The Demography of Adaptation to Climate Change

UNFPA

iied

EL COLEGIO DE MÉXICO

GRAND DUCHY OF LUXEMBOURG
Ministry of Foreign Affairs

The Demography of Adaptation to Climate Change

The Demography of Adaptation to Climate Change

UNFPA
iied
EL COLEGIO DE MÉXICO
GRAND DUCHY OF LUXEMBOURG
Ministry of Foreign Affairs

EDITORIAL TEAM
George Martine and Daniel Schensul

This book should be cited as:
Martine, George and Daniel Schensul (eds.) 2013. *The Demography of Adaptation to Climate Change*. New York, London and Mexico City: UNFPA, IIED and El Colegio de México.

COORDINATION
José Miguel Guzmán

DISCLAIMER
The views expressed in this book do not necessarily represent those of UNFPA, IIED or El Colegio de México.

Cover design by Gisela Martine and Prographics, Inc
Cover photo: ©Marlene Bergamo/Folhapress

ISBN: 978-0-89714-001-0

UN Sales Number: E.13.III.H.2

Acknowledgements

This book emerged from the results of an expert group meeting held in at El Colegio de México in Mexico City, October 2010, entitled "Population Dynamics and Climate Change II: Building for Adaptation." The meeting was organized by UNFPA, the United Nations Population Fund, IIED, the International Institute for Environment and Development and El Colegio de México. Support and contributions were provided by a wide range of international and national institutions, including UN-HABITAT, IOM, UNDP, ECLAC, UNIFEM, Population Division, UN/DESA, UNITAR, World Bank, Mexico's Ministry of Environment, Ministry of Foreign Affairs, Consejo Nacional de Población, Instituto Nacional de Ecología, Instituto Nacional de Estadística y Geografía, and the Sociedad Mexicana de Demografía.

This book has been realized with the support of the Government of Luxembourg through the project on *Demographic Evolutions*.

We would like to thank Phyllis Brachman for editorial work that significantly improved each of the papers and the book as a whole. Guillermina Herrera of El Colegio de México provided extensive support in the organization of the meeting in 2010, and Madeleine Sacco provided invaluable administrative assistance in the preparation of the book.

Contents

List of Boxes

List of Figures

List of Tables

Foreword

Adaptation to climate change is urgent. It is something that we must engage in immediately, or risk disaster. Adaptation is also not just about acting, particularly when we do so reactively. It is about planning, about development and about preparing for the world as it *will* be, not just as it is.

Adaptation is about more than infrastructure and ecosystems. It is about *people*—their characteristics and resources, and how they come together in communities and countries. It is more important than ever that we understand how people, not just places, are vulnerable to climate change, and how they are and can become more resilient.

This book represents the continuation of a process to create a foundation for adaptation that has people, now and in the future, at its centre by bringing together population dynamics and data with climate response. The three organizations that have collaborated to release this book—UNFPA, IIED and El Colegio de México—have spent years building programmes of work in this area. In 2010, we all came together to host an Expert Group Meeting in Mexico City on the aspects of population dynamics that focus particularly on adaptation to climate change.

This book is intended to bring together the knowledge, methods and practices that emerged out of the 2010 meeting, as well as the projects and advances that have followed, to improve adaptation, particularly for those who are most vulnerable to the impacts of climate change. It is intended to catalyze action in global, national and local communities around a more informed, data driven adaptation process. And it is intended to bring together disparate disciplines, from environment science to planning to social science and beyond, that have been working hard but in silos to address this vital issue. The use of spatial data—growing in leaps and bounds everywhere around the world, in the public and private sectors alike—is at the core of this agenda.

As the links between population dynamics and adaptation remain a new area of work, a range of different, yet consistent, approaches are presented in this book. However, more than creating new approaches, this book attempts to provide tools and entry points for policy makers, planners and practitioners to make the critical links to population dynamics a reality for effective adaptation on the ground. What it proposes will continue to unfold in the months and years to come, through continued collaboration between our organizations, our partners, and the wide array of stakeholders for whom adaptation is a necessity.

We invite you to join us on this journey.

Jose Miguel Guzman
Chief, Population and
Development Branch
UNFPA

Gordon McGranahan
Principal Researcher
Human Settlements Group
IIED

Silvia Giorguli
Director, Center for Demographic,
Urban and Environmental Studies
El Colegio de México

About the Authors

Deborah Balk is Professor at the City University of New York (CUNY)'s Baruch School of Public Affairs and the CUNY Graduate Center (in the Sociology and Economics Programs) and Associate Director of the CUNY Institute for Demographic Research. Her expertise lies in spatial demography and the integration of earth and social science data and methods to address interdisciplinary policy questions. Her current research focus is on urbanization, population, poverty, and environmental interactions (such as climate change). She has co-authored numerous papers on population and climate change, including a recent one on city population forecasts and water scarcity.

David Dodman is a Senior Researcher at the International Institute for Environment and Development (IIED) where he is team leader for institutional objectives on 'Cities and Climate Change' and 'Research Quality'. He is the author of more than thirty journal articles and book chapters, and the co-editor of 'Global Change and Caribbean Vulnerability: Environment, Economy and Society at Risk' (Kingston, UWI Press) and 'Adapting Cities to Climate Change: understanding and addressing the development challenge' (London, Earthscan). He is a College Teaching Fellow at University College London, and a Lead Author on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Regina Fuchs is a research scholar at the International Institute of Applied Systems Analysis (IIASA), as well as a Teaching and Research Associate at the University of Economics and Business (WU) in Vienna, Austria, where she was awarded a doctorate in the fall of 2012. Her research is focused on household demography and the demographic transition in developing countries.

Boris Graizbord is National Program Director for LEAD Mexico. Before joining LEAD, he served twice as academic coordinator for the Master's programme in urban development at El Colegio de México. Since 1979, he has been a research professor at the Center for Demographic, Urban and Environmental Studies at El Colegio de México; lecturer in the post-graduate division in the faculty of architecture at Mexico's National University (UNAM); and, since 1992, lecturer in the Master's programme in Regional Studies at Instituto Mora. He also teaches full and short courses in other academic institutions, including the University of Southern California, University of Pennsylvania and the New School University in New York.

José Miguel Guzmán is the Chief of the Population and Development Branch of UNFPA. He holds a Ph.D. in Demography from the University of Montreal, Canada. He works on a wide range of issues related to population and development, including climate change, urbanization, ageing, fertility transition, child and maternal mortality and health, gender, international migration, poverty, natural disaster impacts and surveys/census and information systems.

George Martine is a Canadian sociologist and demographer who has spent most of his professional life working on social development issues in Latin America, especially in Brazil. He has written extensively on social, demographic and environmental topics. Mr. Martine authored UNFPA's path-breaking *The State of World Population 2007: Unleashing the Potential of Urban Growth*. He is currently Technical Director of Dhemos Consulting, an independent firm that provides support mostly to international organizations on socioeconomic, demographic and environmental issues. Mr. Martine previously served as President of the Brazilian Population Association; Director of UNFPA's Country Support Team for Latin America; Senior Fellow at Harvard University's Center for Population and Development; Director of a Brazilian NGO on population and environment; and coordinator of several United Nations projects in social development.

Dunstan Matekenya is the head of the GIS Section of Malawi's National Statistical Office. His current work focuses on spatial data for the 2008 census, and he is leading in planning the 2018 census mapping. He is also a part-time consultant in GIS and remote sensing. Mr. Matekenya has an M.Sc. in Geospatial Science.

Gordon McGranahan is Principal Researcher in the Human Settlements Group at the International Institute for Environment and Development (IIED). He works on a range of urban environmental issues, with an emphasis on addressing poverty and environmental problems in and around the home, and on understanding how the critical scale of urban environmental burdens changes as cities become wealthier. Publications include: *The Citizens at Risk: From Urban Sanitation to Sustainable Cities* (Earthscan, 2001); the urban systems chapter of the *Millennium Ecosystem Assessment* (2005); "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones" (*Environment and Urbanization, 2007*); and "Evolving Urban Health Risks: Housing, Water and Sanitation, and Climate Change" (In: *The Urban Transformation: Health, Shelter and Climate Change*, Earthscan, 2012).

David Mkwambisi is an environment and development expert with a Ph.D. and an M.Sc. in Environment and Development from the Universities of Leeds and East Anglia (United Kingdom), respectively. He is currently working as a Lecturer in Environment and Development Studies at Bunda College, University of Malawi. He is also a regional expert providing technical advice to government negotiators at the United Nations Framework Convention on Climate Change (UNFCCC) on agriculture and climate change within SADC and COMESA countries.

Thomas Munthali manages the Population and Development Programme for UNFPA-Malawi, where he is the focal point on climate change and natural resource management. He is also the outcome leader for population and sustainable development for the United Nations (Malawi) under the United Nations Development Assistance Framework (2012-2016). He has a Ph.D. in Economics from the University of Leeds and is the immediate past President of the Economics Association of Malawi (ECAMA). He previously worked with the Government of Malawi as an economist in the Ministry of Economic

Planning and Development, where he was part of the team that developed the Malawi Economic Growth Strategy (MEGS). A former World Bank economist, he has written and presented extensively on development economics, including on population dynamics and climate change.

Ricardo Ojima is a sociologist and demographer with a Ph.D. from the University of Campinas. He is currently Associate Professor in the graduate programme in demography at the Federal University of Rio Grande do Norte. He also serves as the coordinator (2011-2012) of the working group "Population, Space and Environment" in the Brazilian Association of Population Studies (ABEP). His research has focused on the areas of population and environment, spatial mobility of population and urbanization.

Landy Sanchez Peña is a professor in the Center for Demographic, Urban and Environmental Studies at El Colegio de México. She has worked on spatial inequality, as well as demographic change and the environmental implications of household consumption. Her current research focus is on cities and climate change in Mexico.

