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Climate Change Vulnerability in Southern African Cities

Building Knowledge for Adaptation

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Foreword

I am delighted to introduce this landmark volume focusing specifically on the challenges of climate change in the southeastern African context, where vulnerabilities are high and resources and preparedness still very limited in all but a few specific locations. In a region affected by decades of structural adjustment and deepening poverty, the recent economic upturn, driven in significant part by a resources boom, has renewed foreign investor interest and begun to reverse the legacy of 'de-development'. Its impact, however, remains highly unequal, both geographically and socially, being concentrated overwhelmingly in a few select areas of capital and commercial cities, along narrow transport corridors and (outside of South Africa) in the hands of elites and small professional classes. Despite some promising signs, including of greater governmental transparency and accountability, few of the Millennium Development Goals will be achieved and poverty remains entrenched.

In other words, institutional capacity and public resources generally remain seriously inadequate for addressing the diverse and long-standing development challenges and priorities. Many governments are still seeking to catch up with implementation backlogs from the lean years through flexible combinations of domestic investment and concessionary official development assistance. As climate or broader environmental change began rising rapidly up the global agenda over the last 10–15 years, it is unsurprising that African responses were mostly cautious and even sceptical. Unlike 'climate sceptics' in wealthy countries, however, this had little to do with doubting the science or related projections; rather it reflected a combination of several factors. First, the science—as expressed, for instance, in global climate models—was often not understood. Second, in situations where many people go hungry and meeting basic needs was again being prioritised, there was little obvious political or practical mileage in diverting scarce resources towards addressing problems that were still generally modest but likely to become severe in several decades' time. Finally, it often seemed hypocritical of OECD leaders to be asking (or requiring through aid conditionalities) their counterparts in poor countries to tackle deforestation and greenhouse gas emissions for the global good when OECD countries had grown rich through polluting and resource-intensive industrialisation.

Indeed, this perception has been sufficiently widespread and politically convenient to have underpinned the negotiating position of the G77 group of poor

countries over the replacement of the Kyoto Protocol of the UN Framework Convention on Climate Change (UNFCCC). They have been arguing for the establishment of a sizeable global adaptation fund by OECD countries to support climate-friendly and sustainable development in exchange for action to tackle climate change. Nevertheless, over the last decade, most governments have adopted National Adaptation Plans of Action (NAPAs) or similar strategies that demonstrate increasing acceptance of the realities of climate change and the necessity of putting in place frameworks to address it. Recently, too, the East African Community and Southern African Development Community have focused attention on the transboundary nature of many of the key climate and environmental challenges which require regional-scale programmatic interventions (Simon 2012).

One conspicuous feature of virtually all of these national and (sub-)regional strategies is their framing in undifferentiated national terms and then an almost total focus on traditional sectoral and rural interventions, while neglecting or omitting explicit attention to the urban dimension. This is ironic because urban areas are everywhere becoming more important demographically and economically. Even in the less urbanised countries of southeastern Africa, towns and cities represent the densest concentrations of population, resource use, economic opportunity, wealth generation and emissions production. Wealth and poverty stand in sharp, spatially defined juxtaposition and, to be sure, the rich and poor have very different livelihood and emissions profiles. Nevertheless, both are potentially problematic in different ways. While the conventional focus is on car and industrial emissions, in poor urban communities smoke generated by burning wood or charcoal contributes significantly on account of the number of such fires. This smoke is also a major cause of chronic respiratory illness as a result of long-term inhalation in confined spaces within unventilated or poorly ventilated dwellings. The loss of woody biomass in peri-urban and increasingly in distant rural areas to supply urban demand, through what is often now a highly commoditised and large-scale industry, is also contributing to the land-use cover change and the loss of important carbon sinks in those source areas.

Projections of rising temperatures and falling and increasingly variable and unpredictable rainfall across much of Sub-Saharan Africa have become clearer in successive assessment reports of the Intergovernmental Panel on Climate Change (IPCC). Indeed conditions are already changing and are starting to reduce the growth and regeneration rates of woody biomass on which rural and much urban energy demand relies, as well as posing increasing food security challenges, including for urban areas. The complexity of these examples highlights the need for appropriate and collaborative action by a range of institutions and actors, of which urban local authorities are but one—albeit vitally important—category.

