in Southern Africa*, Urban Food Security Series No. 2. Queen's University and AFSUN, Kingston and Cape Town.

GNDR (2013), *Views from the frontline (VFL): Beyond 2015*. Global Network of Civil Society Organisations for Disaster Reduction. [online URL: http://www.globalnetwork-dr.org/views-from-the-frontline/vfl-2013.html]

GoS (2009), *Needs Assessment Report on Flooding in Dakar*, Government of Senegal, Dakar.

Green, J., O.L. De Weck, P. Suarez (2011), "Sustainable urban sanitation: simulating a desludging service in Senegal", in *POMS 23rd Annual Conference,* Chicago.

Guzmán, J., D. Schensul, S. Zhang (2013), "Understanding vulnerability and adaptation using census data", in Martine, G., D. Schensul (eds.), *The Demography of Adaptation to Climate Change*, UNFPA, IIED and El Colegio de México, New York, London and Mexico City.

Hardoy, J., G. Pandiella (2009), "Urban poverty and vulnerability to climate change in Latin America", *Environment and Urbanization,* 21(1): 203-224.

Hebbert, M., V. Jankovic (2013), "Cities and climate change: the precedents and why they matter", *Urban Studies* 50(7): 1332-1347.

Hewitson, B., R. Crane (2006), "Consensus between GCM climate change projections with empirical downscaling: precipitation downscaling over South Africa", *International Journal of Climatology* 26: 1315-1337.

Hoaglin, D., F. Mosteller, J. Tukey (1983), *Understanding Robust and Exploratory Data Analysis*, Wiley, New York.

IFRC (2010), *World Disaster Report: Focus on Urban Risk*, International Federation of Red Cross and Red Crescent Societies, Geneva.

IPCC (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC (2012), "Summary for Policymakers", in Field, C.B., *et al.* (eds.) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation,* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge and New York.

ISET (2011), *Catalyzing Urban Climate Resilience: applying resilience concepts to planning practice in the ACCCRN Program (2009-2011),* Institute for Social and Environmental Transition, Boulder.

Jeans, H. *et al*. (2014), "The role of ecosystems in climate change adaptation: lessons from scaling up", in Schipper, L., *et al.*, (eds.), *Community-Based Adaptation to Climate Change,* Routledge, pp. 253–266, London.

Kamete, A. (2012), "Missing the point? Urban planning and the normalisation of 'pathological' spaces in southern Africa", *Transactions of the Institute of British Geographers,* Early online edition, DOI: 10.1111/j.1475-5661.2012.00552.x.

Karanja, I. (2010), "An enumeration and mapping of informal settlements in Kisumu, Kenya, implemented by their inhabitants", *Environment and Urbanization,* 22(1): 217-239.

Livengood, A., K. Kunte (2012), "Enabling participatory planning with GIS: a case study of settlement mapping in Cuttack, India", *Environment and Urbanization*, 24(1): 77-97.

Lwasa, S. (2013), "A Worldview of Urban Nature that includes 'Runaway' Cities", *Nature of Cities* blog post by Shuaib Lwasa (6 November 2013). [online URL: http://www.thenatureofcities.com/2013/11/06/a-worldview-of-urban-nature-that-includes-runaway-cities/

Makau, J., S. Dobson, E. Samia (2012), "The five-city enumeration: the role of participator enumerations in developing community capacity and partnerships with government in Uganda", *Environment and Urbanization*, 24(1): 31-46.

McGranahan, G., D. Balk, B. Anderson (2007), "The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones", *Environment and Urbanization,* 19(1): 17-38.

Mitlin, D. (2013), *Locally managed funds: a route to pro-poor urban development,* IIED Briefing, May 2013. [online URL: http://pubs.iied.org/pdfs/17154IIED.pdf]

Mitlin, D., D. Satterthwaite (2007), "Strategies for grassroots control of international aid", *Environment and Urbanization,* 19(2): 483-500.

Mitlin, D., D. Satterthwaite (2012), *Urban Poverty in the Global South: Scale and Nature*, Routledge, Abingdon.

Mora, C., A. Frazier, R. Longman, R. Dacks, M. Walton, E. Tong, J. Sanchez, L. Kaiser, Y. Stender, J. Anderson, C. Ambrosino, I. Fernandez-Silva, L. Giuseffi, T. Giambelluca (2013), "The projected timing of climate departure from recent variability", *Nature,* 502: 183-187 (10 October 2013).

Moser, C., A. Stein (2010), *Implementing Urban Participatory Climate Change Adaptation Appraisals: a methodological guideline*, Global Urban Research Centre Working Paper 5, University of Manchester.

Muller, A., E. Mbanga (2012), "Participatory enumerations at the national level in Namibia: the Community Land Information Programme (CLIP)", *Environment and Urbanization,* 24(1): 67-75.

Mulyana, W., I. Setiono, A. Kracker Selzer, S. Zhang, D. Dodman, D. Schensul (2013), *Urbanisation, Demographics and Adaptation to Climate Change in Semarang, Indonesia*, International Institute for Environment and Development, Urbanization and Emerging Population Issues Working Paper 11.