Daniel Schensul is a Technical Specialist with the Population and Development Branch of the Technical Division, UNFPA, where he works on climate change, urbanization and data analysis and dissemination. He co-edited the book, *Population Dynamics and Climate Change*, and has published research on urbanization, governance and environment. Mr. Schensul has worked extensively on climate change adaptation, with a particular focus on the data foundations of vulnerability assessment and the spatial distribution of vulnerability in a wide range of contexts, including in Malawi and Indonesia. He received his Ph.D. in Sociology from Brown University, with a concentration on urban development and spatial analysis.

Cecilia Tacoli is Principal Researcher in the Human Settlements Group at the International Institute for Environment and Development (IIED). Her work explores how the relations between rural and urban areas, people and enterprises are transformed by urbanization processes. Publications include: *The Earthscan Reader in Rural-Urban Linkages* (Earthscan, 2006); "Crisis or Adaptation? Migration and Climate Change in a Context of High Mobility" (2009) in *Environment and Urbanization* 21(2); and *Urbanization*, *Gender and Urban Poverty: Paid Work and Unpaid Carework in the City* (2012), Urbanization and Emerging Population Issues Working Paper Series, London and New York: IIED and UNFPA.

Sainan Zhang has worked for UNFPA on population, urbanization and climate change. She is a Ph.D. Candidate at the School of Sustainability at Arizona State University and studied Urban Environmental Management in Wageningen University in the Netherlands for her MSc. Prior to her studies, she had worked in the Chinese Central Government for three years on UN and European Commission-funded projects in environmental management, climate change, energy efficiency and urban planning. She also worked for The Nature Conservancy in ecosystem protection and climate change projects. Her Ph.D. research focuses on sustainable urban development, especially the interlinked issues of human and environment dynamics.

Introduction

George Martine and Daniel Schensul

Growing awareness that the impacts of climate change on human populations are imminent, as well as potentially devastating, has prodded some policymakers and most of the scientific community to call for more effective action. Deepening alarm at the scale of the development-environment quandary in the Anthropocene Era (Steffen et al, 2011) is typified in recent compelling statements by the world's most influential multilateral leader, Ban Ki-Moon, the United Nations Secretary General. In words that would have been viewed as anathema by the development community not long ago, Ban Ki-Moon told a recent gathering of the world's business and policymaking leaders in no uncertain terms that - "In the 21st century, supplies are running short and the global thermostat is running high. Climate change is showing us that the old model is more than obsolete. It has rendered it extremely dangerous. Over time, that model is a recipe for national disaster. It is a global suicide pact" (Ban Ki-Moon, 2011).

A few short years ago, the UN's Millennium Ecosystem Assessment warned that "human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (Millennium Ecosystem Assessment, 2005). The latest scientific evidence and recent extreme climate events now makes this early warning sound bland. It is already obvious that human demands on the planet have outstripped supply, biodiversity has declined globally, and rising levels of atmospheric CO_2 are causing increased global temperatures, climate change and ocean acidification. As reflected in the authoritative work published by the Stockholm Resilience Center, the abusive utilization of the Earth's material, energetic and biotic resources by the global economic system has already overstepped planetary boundaries in three domains (climate change, biological diversity and nitrogen input to the biosphere) and threatens to exceed them in at least six known additional areas (Rockstrom et al, 2009).

Although efforts to change our civilization's patterns of production and consumption in order to reduce the concentration of greenhouse gases in the atmosphere are ever more urgent, a flurry of extreme weather events has dramatically highlighted the need to respond more effectively to the threats already upon humankind. Mitigation is urgent, critical and irreplaceable, but even if known pathways were followed quickly and universally, the impacts of climate change are already upon us and are certain to increase in frequency and magnitude. Adaptation to climate change, already a major front in global climate response, must therefore be considerably improved in order to reduce the human suffering that climate change is causing. Adaptation is particularly essential in relation to the world's poor, who are universally acknowledged as the social contingent that has made the least contribution to climate change, yet will experience its most deleterious consequences.

Understanding and reducing climate vulnerability are at the center of effective adaptation. To this purpose, a broader understanding of the drivers of social change is essential in order to avoid superficial, overly general and deterministic perspectives. This book makes the point that population dynamics play a central role in livelihoods, location, economic vulnerability, environmental vulnerability and resilience. Understanding population dynamics is also critical in avoiding static perceptions of vulnerability: Changes that affect the size, distribution and composition of human populations also affect both the nature of vulnerability and adjustments in natural or human systems in response to actual or expected climatic stimuli.

Existing approaches to adaptation have had serious limitations, chief among which have been their reactive nature and the lack of solid data on which to base decision-making. Until now, the bulk of measures to reduce the impacts of climate-related hazards have been responsive in nature. Lingering beliefs that the ongoing escalation of the pace and intensification of extreme climate events reflects random occurrences unrelated to human actions, combined with the disinclination of politicians everywhere to undertake projects that will mature only in the long term, have made post-hoc measures the norm rather than the exception. The human and financial costs of such reflexive approaches are incalculable. Continuing the move towards anticipatory adaptation, including more longer-term preparation for climate impacts that will play out on decadal time frames, will be critical for effective and cost-effective climate response, and also for making a strong link to poverty reduction and development.

The lack of solid information related to risk and vulnerability often provides a convenient justification for the lack of effective, proactive approaches. This is no longer a valid excuse: The correct use and exploitation of demographic data could provide a wealth of analyses and insights that can orient more effective approaches, particularly when applied to maps and tied to the geography of current and expected climate-related hazards. A focus on demographic dynamics can help address another major issue that many have identified in the global climate change response to date: that is, an inordinate focus on technical and economic challenges, without sufficient consideration of people's livelihoods and opportunities. The path to adaptation in the decades to come must be more people-centred, with the well-being and rights of the most vulnerable people and communities considered a critical component of success.

The benefits of including population dynamics in the design of adaptation strategies are several, as noted in the chapter by Daniel Schensul and David Dodman. First, population projections generally provide the most reliable scenarios concerning the size, location and characteristics of the need for adaptation efforts. Second, population issues are in themselves closely linked to economic and social development. The interactions between fertility, migration, spatial distribution, age structure, household size and composition, race and ethnicity and gender dynamics shape economic growth, as well as access to social safety nets and services which are integral to secure livelihoods. Third, some aspects of population dynamics, such as migration, urbanization and age structure are directly linked to adaptation. Hence, analysis of population characteristics and dynamics can be a powerful tool for adaptation programming and for building adaptive capacity.

In the midst of a rapidly expanding global adaptation agenda, it is of primary importance to get adaptation and its constituent parts right, in order to generate the most appropriate and effective interventions. This book addresses a major gap in adaptation efforts to date by pointing to the vital role that an understanding of population dynamics and data has in developing pre-emptive and effective adaptation policies and practices. Politics and an oversimplified understanding of demographic dynamics have long kept population issues out of serious discussions in the framework of climate negotiations. Within adaptation actions, however, this is beginning to change, and this volume is intended to provide a framework for taking that change forward. The remainder of this introduction briefly describes the three sections of this book, and how the information and approaches they contain can contribute to helping vulnerable territories and peoples to adapt to a changing climate.

Population Dynamics and Adaptation – Key Concepts and Perspectives

Most public and scientific discussions of what to do about climate change include, as they should, concern about population dynamics. Shifts in population trends do indeed have multiple implications in the climate change context. However, their nature and actual impact are often misunderstood or oversimplified, a fact which tends to have population dynamics ignored both in intergovernmental climate change negotiations, as well as in the practice of adaptation to climate change. As argued by Daniel Schensul and David Dodman in Chapter 1, interest in the topic of adaptation is expanding rapidly, but overlooking population dynamics leaves a significant gap in the development and implementation of adaptation projects. Appropriate consideration of population growth, composition and distribution is critical in understanding how vulnerability is distributed across different groups of people. Vulnerability, exposure and adaptive capacity are shaped by demographic issues in specific ways. Schensul and Dodman propose an initial framework for integrating development, adaptation to climate change and disaster risk reduction that uses a holistic understanding of population dynamics to connect the lives of individuals, households and communities.

Within the framework of ongoing demographic changes, the urban transition underway in developing regions, especially of Africa and Asia, is far and away the most impactful for the global social, economic, demographic and environmental future, and it is occurring simultaneously with as yet uncharted, but enormously significant, climate changes. In Chapter 2, Gordon McGranahan and colleagues pose a set of crucial questions inspired by the onset of these simultaneous trends: How will urbanization and climate trends interact? How will cities cope with, respond to and plan for this interaction? How will potentially vulnerable groups be affected? What are the challenges that these changes pose to political equity and urban governance? The authors note that the issues of urbanization in general, the location of receiving urban centres and population density and distribution within those settlements each relates quite differently to climate change and poses different political and governance challenges. An underlying concern of Chapter 2 is that urban policy regimes already disadvantage those urban and rural dwellers who could be further threatened by climate change. If urban policy regimes become more exclusionary in response to climate change, vulnerable people could end up doubly burdened—by climate change itself and by inequitable responses to it. Moreover, the current tendency to treat urbanization as a driver of climate change—and of mal-adaptation—diverts attention from the diverse forms urbanization can take, and the ways it can become a means of addressing the risks of climate change. McGranahan and colleagues highlight the fact that land issues, already central to the challenge of contemporary urban population growth, are at the core of urban climate challenges. This can be perceived as a recurrent theme throughout much of this book, particularly in the Section 3 chapters.

Growing concern about the impacts of climate change has also re-ignited discussions on their implications for population distribution and mobility. Earlier views tended to perceive environmental migration as essentially a failure to adapt to degradation that resulted in huge numbers of impoverished displaced people. The reality, however, is far more complex. An alternative view depicts mobility and migration as key adaptive strategies. In Chapter 3, Cecilia Tacoli argues that a better grasp of these admittedly complex dynamics is necessary to achieve an improved sense of what can be done to support and accommodate migration in a changing climate. More accurate information is also needed to dispel misconceptions that are often at the root of discriminatory policies against migrants. A more correct understanding of the wide range of destinations, duration of movements and composition of migratory flows is a necessary first step towards the formulation of policies relevant to population mobility. Drawing on the findings of recent empirical research in Bolivia, Senegal and the United Republic of Tanzania, Tacoli proposes a typology of mobility that takes into account the interrelations between slow-onset climate change and socioeconomic and cultural transformations and that highlights the diversity of migration and its drivers.