Against the background sketched above, a few cities in southern Africa—and especially South Africa's metropoles of Durban, Johannesburg and Cape Town—have taken the lead in assessing, articulating and starting to address the range of issues under the climate change umbrella. They are, therefore, far ahead of the national government. Key to their efforts has been the catalytic role played by

well-informed individual 'champions' in senior environmental or political positions able to raise and maintain the focus, and to explain the local implications of broader processes, and how cities would benefit from addressing rather than neglecting climate change through integrating climate change concerns with ongoing 'normal' infrastructural or development activities. Comprehensive accounts of climate change strategies at the city scale are now beginning to emerge through local governments' own efforts in collaboration with university or local consultancy partners (ASSAf 2011; Cartwright et al. 2012).

Such purely endogenous initiatives are not possible for the majority of towns and cities which lack the personnel, institutional capacity and resources for more than incipient efforts (Simon 2010; Carmin et al. 2012). External support through bilateral donors, multilateral agencies such as UN-HABITAT's Cities and Climate Change Initiative (CCCI) and institutional partnerships with foreign researchers is, therefore, essential. Such is the nature of the important and innovative research reported in this stimulating volume, which will surely become a benchmark for understanding the challenges of climate change and how to address them in Dar es Salaam and Maputo, with additional chapters on Dakar and Mozambique's Caia District. As the editors explain in their Preface, the research was undertaken largely under the umbrella of two Italian-funded collaborative projects with local authorities, academics, CCCI staff and others in Dar and Maputo. The chapters cover biophysical dimensions of environmental change, socio-economic assessments of hazard vulnerability to the most important dimensions of climate change (especially flooding and saltwater intrusion), and analyses of coping capacity and the difficulties involved in mainstreaming climate change adaptation. The authors are well versed in the current international literatures from academic and more practice-based sources, and integrate their own research effectively in this context, ensuring that the book does much more than simply local gap-filling in terms of case studies. I am confident that this volume will find its place at the forefront of the expanding literature on assessing and addressing urban climate/environmental change in Africa and beyond.

Egham, UK David Simon

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Preface

This book was written to bridge a gap that we believe is still affecting the scientific literature on climate change in Southern Africa, namely the lack of understanding of hazards and the impact they have on areas prone to them, of the local population's capacity to adapt and local authorities' ability to respond, not to mention the methods used to estimate levels of risk and vulnerability, factors that are useful when planning adaptation to climate change in large cities.

This book is the product of work done by two research teams created by a partnership between Italian universities and African institutions. One of these teams, based at the Interuniversity Department of Regional and Urban Studies and Planning (DIST) of the Politecnico di Torino, is run by Maurizio Tiepolo. Its members include Sarah Braccio, Antonio Cittadino, Magueye Diop, Francesco Fiermonte, Diéthié Ndiaye, Pamoussa Ouedraogo, Enrico Ponte and Stefania Tamea. The other team, based at Sapienza University of Rome's Department of Civil, Building and Environmental Engineering (DICEA), is run by Silvia Macchi and is comprises of 20 researchers from Italy and Tanzania, including Francesco Cioffi, Luca Congedo, Giuseppe Faldi, Laura Fantini, Michele Munafò, Liana Ricci, Matteo Rossi, Giuseppe Sappa, as well as Gabriel Kassenga and Dionis Rugais from Dar es Salaam's Ardhi University.

In May 2010, the two groups joined forces to present the research project entitled *Assessing, Planning and Managing the Territory and the Environment Locally in Sub-Saharan Africa* at the Italian Ministry for University and Scientific Research as part of the call for Research Projects of National Interest (known by the Italian acronym PRIN). The project was co-financed in July 2011 (no. 2009SX8YBH) and developed from August 2011 to October 2013 under the supervision of Maurizio Tiepolo.

In the first few months of work, it quickly became clear that urban vulnerability to climate change was a growing environmental concern in Southern Africa. It was felt that in order to make the comparison clearer, it would be useful to identify case studies involving similar hazards, i.e. sources of potential harm in terms of human injury and damage to health, property, the environment and other things of value. Moreover, when it came to this particular issue, we felt it would be best to choose cases of exposure to effects caused by multiple hazards, such as the floods caused by extreme rains and sea-level rise in dense urban areas, or groundwater salinization resulting from the combined effect of decreasing rainfall and increasing

temperature as well as soil sealing in peri-urban areas. The large coastal cities of Maputo, the capital of Mozambique, (Politecnico di Torino) and Dar es Salaam, Tanzania's largest city (Sapienza University of Rome) were therefore selected.