Odeye-Finzi, M. (1985), *Les associations en villes Africaines*, L'Harmattan, Paris.

Patel, S., C. Baptist, C. d'Cruz (2012), "Knowledge is power – informal communities assert their right to the city through SDI and community-led enumerations", *Environment and Urbanization,* 24(1): 13-26.

Patz, J.A., D. Campbell-Lendrum, T. Holloway, J.A. Foley (2005), "Impact of regional climate change on human health", *Nature*, *438*(7066), 310–7. doi:10.1038/nature04188.

Pharoah, R. (2009), "Fire Risk in Informal Settlements in Cape Town, South Africa", in Pelling, M., B. Wisner (eds.), *Disaster Risk Reductions: Cases from Urban Africa*, Earthscan, London.

Potts, D. (2012), *Whatever happened to Africa's rapid urbanization*?, Africa Research Institute, London. [online URL: http://www.africaresearchinstitute.org/podcast/whatever-happened-to-africas-rapid-urbanisation-2/]

Rakodi, C., C. Leduka (2004), *Informal Land Delivery Processes and Access to Land for the Poor: A Comparative Study of Six African Cities*, International Development Department, University of Birmingham.

Roberts, D. (2010), "Prioritizing climate change adaptation and local level resilience in Durban, South Africa", *Environment and Urbanization,* 22 (2): 397-413.

Romero-Lankao, P., H. Qin (2011), "Conceptualizing urban vulnerability to global climate and environmental change", *Current Opinion in Environmental Sustainability*, 3(3), pp.142–149.

Rosenzweig, C., W. Solecki, S. Hammer, S. Mehrotra S (eds.) (2011), *Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network*, Cambridge University Press.

Satterthwaite, D. (2011), "What role for low-income communities in urban areas in Disaster Risk Reduction?", Background Paper for the UN-ISDR *Global Assessment Report*. [online URL: www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Satterthwaite_2011.pdf]

Satterthwaite. D. (2013), "Eight points on financing climate change adaptation in urban areas", IIED blog post (20 June 2013). [online URL: http://www.iied.org/8-points-financing-climate-change-adaptation-urban-areas]

Schensul, D., D. Dodman (2013), "Populating adaptation: incorporating population dynamics in climate change adaptation policy and practice", in Martine, G., D. Schensul (eds.), *The Demography of Adaptation to Climate Change*, UNFPA, IIED and El Colegio de México, New York, London and Mexico City.

Simone, A. (2004a), *For the city yet to come: changing African life in four cities*, Duke University Press, Durham.

Simone, A. (2004b), "People as Infrastructure: Intersecting Fragments in Johannesburg", *Public Culture*, *16*(3), 407–429.

Smith, B., D. Brown, D. Dodman (2014), *Reconfiguring Urban Adaptation Finance*, IIED Working Paper, IIED, London. [online URL: http://pubs.iied.org/10651IIED]

Tacoli, C. (2013), *Urban poverty, food security and climate change*, Briefing Papers, IIED, London.

Tacoli, C., B. Bukhari, S. Fisher (2013), *Urban poverty, food security and climate change*, Human Settlements Working Papers Series on Rural-Urban Interactions and Livelihood Strategies, No. 37, International Institute for Environment and Development (IIED), London.

Tyler, S., M. Moench (2012), "A framework for urban climate resilience", *Climate and Development*, 4(4), pp.311–326.

UN Habitat (2003), *The Challenge of Slums*, Global Report on Human Settlements, United Nations Human Settlements Programme, Earthscan, London.

UN Habitat (2011), *Cities and Climate Change,* Global Report on Human Settlements, UN-Habitat, Nairobi.

UNISDR (2009), *Global Assessment Report on Disaster Risk Reduction: Risk and Poverty in a Changing Climate,* ISDR, United Nations, Geneva.

UNISDR (2011), *Revealing Risk, Redefining Development: The 2011 Global Assessment Report on Disaster Risk Reduction,* United Nations International Strategy for Disaster Reduction, Geneva.

United Nations Population Division (2011), *World Population Prospects: The 2010 Revision and World Urbanization Prospects: The 2011 Revision*, United Nations Department of Economic and Social Affairs (UN-DESA).

Wallace, D., R. Wallace (2008), "Urban Systems during Disasters: Factors for Resilience", *Ecology And Society*, *13*(1), 18. [online URL: http://www.ecologyandsociety.org/vol13/iss1/art18/]

Washington Post (9 October 2013), "These are the cities that climate change will hit first". [online URL: http://www.washingtonpost.com/blogs/worldviews/wp/2013/10/09/map-these-are-the-cities-that-climate-change-will-hit-first/]

WHO (2002), *The World Health Report 2002 – Reducing Risks, Promoting Healthy Life,* The World Health Organization.

WHO (2007), *World Health Report 2007 – A safer future*: *global public health security in the 21*st *century,* The World Health Organization.

Wilbanks, T. *et al.* (2007), "Industry, settlement and society" in Parry, M. *et al.* (eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the *Fourth Assessment Report* of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.