Population Data for Adaptation: Sources and Methodologies

Adaptation encompasses a diverse and complex set of interventions and outcomes, yet data inputs to adaptation have been derived mostly from a limited set of sectors focusing on the geography of climate exposure and the kind of large-scale infrastructure necessary to protect exposed areas. To fill the gap in demographic and social data, this section of the book maps out a path to incorporating such data into adaptation analysis and programming. In Chapter 4, José Miguel Guzmán and colleagues situate data derived from the census within the layered schema of climate adaptation, suggesting that census data can fill vital gaps in information on individuals and households, while complementing existing vulnerability assessment methodology that focuses on communities, municipalities and countries. They then proceed to develop a set of indicators of climate vulnerability, both general to climate change and specific to individual climate hazards such as floods, drought, heatwaves and sea level rise. Many of these indicators, which have inputs derived from demographic, human and social capital and built environment information, can be calculated all or in part from census data. As a result, they can be mapped at the neighborhood level and joined with a range of other spatial data.

In Chapter 5, Deborah Balk and colleagues take on the process of joining census data with other critical climate information using geographic information systems (GIS). They suggest that the processing of census data in National Statistical Offices (NSOs) has historically been oriented to larger administrative boundaries: the country as a whole, provinces and sometimes municipalities. Climate hazards, however, operate on entirely different scales – sometimes smaller, sometimes larger, always cutting across administrative boundaries. Census data need to be processed in reference to the geography of climate hazards, which is far more widely possible in light of the major advances in GIS infrastructure made in the buildup to and implementation of the 2010 round of censuses. The chapter reviews data types and critical choices that need to be made in the processing of census data for geographic use, as well as with joining these data to information on climate exposure like low elevation coastal zones. Part of broader efforts to develop a guide for NSOs on census data for climate adaptation analysis, this chapter can help NSOs deliver the right data products to other parts of government that are developing climate adaptation solutions. The authors also identify some significant gaps in the capacity of NSOs that need to be addressed in order for countries to maximize use of the data at their disposal.

The final chapter in this section, Chapter 6 by Landy Sanchez and Regina Fuchs, makes the case for the integration of survey data into climate adaptation efforts. Survey data provide much more detailed information than censuses, often at much more frequent intervals; however, their major shortcoming relative to census data is that they do not provide direct results for small geographic areas. This chapter examines the Income and Expenditure Household Surveys (IEHS), using data from Brazil, India, Indonesia and Mexico, for information useful in understanding climate vulnerability and adaptive capacity. It then uses the techniques for survey sampling to apply the results of the IEHS and other similar surveys to geographic extents. It concludes by examining modeling processes that allow survey data to be combined with other types of data, including from the census, for a variety of purposes from emissions modeling to improving small area estimation of vulnerability.

The Planning and Practice of Adaptation

Adaptation efforts under the threat of global climate change continue to need significant guidance, and the final section of this book demonstrates how bringing population concepts, data and practices together can help to make these efforts more proactive and effective. In Chapter 7, Daniel Schensul and colleagues provide a concrete example of how census data can help to strengthen adaptive capacity and reduce vulnerability even in countries considered as least-developed and most vulnerable. Their case study combines spatial analysis of the Malawi 2008 census with policy and stakeholder analysis, showing results that can be replicated elsewhere using existing in-country GIS capacity developed as part of the 2010 round of censuses.

Focusing on five urban extents, Chapter 7 examines vulnerability linked to water, infrastructure, housing, energy and livelihoods expected to be the hardest hit by climate change events. Mapped census data show significant variations in the adaptive capacity of households and communities. The fact that many poor urban areas are far more similar to rural areas in vulnerability indicators is critical since aggregate statistics showing better average outcomes in urban areas tend to lead policy makers to consider vulnerability a rural problem. In addition, growing urban populations increase the spatial concentration of demands of energy, building materials and water. But their use also shapes patterns of urban vulnerability: As low-income residents are more heavily dependent on biomass for energy and natural materials for houses, they will suffer the most as the natural asset base is depleted. Existing efforts to address climate change in Malawi do not yet take into account many of these factors.

The fact that most urban growth in Asia and Africa is still to come provides an opportunity to address urban vulnerability as or before it emerges. In Chapter 8, George Martine and Ricardo Ojima suggest that the increasing concentration of population in towns and cities of the developing world presents the most pressing challenge, and the greatest opportunity, for future adaptation efforts globally. Urban areas are, on the whole, more resilient to climate variability due to their economic and social advantages, yet, they are adding growing masses of population groups that are often the most vulnerable to climate change – the urban poor in exposed areas. Rapidly-urbanizing regions have a one-time chance to prepare better for potential risks. To do so, however, they will need better strategies and policies than the ones adopted so far in order to promote positive and forward-looking approaches. The authors present a case study of Brazil, a developing country which has practically completed an early urban transition, but whose urban population suffers unduly from natural disasters. They suggest that today's vulnerability reflects the negative attitudes of decision-makers to urbanization, and analyze the implications of these attitudes for governance in relation to such issues as urban expansion, land use, sanitation and transportation.

The growth in the number and size of megacities is cause for increasing concern in the context of climate change. Boris Graizbord, in Chapter 9, maps the areas at risk from hydro-meteorological hazards within one of the largest megacities – the Mexico City Metropolitan Area (MA) – and identifies vulnerable populations and housing based on socioeconomic indicators derived from the census. The MA has continued to grow in terms of both population and area, but the demographic growth rate reached its peak in the 1960s at 3.6 per cent per year and declined steadily to 1 per cent recently, while the physical expansion of the urban area continued rapidly with decreasing density and, more recently, in a leapfrog pattern of growth. Economic growth and employment have not kept up as urban expansion has resulted both in an increase in the number and proportion of poor residents and an increased demand for public and private goods and services that has put more pressure on ecosystem resources. High vulnerability to natural hazards, based on population attributes and housing characteristics, affects close to

27 per cent of the MA´s population (4.6 million inhabitants) and close to a million dwellings. Highly vulnerable neighborhoods in areas exposed to intense rain events, landslides and heat waves were identified in the study. Despite the inherent advantages of cities to improve adaptive capacity and to implement risk management strategies, the manner in which Mexico City has evolved, particularly in relation to land use change, has increased the vulnerability of the poor to climate change.

References

Ban Ki-Moon. 2011. "Secretary-General's Remarks to the World Economic Forum Session on Redefining Sustainable Development," Davos, Switzerland, 28 January 2011. Website: http://www.un.org/sg/statements/?nid=5056, accessed 16 November 2012.

Millennium Ecosystem Assessment. 2005. Living Beyond Our Means: Natural Assets and Human Well-Being: Statement from the Board: Millennium Ecosystem Assessment. New York: Millennium Ecosystem Assessment, United Nations.

Rockström, J., et al. 2009. "A Safe Operating Space for Humanity." Nature 461: 472 – 475.

Steffen, W., et al. 2011. "The Anthropocene: From Global Change to Planetary Stewardship." Ambio 40(7): 739-761.

CHAPTER 1

Populating Adaptation: Incorporating Population Dynamics in Climate Change Adaptation Policy and Practice

Daniel Schensul and David Dodman

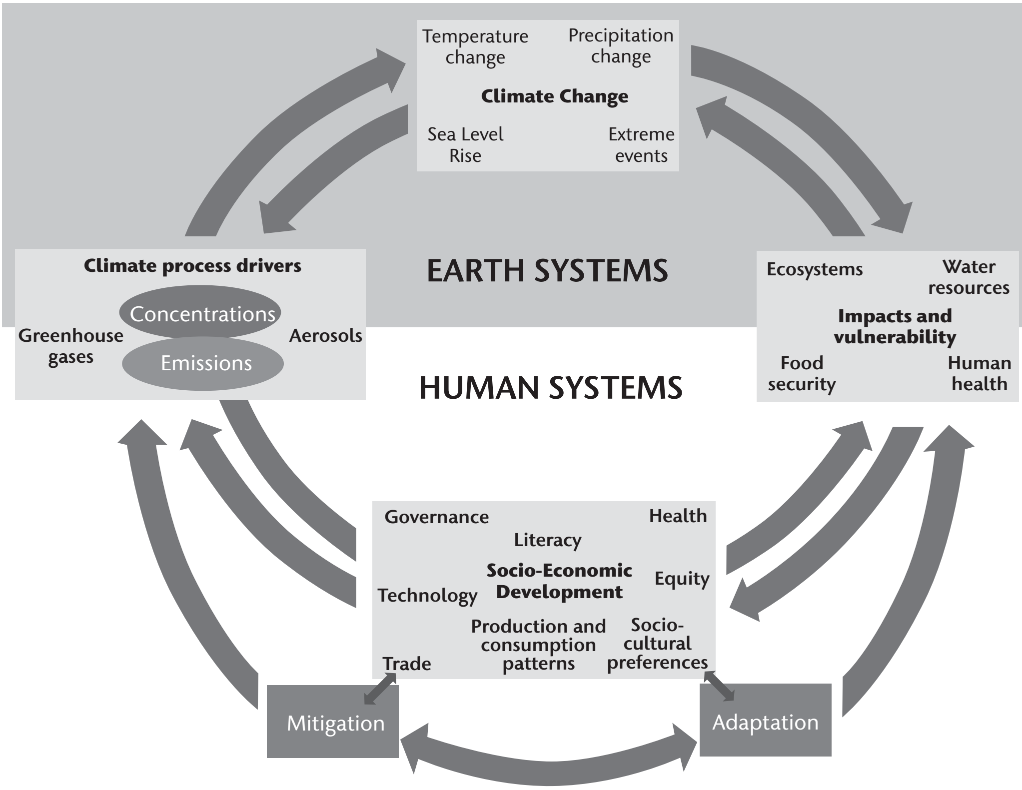
Introduction

Climate change is increasingly recognized as a major challenge facing households and communities, local and national governments and international agencies and organizations. The earth's climate has already been altered to such an extent that mitigation (efforts to reduce the concentrations of greenhouse gases in the atmosphere) alone will be inadequate. Therefore adaptation (responding to the impacts of climate change) is increasingly necessary. Budgets for adaptation are increasing, programmes are expanding and political infrastructure is being negotiated and implemented. In the meantime, significant advances have been made in the development of adaptation programmes. Yet, to this point, existing approaches have had serious limitations. In the midst of a rapidly expanding global adaptation agenda, it is of primary importance to get adaptation and its constituent parts right, in order to generate the most appropriate and effective interventions. This chapter addresses a major gap in adaptation efforts to date by pointing to the vital role that an understanding of population dynamics has in developing effective adaptation policies and practices. It examines the key components of climate change vulnerability and adaptation and assesses the ways in which these interact with population dynamics.