The results of the preliminary studies conducted by the two research teams were presented at the international Urban Impact of Climate Change in Africa (UICCA) conference, organised in partnership with Turin's provincial government on 16 November 2011 in Turin. Other Italian research centres studying climate change adaptation in Sub-Saharan Africa were invited to attend (the IBIMET-CNR National Research Council's Institute of Biometeorology of Italy, Venice's IUAV Istituto Universitario di Architettura, the University of Florence, and the University of Trento), as well as many Italian local authorities and ministerial departments, so as to broaden the discussion increase opportunities for debate and raise awareness of this issue among the many different levels of cooperation (bilateral and decentralized).

After the conference, this book began to take shape and later saw a further opportunity for verification at the international workshop entitled 'Towards Scenarios for Urban Adaptation Planning: Assessing Seawater Intrusion Under Climate and Land Cover Changes in Dar es Salaam', organized at Sapienza University of Rome on 20–22 April 2013.

The contents of this book range from the assessment of risks associated with climate change to the adaptation strategies for reducing vulnerability in two of the most populated cities on the eastern coast of Africa: Dar es Salaam (4.4 million inhabitants) and Maputo (2.4 million). These two main case studies were supplemented by two complementary studies on Dakar (2.9 million) and the Caia district in Mozambique (Fig. 1).

The conceptual frameworks for disaster risk management and climate change adaptation in the scientific literature as well as in those produced by the main multilateral and bilateral development aid agencies are clarified. Next, the assessment methods and applications concerning the various different factors involved are presented, adapted to situations where information is often lacking or where information is scattered and access to it is limited. We believe this is why this book is so ground-breaking compared to the publications currently available on urban adaptation to climate change in Africa. If this achievement has been attained, it is thanks to the in-depth knowledge of sources of information, combined with the great efforts made to fill gaps by obtaining new data, and thanks also to the practical goal of this research, namely to provide urban authorties with the risk analysis and adaptation planning tools necessary to diminish local vulnerability to climate variability and change.

This approach makes the book particularly useful to graduate students, researchers, and practitioners interested in enhancing their knowledge and skills as regards integrating climate change into applied research and development projects in urban Africa.

The book begins with two introductory chapters that review the current state of adaptation to incremental climate stress (Chap. 1) and flood risk reduction and

Fig. 1 The 42 largest cities south of the Sahara in 2010. Over 6 million inhabitants (*very large dot*), 4–5 million (*large dot*), 2–3 million (*medium dot*), 1–2 million (*small dot*) (formulated by E. Ponte based on data published by UN-Habitat's State of the World's Cities 2012/2013. Prosperity of Cities, 2012)

climate change (Chap. 2) in urban studies. The body of the book then presents relevant case studies (Chaps. 3–14), followed by conclusions and recommendations (Chap. 15).

Chapter 1 (Macchi) examines the issue of adaptation planning in cases where incremental stress on systems of natural resources is foreseen due to the combined effects of climate change and a series of other factors of environmental decay, such as urban sprawl. The chapter particularly tackles the vulnerability of access to water caused by the continued degradation of water sources in peri-urban coastal areas of large Sub-Saharan cities. After situating the issue of adaptation within the international discourse on responses to global warming, the specific spatial context under examination is introduced, together with the guiding concept for vulnerability assessment: the adaptive capacity of inhabitants. In addition, three theoretical pillars for adaptation planning are explored: uncertainty as an opportunity for

an unfettered vision of the city's future; the centrality of incremental environmental stress in assessment of vulnerability to extreme weather and climate events; and crossing boundaries within science and between science and society for an effective and equitable definition of the problem.

Chapter 2 (Tiepolo) illustrates flood risk reduction following extreme physical events attributable to climate change in large cities south of the Sahara. Large cities are understood here as those with a population greater than one million inhabitants, and the term 'extreme physical events' refers to those events whose likelihood in a given place and time is in the 90th percentile. The main hazard that increasingly hits cities south of the Sahara is flooding. In coastal cities, this is caused by extreme rainfall and sealevel rise. The chapter assesses whether there is enough information available to assert—as the literature currently does—that urban flooding is caused by climate change. The scale of flooding and its impacts are then examined. Finally, the current state of knowledge concerning adaptation measures is presented, with a particular focus on strategies and local adaptation plans. Overall, our results have revealed several commonly held misconceptions in the field of adaptation. In particular, understanding of the mechanisms that cause flooding has proven to be virtually non-existent, a gap that makes it difficult to develop and identify adequate adaptation measures, from early warning to stormwater drainage. In addition, the knowledge of adaptation plans and the development of uniformly applied best practices is less advanced than expected. Adaptation plans have been adopted by few large cities, and those that are in place demonstrate considerable heterogeneity, despite years of support from international organizations promoting best practices.