Understanding and reducing climate vulnerability are essential for effective adaptation. The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a systemic characteristic associated with a range of factors, including ecosystems, water, food security, human settlements and health (see Figure 1.1). Vulnerability is identified as a function of climate change and development, and development includes changes in population dynamics, along with many other factors. This model illustrates a complex and interwoven system of causes and effects, without identifying or assessing the nature of the relationships between these factors. Partly as a result, current approaches to vulnerability and adaptation are based on a model with hidden gaps in understanding, which results in many key linkages being ignored, assumed or glossed over.

Population dynamics are especially ignored, both for substantive reasons that this chapter will elaborate and attempt to ameliorate, but also unquestionably for political reasons. To many, population dynamics suggest size and growth. In the environmental

Figure 1.1: IPCC Schematic Diagram Linking Drivers, Impacts and Responses to Climate Change



Source: IPCC, 2007, Figure I.1.

community, there is a long history—from Malthus to Erlich to the recent resurgence of concerns linked to climate change and sustainable development—of blaming population growth for the world's problems. Consequently, as Michael Zammit Cutajar, who established and headed the United Nations Framework Convention for Climate Change (UNFCCC) until 2002, said at an event attended by one of the authors during the Cancun Climate Change Talks in 2010, demographics have never been brought up within the framework of the climate negotiations. Within adaptation actions, however, this is beginning to change, and this volume is intended to provide a framework for taking that change forward.

One of the key gaps is in understanding how vulnerability is distributed across different groups of people, as a particularly important subset or component of system vulnerability. For instance, in Figure 1.1, population and settlements are separated, despite having strong links, and it is not clear where other essential population dynamics like mobility and composition would fit. As this chapter shows, these gaps result in a fundamental misspecification of the continually changing nature of vulnerability and how to decrease it. In addition, the outline for the IPCC Fifth Assessment Report (to be published in 2014) only identifies population issues in the section on "human health, well-being and security" (with the exception of migration, which is also referred to in the chapter on rural areas). The focus for these issues is on identifying "vulnerable" or “marginalized” populations, with an emphasis on inequalities, children and gender. Without better consideration of the limitations of current understandings of vulnerability and adaptation, and incorporation of an understanding of population dynamics in addressing these limitations, adaptation policies and programmes will increasingly fall short of their intended outcomes.

In particular, this chapter shows how incorporating a range of population dynamics and related demographic issues in adaptation policies and programmes can aid in reducing **exposure** to the impacts of climate change and in strengthening **adaptive capacity** to deal with these impacts. Population dynamics is here defined as the change in population size, distribution by age, spatial distribution (including urbanization), density, composition of households and family and the variables that generate these results: fertility, mortality, migration and marriage patterns.

The next section reviews the limitations of current approaches to vulnerability and adaptation and argues that many of these can be addressed by an appropriate consideration of population dynamics. The following three sections unpack the concepts of vulnerability, exposure and adaptive capacity and illustrate the specific ways in which these are shaped by demographic issues. The final section of the chapter identifies some initial directions towards a framework for integrating development, adaptation to climate change and disaster risk reduction, based on the importance of connecting with the lives of individuals, households and communities, informed by both population data and a holistic understanding of population dynamics.

Current Limitations in Approaches to Adaptation

Since the recognition of adaptation as one of the core pillars of global responses to climate change (along with mitigation, technology transfer and financing), there has been a rapid growth of interest in the topic and a rapid expansion in the development and implementation of adaptation projects. The overwhelming scientific consensus on the causes and likely effects of climate change suggests that much of this adaptation activity has been driven by a sense of urgency to safeguard the lives and livelihoods of people living in particularly vulnerable countries (Huq and Ayers, 2007). However, these expansion efforts have often taken place without a broader understanding of the drivers of social change, with the result that several key limitations can be identified.

First, perspectives on vulnerability have often been superficial, overly general and deterministic. Direct translation of vulnerability to climate change solely from economic, social or political factors is common, without full consideration of what that translation may mean.[1] Adaptation and poverty reduction are not the same thing, and, while vulnerability associated with poverty is related to climate vulnerability, the two do not overlap perfectly. As a result of this mistranslation, practitioners frequently list vulnerable groups (e.g., women, children, the elderly, indigenous groups or disabled people) rather than specifying the underlying mechanisms that create vulnerability. Members of these groups may indeed have heightened vulnerability to the impacts of climate change, but, specifying a framework for understanding and addressing that vulnerability is essential. One of the purposes of this chapter is to fill this gap.

The second set of limitations has to do with approaches that are "impact-first". Prevalent in the disaster response and disaster risk reduction communities, which have had growing convergence with climate change adaptation,[2] impact-first approaches begin with the identification of a particular hazard, or with historical experiences of post-hazard responses, and work backwards to decrease exposure and increase the resilience to this hazard. While these approaches are becoming broader and showing increased efficacy, they have two problems. The first is a general focus on the impact of hazards on geography and the built environment at the expense of other mechanisms and types of impacts on individuals, households and communities. The relatively simple step forward of adding to this physical focus an analysis of where people are in relation to hazards can significantly improve programming, while representing just the start of what adding population dynamics will achieve. The second problem is an isolated understanding of impacts and resiliency measures, which can vary widely depending on the hazard and can result in overly targeted risk reduction measures. Of course, the narrow, isolated nature of impact-first approaches can in some ways be a strength, in so far as more targeted risk reduction activities may be more effective in reducing the risk from a particular hazard. However, the impacts of climate change vary widely in scale, time horizon and severity, such that a series of disparate hazard-specific risk reduction activities may not add up to a reduction in vulnerability or increase in resiliency associated with the broad set of hazards expected from climate change. O'Brien et al. (2008, p. 198) argue that because of the breadth of hazards, "[c]limate adaptation is a problem where large groups of individuals have to change their mindsets and behaviour." The targeted outcomes associated with hazard-specific resilience—for example, targeted preparation for a flood or for a heat wave—may not, and are not intended to, result in widespread changes in mindsets and behaviour. This is at the core of the argument for adaptation based in development and linked to population dynamics.

The third set of limitations is associated with a static perspective on the inputs to vulnerability. A very basic inclusion of population issues, particularly in the form of deterministic lists of vulnerable groups, can coincide with a lack of consideration of the future direction and pace of change. Fast-paced urbanization in many countries, the changing migration calculus, declining fertility and the resulting temporary "youth bulge", the increase in elderly populations over time and other dynamics of population composition and distribution promise significant changes in both individual and systemic vulnerability going forward. Without these perspectives, adaptation plans based on, for instance, the current size of a city or the current age structure of a country will constantly be responding to yesterday's problems and therefore will undoubtedly be rendered irrelevant. There is some limited recognition of the importance of a dynamic perspective on population within the IPCC, for instance:

> The assessment of key vulnerabilities involves substantial scientific uncertainties as well as value judgments. It requires consideration of the response of biophysical and socio-economic systems to changes in climatic and non-climatic conditions over time (e.g., **changes in population**, economy or technology), important non-climatic developments that affect adaptive capacity, the potential for effective adaptation across regions, sectors

> and social groupings, value judgments about the acceptability of potential risks, and potential adaptation and mitigation measures [emphasis added] (Schneider et al., 2007, p. 784).

While this type of reference, a carryover from the ubiquitous IPAT formula (emissions as a function of population, affluence and technology), keeps population issues in the discussion, it only further accentuates the need for a stronger framework in which to consider population dynamics over time, particularly as they include more than just population growth. Without this framework, and without significant attention to coming social changes rather than just climatic ones, adaptation will remain in many ways merely reactive.

The case for incorporating population dynamics

One of the consistent themes of the literature on the links among disaster risk reduction, development and climate change is the isolation between practitioners of each (Thomalla et al., 2006). Cannon and Müller-Mann (2010, p. 627) argue that "the conceptualisation of climate change and adaptation has so far been largely dominated by natural science perspectives". In addition, as advances in remote sensing of the impacts of disasters on the built environment have outpaced monitoring of impacts on population (see the discussion below of remote sensing after the Haiti earthquake), the former have driven the understanding of both impact and post-disaster responses. The result is that vulnerability may be defined as something that can be observed remotely—particularly the different types of built environment across varying geographies—by virtue of the available data inputs into the calculus.

Incorporation of population dynamics can help to address these limitations, both directly and indirectly, through recognition of the central role population dynamics play in livelihoods, location, economic vulnerability, environmental vulnerability and resilience. The benefits of including population dynamics are several. First, population projections can provide reliable scenarios about the size and composition of the population in the future, with important implications for policy. For instance, rates of national population growth and urbanization and projected changes in age structure can provide a snapshot of the nature of national and local populations decades into the future, matching the timeline of climate impacts.

Second, population issues are closely linked to economic and social development. Fertility, migration, spatial distribution, age structure, household size and composition, linked to issues such as race and ethnicity and gender dynamics, affect formal and informal economic development, access to social safety nets and services, provision of education, dependency ratios and other key components of development. These factors, which are integral to secure livelihoods, are essential components of resilience in the face of the broad range of environmental changes projected to occur as the climate changes. This is a pathway to adaptation that O'Brien et al. (2008) call "indirect adaptation", and describe as necessary for poverty alleviation, climate response and the synergy between the two in the long term. Components of development provide mechanisms linking population dynamics and vulnerability and can help move analysis and intervention beyond the demographic determinism of lists of vulnerable populations.

Third, some aspects of population dynamics provide a direct link to adaptation. For example, migration, whether undertaken as a response to the impacts of climate change or as a driver of changes in people's location and exposure to hazards, must be considered in adaptation frameworks. When people have more control over their movements and location, including through migration and urbanization, they can decrease their exposure to climate risks. In addition, population ageing has been shown in many instances to affect vulnerability, for instance, with high levels of mortality among elderly individuals during heat waves (Semenza et al., 1996; Fouillet et al., 2006), while young children are particularly at risk from the more frequent and intense extreme weather events anticipated as a result of climate change (Barlett, 2009). The fact that women have less access to economic resources and less influence in decision-making means that gender plays an important role in affecting individual and household vulnerability (Alber, 2009). When the mechanisms linking these groups and their vulnerability are correctly specified, analysis of population characteristics and dynamics can be a powerful tool for adaptation programming and for building adaptive capacity.

Including population dynamics in adaptation will help to fill a major gap that many have identified in the global climate change response to date: a focus on technical and economic challenges, without sufficient consideration of people's livelihoods and opportunities. As we chart a path to adaptation in the decades to come, the result must be people-centred, with the well-being and rights of the most vulnerable people and communities considered a critical component of success. Incorporating population dynamics into adaptation can help in understanding who is most vulnerable, why and how to target policies to decrease that vulnerability.

Understanding Vulnerability

An understanding of the nature of vulnerability is a vital first step in responding to the challenges posed by climate change. The way in which the term vulnerability—and its related concepts of exposure and adaptive capacity—is defined is closely related to the types of responses that are proposed. At the most basic level, identifying vulnerability as a function of inadequate infrastructure will lead to a focus on infrastructural responses; in contrast, identifying vulnerability as a function of inadequate social capital or networks will lead to a focus on capacity-strengthening. A more holistic approach will recognize that vulnerability, exposure and adaptive capacity need to engage with broader issues of development. This is one of the advantages of a systems perspective that incorporates population dynamics as important factors shaping all of these processes.

Definitions of vulnerability

Specifically in relation to climate change adaptation, the most frequently used definition of vulnerability is that proposed by the Intergovernmental Panel on Climate Change (IPCC) (2007), which states that it is:

> [t]he 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. . . . The distribution of impacts and vulnerabilities is still considered to be uneven, and low-latitude, less-developed areas are generally at greatest risk due to both higher sensitivity and lower adaptive capacity.

This definition, however, clearly begins with a focus on the effects or impacts of climate change, with no reference to the people that exist within and interact with these systems. A focus on hazards and impacts can lead to vulnerability being seen as the amount of damage caused to a system and often ignores the role of humans and their institutions in mediating the outcomes of events. As Brooks (2003, p. 3) emphasizes, "we can only talk meaningfully about the vulnerability *of a specified system to a specified hazard or range of hazards*" [emphasis in original]. In contrast, the United Nations International Strategy for Disaster Reduction (UNISDR) focuses less on the nature of the hazard and more on the components of vulnerability itself: "Vulnerability is the condition determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (cited in: Renaud and Perez, 2010, p. 155). Viewing vulnerability as a state that exists within a system brings much more attention to its social and demographic aspects—including poverty and inequality, marginalization, food entitlements, access to insurance and housing quality (Brooks, 2003).[3] However, the UNISDR definition still makes no explicit reference to intentions, strategies, conflicts of interest and institutions.

In this chapter, the importance of engaging with the influential definition of vulnerability proposed by the IPCC is recognized, and the relevance of "exposure" and "adaptive capacity" is emphasized, as these represent the key components when engaging with population dynamics, and with human and social systems more broadly. The concept of "sensitivity" is less directly relevant because human systems are not passively "sensitive", but rather are actively able to shape their own outcomes by drawing on their adaptive capacity. The outcomes of the first UNFPA/International Institute for Environment and Development (IIED) conference on *Population Dynamics and Climate Change* (Guzmán et al., 2009) clearly show that population dynamics shape vulnerability to climate change impacts, for example, through the distribution of populations both globally and within countries. As the editors concluded:

> It is impossible to understand and reduce vulnerability without taking population dynamics into account. From acute, climate-related events like storms and floods to long-term shifts in weather patterns and sea level patterns, the impacts only become clear through an understanding of who is at risk, what the risks are to people rather than just to places and how these risks vary within and across populations (Guzmán et al., 2009, p. 5).

Assessing vulnerability

Understanding vulnerability is a necessary prerequisite of measuring it. The impacts of climate change (and measures to respond to it) obviously cut across geographic, social, political and economic lines. Because of this, vulnerability assessments have tended either to focus within these divisions, resulting in a narrow and splintered approach that fails to recognize the different dimensions of the issue, or to be inclusive and all-encompassing, resulting in an unhelpful broadness that can inhibit concrete action.

The way in which vulnerability is measured is closely linked to the types of responses that are proposed. Preconceptions of the most appropriate response strategies can shape the types of data that are collected, whereas a focus on only one set of data can influence the actions that are taken. To date, many international agencies have prioritized remote-sensing, model-based approaches. These top-down approaches obviously have an important role to play, but cannot incorporate the socially and contextually specific factors shaping the vulnerability of individuals, households and communities. They are also subject to a wide range of uncertainties, particularly when climate-model predictions are applied to relatively small spatial areas. In addition, these top-down approaches tend to encourage adaptation responses that rely on engineering and infrastructure only, which is just a small part of the overall framework necessary for dealing with the challenges of climate change. A more comprehensive approach to adaptation (as described, for example, by the United Kingdom Climate Impacts Programme (UKCIP, 2008) sees "delivering adaptation actions", in this case, conceived of as offsetting losses, preventing effects or bearing losses, as only one component of adaptation, with "building adaptive capacity", including addressing issues of information, governance and social structures, identified as being equally important.

Community-based and non-governmental organizations have developed a range of participatory methods to assess hazards, vulnerabilities and capacities in support of community-based disaster risk reduction (van Aalst et al., 2008). While these risk assessments have the potential to reduce vulnerability to climate change, to be effective they will require a better awareness of the changing risks associated with climate change; this in turn will require better use of climate information at the community level. Broader participation by low-income groups can also increase the efficiency of local development programmes (including those addressing climate change impacts), give value to alternative voices and facilitate meaningful social change (Mohan, 2002). However, it is important to recognize that assessing risk solely at the level of the community neglects the global and regional dimensions of climate change. For example, short-term local observations (which will be affected by a range of different factors) cannot provide an adequate basis for planning for long-term changes in climate. In addition, particularly in densely settled urban areas, there will need to be a balanced set of responses from governments that address both local issues and the provision of large-scale infrastructure (although, of course, decisions made about the location and functioning of infrastructure can and should be shaped by local communities).

Local population enumerations have some similarities to household surveys in low-income areas, but, when used as a tool by effective grassroots organizations, they go beyond this role to involve the residents of these settlements in identifying and asking questions, to cover all households (not just a sample) and to return data to households and neighbourhood organizations. These enumerations provide detailed data on existing infrastructure and services—an essential component of planning for urban development or climate change adaptation (Karanja, 2010). They can be used to gather detailed information on the experiences of past adverse climatic events as a means of highlighting appropriate methods for strengthening resilience at the local level. These enumerations can thus have a place in providing data inputs for assessing vulnerability and building adaptation programming. This means designing vulnerability assessments that incorporate bottom-up information and go deeper than the systemic definitions of vulnerability by detailing how vulnerability varies across populations in specific contexts.

The Relevance of Exposure

Exposure to climate impacts is often understood as being static: a simple description based on geographical location in relation to the direct impacts of disasters or climate change. In this regard, exposure is frequently seen as an underlying factor that influences vulnerability, rather than itself being shaped through a range of social and demographic processes. In this section of the chapter, perspectives of exposure that are based on the relationship between geography and the built environment are presented first. By this definition, for instance, the global distribution of urban areas in Low Elevation Coastal Zones (LECZs) means high exposure to sea level rise. Next, the ways in which this geographic and built environment exposure are actually shaped by broader issues of poverty and development at a variety of scales, but particularly within urban areas (especially in relation to access to land by different groups), are explored. From this, the specific concerns of population dynamics and demographic change and the ways in which this will alter exposure in the long term are examined.

Many assessments of climate risk are based primarily on a limited analysis of exposure to hazards, neglecting the more complex social, political and demographic processes contributing to vulnerability. For example, the World Bank's "urban hot spots" methodology (World Bank/UNISDR, 2008, p. 41) identifies vulnerable locations as being characterized by:

- moderate to high level of one or more natural hazards;
- medium or high observed vulnerability in past disasters;
- moderate- to high-sectoral vulnerability to climate change;
- poor or non-existent urban development plan;
- poor compliance with urban development plan;
- poor quality of building stock;
- high population density;
- medium or high slum density;
- no comprehensive disaster response system;
- economic or political significance to country region.