Once the current state of understanding of the entire Sub-Saharan African region is established, the next two parts examine in detail a few case studies from Southern Africa.

Part II (Chaps. 3–8) presents the research carried out in Dar es Salaam and concludes with a study carried out in Dakar. The six chapters all refer to the conceptual framework for the assessment of vulnerability to climate change developed by the IPCC (see Chap. 1), where adaptive capacity plays a pivotal role. Chapter 3 (Rugai and Kassenga) begins by considering the impact of climate change and the authorities' ability to respond thereto, focusing mainly on highlighting the fact that unchecked and poorly planned expansion of cities is increasing future risk factors as well as the current expenditure on adaptation paid by communities. Chapter 4 (Faldi and Rossi) focuses on seawater intrusion in coastal aquifers. This is a complex phenomenon, due to the combination of natural and human mechanisms, and if aggravated by climate change it could have dramatic consequences, such as impeding the use of the majority of the wells that currently meet human and agricultural consumption needs. Chapter 5 (Congedo and Munafò) investigates urban sprawl, recognising it to be the main non-climatic factor that will accentuate the effects of climate change. This phenomenon affects a great deal of Dar es Salaam's coastal plain, and monitoring it over time is essential if we wish to guide and evaluate the adaptation decisions to be integrated into

urban development planning. The key concept of adaptive capacity is the focus of Chap. 6 (Ricci), which uses it to reinterpret certain characteristics typical of the peri-urban area as essential for guaranteeing the spontaneous adaptation of the local population to present and future environmental changes. An analysis of the information collected in the field leads to a framework proposal for supporting local authorities in decision-making on institutional adaptation. Chapter 7 (Macchi and Ricci) discusses the mainstreaming of adaptation into existing plans and programmes related to the urban development and environmental management sectors. This is an approach to adaptation that is approved by international development agencies, but at the same time has limitations that should be tackled in order to apply it in the right way. Finally, Chap. 8 (Biconne) presents a participatory approach to sharing knowledge among urban players on the environmental, social, and cultural dimensions of climate change. This approach has been tested in the peri-urban settlement of Malika, Dakar, demonstrating its potential as a tool in the decision-making processes of urban adaptation planning.

The second half of the book (Chaps. 9–14) discusses the city of Maputo and is supplemented by a study on the Caia district in central Mozambique. The theme of these six chapters is the mapping of flood risk in case of extreme heavy rain and sealevel rise. The final result is a risk digital map derived from a special open source GIS, and an initial adaptation assessment, i.e. an initial identification of the options for adapting to climate change and their evaluation according to a set of criteria. Given the lack of literature on risk assessment methods in cities south of the Sahara, researchers decided to tackle the various components of risk separately so as to leave more space for an in-depth illustration of the methods used. Thus, flood hazards due to extreme rains (Bacci) and sealevel rise caused by climate change (Brandini and Perna) are discussed in Chaps. 9 and 10. They provide an exhaustive examination of the hazard, which is very rarely discussed in publications dealing with flood risk assessment and mapping, as shown in Chap. 2. Chapter 11 (Braccio) presents the various methods that can be used to identify flood-prone areas. Their use depends on local circumstances (the availability of satellite images with a low cloud cover rate immediately following extreme rain, the availability of local surveys of the flooded areas, etc.). The text then goes on to explain the choice made in the case of Maputo, considering the data and the resources available. Chapter 12 (Ponte) illustrates the choice—among the many options available—to use the equation $R = (H * V * E)/A$ to measure risk, and explains how this equation was used in open source GIS to produce the digital, georeferenced, and updatable map of flood-prone areas. The hazard value calculation identified by Bacci, Brandini, and Perna and the adaptation calculation (Tiepolo, see Chap. 13) are quantified and the vulnerability and exposure calculation is described in detail. Chapter 13 (Tiepolo) treats the adaptation baseline (existing adaptation) and adaptation assessment (future) separately. In this case, reference is made to the complexities involved in ascertaining the measures currently in place when working on large cities with vast flood-prone areas (57.4 km^2 in the case of Maputo). Then the text goes on to elucidate the method

chosen to identify the future priority measures and examine their distribution over time. This part ends with Chap. 14 (Ianni) and an analysis of the vulnerability of the Caia district (population of approximately 115,000) in central Mozambique. The main focus of this chapter is the vulnerability caused by the local population's loss of access to the land.

Silvia Macchi
Maurizio Tiepolo

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Part I
Challenges and Approaches

Chapter 1
Adaptation to Incremental Climate Stress in Urban Regions: Tailoring an Approach to Large Cities in Sub-Saharan Africa

Silvia Macchi

Abstract Research into adaptation strategies to climate change has become a point of great interest for today's urban environmental planners. At the same time, addressing adaptation to climate change in Sub-Saharan cities is an ethical and epistemological challenge. This article presents an approach, developed in the context of a scientific collaboration between an Italian and a Tanzanian university, to adaptation planning in the coastal peri-urban areas of the city of Dar es Salaam. After situating the research within the international discourse on responses to global warming, the specific spatial context of the study is introduced, together with the assumptions that derive from the interpretive key: the adaptive capacity of inhabitants. The three theoretical pillars upon which the approach is based are also explored: uncertainty as an opportunity for an unfettered vision of the city's future; the centrality of incremental environmental stress in assessment of vulnerability to extreme weather and climate events; and crossing boundaries within science and between science and society for an effective and equitable definition of the problem.

Keywords Climate change debate · Urban planning · Peri-urban Africa · Adaptive capacity · Uncertainty

1.1 Planning for Adaptation in Sub-Saharan Cities

Research into adaptation strategies for territories facing the environmental modifications that will be caused by climate change in the near future has become a point of great interest for today's urban environmental planners. Adaptation means anticipating the adverse effects of climate change by adopting appropriate actions to prevent or minimize damage, without forgetting to seize the positive

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opportunities that may also arise. Among the latter is the opportunity to reconsider mainstream planning models by analyzing their impacts on people's *adaptive capacity*, which in Sub-Saharan cities is closely connected to the direct and informal modalities through which people relate to the natural environment. The ACC DAR[1] research project has pursued this path, and the present article will frequently refer to the project in order to focalize certain open questions posed to urban planning by the demand for adaptation in Sub-Saharan Africa.

Addressing adaptation to climate change in Sub-Saharan cities requires an important effort to combine the prevailing themes in the international discourse on strategies for dealing with global warming and the particular characteristics of the settlement modalities and institutional structures of specific locations. After situating the research with respect to several controversial elements of the relationship between adaptation and mitigation and how to conceive the *what to do* about adaptation, the spatial context of the study is introduced: coastal peri-urban areas of Sub-Saharan cities. Adaptive capacity is the interpretive key that allows for a positive view of a reality that is often described exclusively in terms of what it lacks compared with *real* cities. This view informs the choices at the foundation of this research. In addition, three theoretical elements have contributed to the development of a methodological framework: uncertainty as an opportunity for an unfettered vision of the city's future; the centrality of incremental environmental stress in assessment of vulnerability to extreme weather and climate events; and crossing boundaries within science and between science and society for an effective and equitable definition of the problem. On the basis of this theoretical groundwork, the present research seeks to develop a locally tailored approach to the participatory design of adaption initiatives in the field of urban development and environment management planning.

1.2 Elements of the International Debate Surrounding Adaptation

1.2.1 Adaptation and Mitigation

Article 1 of the 1992 United Nations Framework Convention on Climate Change defines climate change as

[1] The Adapting to Climate Change in Coastal Dar (ACC DAR) project is financed by EuropeAid, within the Environment and Sustainable Management of Natural Resources including Energy Thematic Program. It is a three-year project, which will conclude in 2014, that aims to improve the capacity of Dar es Salaam's local governments in local adaptation planning. It is coordinated by the present author and carried out in collaboration with professors and young researchers from Sapienza University in Rome, Italy, and Ardhi University in Dar es Salaam, Tanzania. Chapters 3, 4, 5, 6 and 7 of this book have been developed within the context of that project. All the materials produced in the course of the project are available at www.planning4adaptation.eu.

> a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC 1992).

Although this definition was later revised by the Intergovernmental Panel on Climate Change to include all long-term climate changes irrespective of whether they are due to natural variability or as a result of human activity (IPCC 2001), the international commitment to mitigate climate change through the reduction of its human drivers has become ever stronger over the last two decades. The same cannot be said for adaptation, a strategy that should complement mitigation in meeting the ultimate objective of the UNFCCC. Adaptation refers to

> adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPPC 2001).

In fact, the majority of research and policy efforts have been devoted to stabilizing the concentration of greenhouse gases in the atmosphere (Klein et al. 2005), whereas the commitment to adaptation has become tangible only since the 2007 Bali Conference of Parties under the pressure from the least developed countries who disproportionately suffer the effects of climate change, though they contribute less to GHG emissions than the developed world does.