According to this model, increasing "resilience" is primarily seen as identifying and reducing "hot spots" of risk, which are defined based on past hazards, the existing built environment and plans in place to respond to hazards. The hot spots approach isolates vulnerability geographically and fails to take into account the variation in vulnerability associated with the characteristics, capacities and interactions of people living in the hot spots. A study of the vulnerability of port cities by the Organisation for Economic Co-operation and Development (OECD) (Nicholls et al., 2008, p. 9) takes a similar approach and explicitly refers to the importance of protective measures rather than adaptive capacity in mediating impact: "[T]he linkage between exposure and the residual risk of impact depends upon flood (and wind) protection measures." It is clear, however, that the linkage depends on much more.

In contrast, several recent frameworks for assessing climate risk in urban areas have the stated intention of bringing together measures of exposure to hazards with indices of the potential for cities to withstand and respond to these risks, yet appear in many cases to simply list these rather than incorporate them in a meaningful way. The World Wide Fund for Nature's (WWF) *Mega-stress for Mega-cities* (WWF, n.d.) lists exposure to hazards (temperature, precipitation, sea level rise), physical and social *vulnerability* (infrastructure, population, land use, governance) and low levels of adaptive capacity as the key determinants of urban stress as a result of climate change. Similarly, the Climate and Disaster Resilience Initiative (CDRI) of Kyoto University assesses resilience based on five criteria—physical dimension, natural dimension, social dimension, institutional dimension, economic dimension—and combines these into a single measure of resilience (CDRI, 2009).

Perhaps the approach that takes the largest number of factors into account is the city climate "risk assessment" proposed by Mehrotra et al. (2009), which incorporates hazards, vulnerabilities and adaptive capacity:

- Hazards: temperature (observed trend and projections for 2050s); precipitation (observed trend and projections for 2050s); sea level rise (observed trend and projections for 2050s); extreme events.
- Vulnerabilities: population; density; percentage poor/slum dweller; per cent of urban area (or population) susceptible to flooding; city percentage of national GDP.
- Adaptive capacity: institutions and governance measures affecting climate change actions; willingness of city leadership to address climate change (e.g., through membership of international groups like C40 Cities Climate Leadership Group); information and resources to provide a comprehensive analysis of climate risks for the city; whether an administrative unit is assigned to address climate change.

However, adding more and more measures to an exposure-based index does not result in a better and more actionable understanding of vulnerability, particularly as it applies to the characteristics and capacities of people. These frameworks still present vulnerability as being a characteristic in its own right, rather than seeing it also as an outcome of the interactions between geographical (natural environment), physical (built environment) and social processes. In contrast, it is more useful to ask specific questions that aid in understanding the nature of exposure within countries and communities. These questions highlight the linkages between geography, the built environment and poverty and identify the underlying characteristics that produce vulnerability in a range of different groups. Hardoy and Pandiella (2009, p. 206) propose the following questions to unpack these issues:

- Who lives or works in the locations most exposed to hazards related to the direct or indirect impacts of climate change?
- Who lives or works in locations lacking the infrastructure that reduces risk?
- Whose homes and neighbourhoods face greatest risks when impacts occur?

The answer to all of these questions are those who live and work in illegal or informal settlements that lack provision for infrastructure and services—with no sewers, no drains, poor quality housing and no emergency services. They are people without a safe place to move to, who cannot rely on their homes being protected from looting if they do move and who have no certainty that they will be able to move back to their homes because of their lack of security of tenure. Although characteristic of many low- and middle-income countries, these factors also play an important role within wealthier economies: For example, significant numbers of London's poorest residents live in locations with particularly high levels of flood risk (Mayor of London, 2010).

Assessing exposure: population dynamics to bridge geography, the built environment and the social context

Exposure is generally assessed at the intersection of climate projections, geography and the built environment, which, as noted, leaves a clear gap both conceptually and with regard to policies to address exposure. Exposure must incorporate people in the context of both their social and physical environments. The questions presented above help to make this shift in two ways: by focusing attention on the question of "who is exposed?" (as opposed to "what place?") and on the question of "why them?", or the mechanisms—livelihoods, work, dwellings, networks—of that exposure. Geography is the literal terrain of climate impacts; the built environment is an essential mediator, with housing stock, infrastructure and access to services determining how hazards will play out in given spaces. Yet, a third component remains: how people live in, operate in and move across geography and the built environment. Population dynamics can create a bridge between these factors, in particular through the spatial distribution and mobility of the population.

Spatial distribution, urbanization and urban population characteristics

Urbanization, or the changing proportion of the population living in urban areas, has significant impacts on access to services, dwelling type and distribution of aid during and after crises. While urbanization overall assists in poverty reduction, it can also bring about higher concentrations of poverty (Satterthwaite, 2004; Montgomery, 2009). Urbanization can, therefore, have contradictory consequences for exposure, depending on the nature of the built environment and growth rates in geographically vulnerable areas. The nature of urbanization matters: whether it is unplanned and fast-paced or whether projected urbanization is incorporated into urban and environmental policy (UNFPA, 2007).

As discussed above, LECZs have a heightened vulnerability that is associated with sea level rise, and, in the developing world, they contain many large- and medium-sized cities. Population growth in urban LECZs is projected to be particularly high. Due to these population changes over the next decades, exposure to hazards from sea level rise will increase significantly (McGranahan et al., 2007; Balk et al., 2009)—an increase that would not be captured without incorporation of population dynamics. Given that some of the population growth in LECZs is driven by migration, this growth makes the "climate migration" discussion more complex in that many people are moving towards, not away from, exposure. In doing so, however, they may be increasing their adaptive capacity through better and more resilient livelihoods.

Population density can help to determine how many people are at risk and how access to services is distributed across populations. Density is highly dependent on interactions with the built environment, socioeconomic status, social capital, and prevalence of services and institutions in its relationship with exposure (Dodman, 2009). People in high density areas can be extremely exposed, as is the case in urban slums in LECZs; for instance, significant increases in population density in cities in Bangladesh have resulted in greatly increased flood exposure (Alam and Rabbani, 2007; Dodman, 2009).

At the same time, however, clustering people at higher densities in safer locations can reduce exposure to climatic threats or can make the provision of protective infrastructure more cost-effective. Urban slums can bring together each of the dimensions of exposure referred to above, frequently combining geographic risk, poor infrastructure and the built environment, poverty and population factors, including high density, that can exacerbate exposure. For example, the image of an urban slum in Bacon Poblacion, Sorsogon, Philippines (see Figure 1.2), illustrates how these factors can come together in a single location. Hasan et al. (2010) applied innovative design models to case studies of urban slums in

Figure 1.2: Bacon Poblacion, Sorsogon, Philippines

Photo: David Dodman

Karachi, showing that it is possible to support similar levels of density in existing informal and substandard dwellings, while also providing better housing and economic opportunity to residents. Some urban slums are located in flood plains or other areas of particularly high climate risk, yet these examples show that deterministically linking urbanization or urban slum residence with heightened vulnerability can miss vital internal variation. Factors associated with population dynamics and development can change the nature of urban exposure.

Mobility and migration

Defining vulnerability and exposure only in terms of geography and the built environment leads to the cataloguing of those who move due in part to climate change impacts as a vulnerable group. In this model, people's mobility in the face of climate change is seen as an outcome of their vulnerability and the extent of climate impacts where they are (e.g., Stern 2006, among many). The hazard occurs, and people are displaced. However, although climate migrants have often been classed as a "vulnerable" group, they are frequently people who have engaged in contextually appropriate adaptive behaviour and have used mobility to reduce their vulnerability. In this way, individuals who have stayed behind in the original location may remain exposed to climate-related hazards (Government Office for Science, 2011). Consensus is therefore growing that migration is an adaptation strategy, rather than a response based on a failure of adaptation (Tacoli, 2009). The discourse and scholarship on these areas is more fully explained in Chapters 2 and 3.

One additional point remains, however, regarding the relationship between individual behaviour and aggregate population dynamics. To conceive of migration as part of adaptation, population spatial distribution needs to be incorporated into exposure (and adaptive capacity, as described below). First, even using a narrow definition of exposure, if people change their location, for instance through seasonal migration, and therefore their exposure, then spatial distribution and mobility need to be taken into account. Second, migrants are incorporating climate change into their migration calculations (as they have with environmental change since the first people migrated), meaning that people may move in part based on their perceptions of exposure (International Organization for Migration [IOM], 2009). This is the crux of migration as adaptation, and why seeing migration as simply an outcome of climate change hazards is such an oversimplification. If current or future population spatial distribution is based in part on the geography of expected environmental risk, then separating the two into hazard as cause and migration as effect is problematic. Without the shift in spatial distribution of the population from an outcome of exposure to an ingredient in exposure, these linkages remain hidden.

Engaging with Adaptive Capacity

The third component of the IPCC's definition of vulnerability is adaptive capacity, which it defines as "[t]he ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantages of opportunities, or to cope with the consequences" (Technical Summary, Box 1). A broader definition is proposed by Brooks et al. (2005, p. 168), who suggest that adaptive capacity is:

> [t]he property of a system to adjust its characteristics or behaviour, in order to expand its coping range under existing climate variability, or future climate conditions. In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards.

Another concept closely related to adaptive capacity is that of resilience. The IPCC Fourth Assessment Report Glossary defines resilience as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change." However, when assessing the relationship between climate change adaptation, development and population dynamics, it is obvious that returning to the "same basic structure" is not sufficient. In contrast, Dodman et al. (2009) suggest that it is more appropriate to consider resilience as a process that enables not only the ability to cope with added shocks and stresses but also addresses the myriad challenges that constrain lives and livelihoods and facilitates more general improvements to the quality of human lives. They go on to argue that resilience is shaped by individual, household or community access to a range of rights, resources and assets. This is a more systems-oriented and dynamic approach, with adaptive capacity at its core (Nelson et al., 2007).

Community resilience is based on "the capacity to retain critical functions, self-organize, and learn when exposed to change" (World Bank, 2010, p. 105). It is important to build on local and traditional knowledge for managing climate risk: Many communities already have context-relevant knowledge and strategies, and many adaptation strategies need to be undertaken at the local level. At the level of the city, the Asian Cities Climate Change Resilience Network (ACCCRN) suggests that "resilient cities create, enable, and sustain the services and institutions required for basic ongoing survival and are characterized by their ability to generate new opportunities for their residents. They avoid relying on solutions that depend on anticipating specific hazards, and instead take a broader, integrated approach" (ACCCRN. 2009, p. 405). This involves incorporating redundancy, flexibility, the capacity to reorganize and the capacity to learn (see Figure 1.3). Several different types of adaptation measures and processes can be identified: engineering options; social response options; land use planning; economic instruments; natural system management; sector-specific practices; and traditional responses of communities exposed to natural hazards and climate change (Birkmann et al., 2010).

Linking adaptive capacity to population dynamics

Hardoy and Pandiella (2009, p. 206) propose a second set of questions that highlight adaptive capacity at the local level:

- Who lacks knowledge, capacity and opportunities to take immediate short-term measures to limit impacts?
- Who is least able to cope with impacts?
- Who is least able to adapt to avoid impacts?

Figure 1.3: Resilience Framework

Source: ACCCRN, 2009, p. 405.

These questions bridge the gap between hazards, adaptive capacity, development and population by again focusing the questions on "who?" and "why them?" Responding to these questions from the poverty and development perspective allows individuals and families with limited incomes or who rely on assets (including their homes and possessions) that are not climate proof to be identified. Of course, richer enterprises and households can frequently buy their way out of risk with better infrastructure or by moving to safer locations, whereas most low-income groups are tied to the location and dangerous sites for their livelihoods, homes, assets, social networks and culture. Yet all of these factors are also shaped by demographic characteristics, including age, gender, race and ethnicity, among others (Bartlett, 2008; Patt et al., 2009), and their links to health, resources and human and social capital.

Mobile populations have more adaptive capacity, to the extent that mobility is a component of adaptation by way of reducing exposure, as argued above. Resources are central to mobility and mediate the relationship between race and ethnicity and adaptive capacity. For instance, in New Orleans, low-income African-American residents cited financial constraints as an impediment to evacuation prior to Hurricane Katrina, a situation exacerbated by a lack of cash for petrol and other incidentals caused by the hurricane striking at the end of the month, shortly before payday (Elder et al., 2007).

Strong social networks are also necessary for particular types of mobility (Boyd, 1989; Massey, 1990). "The effective units of migration were (and are) neither individuals nor households but sets of people linked by acquaintance, kinship and work experience" (Tilly, 1990, p. 84). Tacoli (2009, p. 108) shows an example of links between weather patterns and mobility in a context of varying human and social capital:

> Recent research in Burkina Faso suggests that a decrease in rainfall increases rural-rural temporary migration; on the other hand, migration to urban centres and abroad, which entails higher costs, is more likely to take place after normal rainfall periods and is influenced by migrants' education, the existence of social networks and access to transport and roads.

The link between migration decisions and climate impacts also goes through human capital formation, particularly knowledge of current changes in climate, expectations of future trends and the potential impacts of these on livelihoods and economic opportunity. Networks that cross rural-urban divides have more access to information and more diversified income sources, creating a foundation for short- and long-term rural-urban migration. In settings, therefore, where rural-urban migration, both short and long term, is prevalent, and where rural-urban linkages are strong, people may have greater adaptive capacity. Wide and geographically diverse social networks are thus at the core of migration as adaptation.

The importance of social networks may be overstated for other types of vulnerability, which can be demonstrated by careful analysis of variations across populations. A common claim is that the elderly are more vulnerable due to lack of social ties. Studies of heat waves have pointed to old age, prior morbidity and social isolation as key causes of mortality (e.g., Semenza et al., 1996; Fouillet et al., 2006), which have been used to support the social network link between elderly populations and vulnerability. Yet Browning et al. (2006) examined the distribution of deaths in the 1995 Chicago heat wave and found that African-Americans and Latinos had similarly sized social networks, but much different mortality rates. What appeared to be isolation from lack of social networks was better explained by neighbourhood factors, including safety concerns and poor infrastructure, which kept people from leaving their homes. Kovats and Hajat (2008) add culture as a covariate of subpopulation vulnerability.

The importance of the links between population and development for adaptive capacity are underscored in assessing vulnerability across two frequently discussed populations: women and children. Women as a group are often considered highly vulnerable to climate change, yet Alber (2009, p. 149) points out that "if the underlying reasons for women's (and men's) specific vulnerabilities are not analysed and addressed properly, the results will be merely rhetorical". Alber identifies gendered division of labour, income differences between men and women, power differences and cultural patterns and roles as key mechanisms. Access to reproductive health plays a central role in enhancing women's empowerment and opportunities and to creating a foundation for community-based adaptation (UNFPA, 2009). Children and youthful populations will be disproportionately impacted by climate change, because of a range of social and biological developmental mechanisms (Bartlett, 2009). These include income differences and the prevalence of child poverty, as well as brain and physical developmental delays associated with, for instance, poor health and malnutrition, which stretch impacts for decades beyond isolated crises.

Taken together, these mechanisms linking population, development and adaptive capacity go beyond the scope of impact-first programmes and, where they are included in impact-first programmes, would make the programmes themselves oriented towards broader development. They also underscore the importance of specifying and assessing mechanisms of vulnerability and adaptive capacity linking population and development in order to avoid missing the target in programming.

Improving Adaptation Programming Through Links to Disaster Risk Reduction and Population Data

This section reviews two key measures to improve adaptation programming based on the arguments presented above: creating better links between development, adaptation and disaster risk reduction and incorporating population data into assessments and programming. This chapter began by suggesting that "impact-first" responses, which include many disaster risk reduction approaches, fall short of the broader adaptation needed and that this type of broader adaptation must be at least partially situated in the development arena. It reviewed a series of linkages between population dynamics, development and components of vulnerability and adaptation, including exposure and adaptive capacity, which may help to create that kind of broader adaptation linked to development. The remainder of this chapter explores ways in which large groups might change their mindsets and behaviour, a process that necessitates changes in livelihoods and lifestyles that go beyond hazard-specific preparations and instead sets the foundation for preparation for climate change.

Bringing together disaster risk reduction and climate change adaptation

There are obviously close synergies between adaptation to climate change, disaster risk reduction and development. Of course, there is no single definition of 'development' that can be linked with population issues and climate change, and the risks from climate change must be seen alongside the other risks that people face (and which they often identify as being far more important in their lives).

Indirect adaptation measures share three key characteristics that underscore their importance for adaptation and complementarities with impact-first responses (O'Neill et al., 2008, pp. 198-199):

1. Rather than being specific responses to the impacts of climate change, these measures generate prerequisites for reduced risk or help people take care of basic needs, like food, water and shelter.
2. They can be effective in the short term because they more accurately reflect the immediate needs as expressed by poor people and communities (as also suggested by Cannon and Müller-Mahn, 2010).

Schipper and Pelling (2006) suggest that climate change affects disaster risk in two ways: Short-term climate variability and its extremes influence the range and frequency of shocks affecting social systems; and longer-term variability can affect the productive base of society. In particular, the impacts of climate change will affect the ability to achieve broader development goals—both by the ways in which these are experienced by different groups within society and through the longer-term effects on productive assets (in both agricultural and non-agricultural systems).

There are also a range of linkages between the disaster risk reduction and the climate change adaptation agendas. Most obviously, institutional structures and tools for disaster risk reduction can reduce the exposure of populations to the types of extreme weather events that will become more frequent and intense as a result of climate change (Schipper and Pelling, 2006). Efforts to reduce this kind of vulnerability work more effectively when they also meet every day developmental needs. For example, recent projects in the Simon Bolivar and La Cañita communities of Santo Domingo in the Dominican Republic have shown that the longest-lasting interventions have been purpose-built staircases (designed to facilitate evacuation during flood events) that are also used on a daily basis by residents of these communities.

There are, however, some key differences. Climate change adaptation and disaster risk reduction operate in distinct time frames: Disaster risk and relief are relatively immediate and concentrated, whereas climate change evolves over longer periods. They also frequently occupy distinct spatial scales, with disaster risk reduction being focused on the local and national scales, and climate change policy often focused on the global scale (although many adaptation activities have taken place at a much more local level). Yet at the same time, existing disaster risks may well be exacerbated by climate change, and existing strategies for reducing disaster risk may contribute to broader adaptation goals (Renaud and Perez, 2010). There is also a distinct need for disaster risk reduction to engage more seriously with issues associated with global political economy; in addition, climate change adaptation needs to focus more deeply on local issues—as has been recognized through the theory and practice of community-based adaptation. There is also potential for greater integration around scales, knowledge and norms (Birkmann and von Teichmann, 2010).

Population data for adaptation analysis

Integration of population data into adaptation analysis and intervention is at the heart of this book's contribution. Better access to information on climate change and its consequences is at the centre of improving adaptation programming and people's adaptive capacity. Agrawala and van Aalst (2008, p. 190) point to three paths to improved data access and usage: improving the usability of climate data; developing climate screening tools for programming; and identifying appropriate entry points for climate data. The World Bank's Urban Risk Assessment (Dickson et al., 2012) suggests a methodology at the city level for bringing together a number of different data types and sources and integrating them into policy processes at the local level. These processes also need to be applied to population data for adaptation analysis, and the use of population data can, in turn, help in their achievement.

One reason for hastening the integration of population data into vulnerability assessments and adaptation efforts is that, particularly over the past 10 years, technology for remote sensing of hazard impacts has improved in leaps and bounds. Shortly after the 2010 earthquake in Haiti, detailed images and maps of damage to the built environment were generated using pre- and post-data from satellite imagery, LIDAR (light detection and ranging), aerial photography and other technologies that could provide data quickly and efficiently, with limited on-the-ground presence in the midst of what was an extraordinarily difficult humanitarian crisis. Much of these data were aggregated onto Open Street Map, which provides data on streets, buildings and damage, as well as available infrastructure and services for support, overlaid with satellite imagery and other sources of visual imaging (http://haiti.openstreetmap.nl/).