This slow movement towards an integrated approach that simultaneously addresses mitigation and adaptation concerns has been accompanied by progressively more complex conceptual frameworks for the assessment of vulnerability to climate change (Füssel and Klein 2006) (Fig. 1.1). At the same time, growing attention has been paid to local *adaptive capacity* which is, among other things, the crux of the relationship between disaster risk management and adaptation to climate change.

While the centrality of the notion of adaptive capacity is explored below, a few comments should first be made on the debate surrounding adaptation strategies and their relationship with mitigation. Many believe the efforts of the world's major economic actors in terms of mitigation have clearly been insufficient, given that the temperature of the planet continues to rise, thus scenarios that would render any planned adaptation effort futile have yet to be forestalled. For such individuals, the best form of adaptation is a drastic reduction of greenhouse gas emissions through a radical revision of the dominant development model. To such assertions, the advocates of a greater commitment to adaptation reply that even the most radical change to the development model will not be able to save us from the consequences of the current levels of global warming. In other words, irreversible climate change has already occurred, and adaptation is therefore a necessity. However, the debate is still open as regards the best path forward, whether it is practicable, and how it should be implemented (aside from the widely accepted fact that it should never conflict with mitigation), and it is these questions that the present article shall explore.

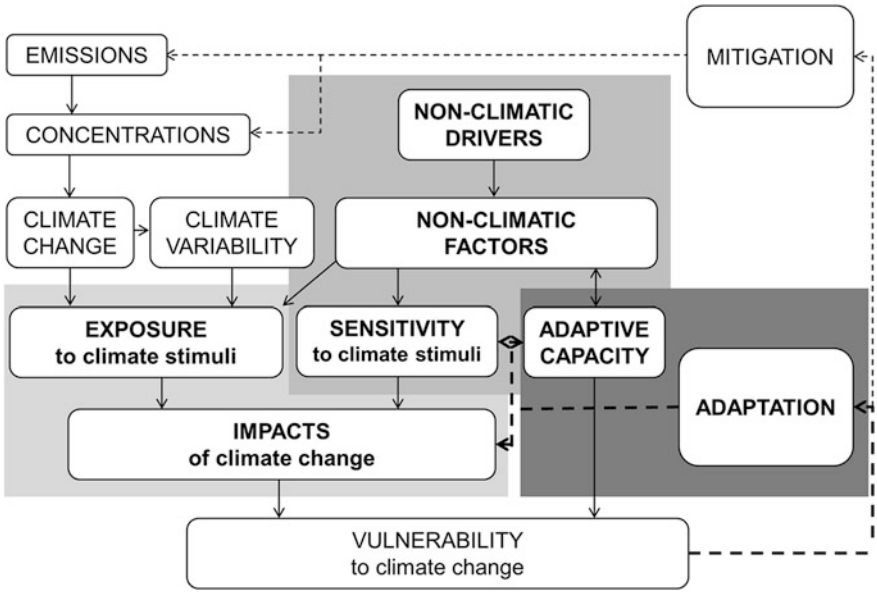

Fig. 1.1 Conceptual framework for the assessment of vulnerability to climate change, with the three areas of interest of the present research highlighted (Modified from Füssel and Klein 2006)

1.2.2 Adaptation: What to Do?

Two positions on adaptation merit particular consideration because they highlight several questions that are crucial for defining the *what to do* of adaptation. Two authors have been selected who have explored those questions by investigating the relationship between climate and human activities, one from a geographical perspective (Parenti 2011) and the other from a historical perspective (Acot 2003).

Parenti's thesis is that assessment of the human impacts of climate change requires an understanding of how changing environmental conditions in the world today are inserted into the *vulnerability trajectory* that is already deeply rooted in the Global South due to the militaristic legacy of the Cold War and the uncontrolled activities of a neoliberal economy. According to Parenti, spontaneous forms of adaptation are already visible, and the common thread among them is violence: in the Global South, ethnic irredentism, religious fanaticism, revolts, xenophobia, banditry, drug trafficking, and local wars for natural resources; in the Global North, counter-insurgency operations, militarization of borders, anti-immigration policies, and xenophobia inspired by the idea of the *armed lifeboat.* In brief, the role of environmental change as regards human activities, whether or not it is caused by climate change, is that of a "drastic accelerant" of the present crisis, "like gasoline on a smoldering fire" (Parenti 2011, p. 65).