No such speedy detection of the human toll of the earthquake was possible. Estimates of the numbers of impacted people trickled in slowly. Across large geographic scales, only censuses provide detailed, geo-referenced data that can be layered onto maps displaying geography and the built environment, yet they do not provide pre- and post-crisis information and may be undertaken years after the hazard. Morbidity and mortality data are also extremely difficult to collect, particularly in crisis situations.

The 2010 *World Development Report* raises a key issue in local adaptation planning (World Bank, 2010, p. 89):

> A compounding set of uncertainties—about demographics, technology, markets, and climate—requires policies and investment decisions to be based on imperfect and incomplete knowledge. Local and national decision makers face even greater uncertainties because projections tend to lose precision at finer scales—an inherent problem of downscaling from coarse, aggregate models. If decision parameters cannot be observed and measured, robust strategies . . . that directly address the reality of a world of shifting baselines and intermittent disturbances are the appropriate framework in a context of unknown probabilities.

This highlights the need for spatially targeted population projections at far smaller scales than national level – for instance, for cities. A number of approaches are being developed for these types of projections. The Report also stresses the importance of small scale enumerations for locally-driven data collection and analysis of the type described above. Climate change will not occur in a vacuum, but will take place alongside a range of other social, economic and demographic shifts. Improved knowledge about any of these will help to guide decision-making, particularly as there are significant levels of uncertainty around predictions of future climates at the regional and local scale.

Conclusion

This chapter has suggested that current approaches to understanding climate change vulnerability, while valuable, have masked important gaps in the understanding and practice of adaptation. These limitations include superficial assessments of who is vulnerable and why, a focus on the physical environment over the social one as well as a lack of connection between the two and a static perception of vulnerability over time. Population dynamics, and their strong links to issues of development, can help to fill these gaps through better assessment of vulnerability, better targeting of adaptation practices to the actual causes of vulnerability and better monitoring and evaluation of adaptation programming. By delving into the concept of vulnerability, and particularly by focusing on exposure and adaptive capacity, this chapter has shown that the extent of vulnerability depends significantly on key population dynamics, including urbanization and mobility. It has also shown that knowing why people are vulnerable depends on understanding the links between population dynamics, demographic characteristics, and developmental mechanisms, such as economic, human and social capital, and is critical to developing policies and programmes to build adaptive capacity. Too often, global adaptation and disaster risk reduction programming targets geography, the built environment and technical solutions, while simultaneously thinking deterministically and superficially about social vulnerability. Incorporation of population dynamics into both exposure and adaptive capacity can help to bridge the persistent programmatic divide between the physical and social dimensions of vulnerability and adaptation.

Yet there are a series of additional challenges to bridging physical and social approaches to adaptation. A host of political and institutional challenges stand in the way of better programming, only a very short selection of which can be mentioned here. Policymaking and technical communities are divided both internally and from each other. The politics and priorities of different local, national and international communities in development, economic growth and climate change can result in imbalanced and potentially maladaptive consequences. Short-term thinking is also a critical problem in the context of impacts that extend far into the future and imperatives for action that are immediate and reactive. The answers to these problems are for the most part not technical, and incorporating population dynamics can generate movement in the right direction.

A focus on population dynamics can help to push the time horizon of decision-making, focusing attention on the long term. Decisions made now with regard to planning for urbanization, support for migration, reproductive health and other population policies have impacts that will become most apparent in a span of decades. The same is true for climate change, both for mitigation and for creating the foundation for effective and developmental adaptation. Taken together, these two agendas can help lead to better future planning by governments and international agencies.

Notes

1. Alber (2009) and Bartlett (2009), for instance, describe and address these shortcomings with regard to women and children, respectively. This kind of common mistranslation has in some ways been associated with the adoption of climate change within development and humanitarian aid communities as a driving issue, without sufficient consideration of the nature of linkages and the resulting impact on development and humanitarian aid agendas (Inomata, 2008).

2. See, for instance, Mitchell and van Aalst (2008), UNISDR (2008), the coverage of climate change in the Hyogo Framework for Action (United Nations, 2005), and the inclusion of disaster risk reduction in the Bali Action Plan (UNFCCC, 2008).

3. The widespread incorporation of the term 'vulnerability' into discussion of climate change has been in large part due to the predominance of natural scientists involved in the initial development of climate change policy and practice. The concept of risk – as used in disaster risk reduction, and as used more frequently by social scientists – often has vulnerability as one of its sub-components, as indicated by the oft-used equation *risk = hazards x vulnerability x exposure*.

References

Agrawala, S., and M. van Aalst. 2008. "Adapting Development Cooperation to Adapt to Climate Change." *Climate Policy* 8(2): 183-193.

Alam, M., and M. D. G. Rabbani. 2007. "Vulnerabilities and Responses to Climate Change for Dhaka." *Environment and Urbanization* 19(1): 81-97.

Alber, G, 2009. "Gender and Climate Change Policy" Pp. 149-163 n: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Asian Cities Climate Change Resilience Network (ACCCRN). 2009. *Responding to the Urban Climate Challenge*. Boulder, Colorado: Institute for Social and Environmental Transition.

Balk, D., et al. 2009."Mapping Urban Settlements and the Risks of Climate Change in Africa, Asia and South America" Pp. 80-103 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London : UNFPA and IIED.

Balk, D., et al. 2009. "Understanding the Impacts of Climate Change: Linking Sattelite and Other Spatial Data with Population Data." Pp. 206-217 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA andIIED.

Bartlett, S. 2009. "Children in the Context of Climate Change: A Large and Vulnerable Population." Pp. 133-148 in: *Population Dynamics and Climate Change* edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

________. 2008. "Climate Change and Urban Children: Impacts and Implications for Adaptation in Low- and Middle-income Countries." *Environment and Urbanization* 20(2): 501-519.

Birkmann, J., et al. 2010. "Adaptive Urban Governance: New Challenges for the Second Generation of Urban Adaptation Strategies to Climate Change." *Sustainability Science* 5(2): 185-206.

Birkmann, J., and K. von Teichma. 2010. "Integrating Disaster Risk Reduction and Climate Change Adaptation: Key Challenges: Scales, Knowledge, and Norms." *Sustainability Science* 5(2): 171-184.

Boyd, M. 1989. "Family and Personal Networks in International Migration: Recent Developments and New Agendas.' *International Migration Review* 23(3): 638-670.

Brooks, N. 2003. *Vulnerability, Risk and Adaptation: A Conceptual Framework*. Tyndall Centre for Climate Change Research. Working Paper No, 38. Norwich, United Kingdom: Tyndall Centre for Climate Change Research.

Brooks, N., W. N. Adger, and P. M. Kelly. 2005. "'The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation." *Global Environmental Change* 15(2): 151-163.

Browning, C. R., et al. 2006. "Neighborhood Social Processes, Physical Conditions, and Disaster-Related Mortality: The Case of the 1995 Chicago Heat Wave." *American Sociological Review* 71(4): 661-678.

Cannon, T., and D. Müller-Mahn. 2010. :Vulnerability, Resilience and Development Discourses in Context of Climate Change." *Natural Hazards* 55(3): 621-635.

Climate and Disaster Resilience Initiative (CDRI). 2009. *City Profile: Climate and Disaster Resilience*. Kyoto: Kyoto University. Website: http://www.unisdr.org/files/8168_cityprofilelowresolution.pdf, last accessed 25 October 2012.

Dickson, E., et al. 2012. *Understanding Urban Risk: An Approach for Assessing Disaster & Climate Risk in Cities*. Washington, D. C.: The World Bank.

Dodman, D. 2009. "Urban Form, Greenhouse Gas Emissions and Climate Vulnerability. Pp. 64-79 in: *Population Dynamics and Climate Change*, edited by J. M Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Dodman, D., J. Ayers, and S. Huq. 2009. "Building Resilience." Pp. 151-168 in: *State of the World 2009: Into a Warming World*. The World Watch Institute. New York: W. W. Norton and Company.

Elder, K., et al. 2007. "African Americans' Decisions not to Evacuate New Orleans before Hurricane Katrina: a qualitative study." *American Journal of Public Health* 97(Supplement 1): S124-S129.

Fouillet, A., et al. 2006. "Excess Mortality Related to the August 2003 Heat Wave in France." *International Archives of Occupational and Environmental Health* 80(1): 16-24.

The Government Office for Science. 2011. *Foresight: Migration and Global Environmental Change. 2011: Final Project Report*. London: The Government Office for Science. Website: www.bis.gov.uk/assets/foresight/docs/migration/11-1116-migration-and-global-environmental-change.pdf, last accessed 25 October 2012.

Guzmán, J M. 2009. "'The Use of Population Census Data for Environmental and Climate Change Analysis." Pp. 192-205 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Guzmán J. M., et al. (eds.) 2009. *Population Dynamics and Climate Change*. New York and London: UNFPA and IIED.

Hardoy, J., and G. Pandiella. 2009. "Urban Poverty and Vulnerability to Climate Change in Latin America." *Environment and Urbanization* 21(1): 203–224.

Hasan, A., A. Sadiq, and S. Ahmed. 2010. *Planning for High Density in Low-income Settlements: Four Case Studies from Karachi*. Human Settlements Working Paper Series. Urbanization and Emerging Population Issues. No. 3. London and New York: IIED and UNFPA.

Henry, S., B. Schoumaker, and C. Beauchemin. 2004. "The Impact of Rainfall on the First Out-Migration: A Multi-level Event-History Analysis in Burkina Faso." *Population and Environment* 25(5): 423-460.

Huq, S., and J. Ayers. 2007. "Critical List: The 100 Nations Most Vulnerable to Climate Change. *IIED Sustainable Development Opinion*. London: IIED.

Inomata, T. 2008. "Management Review of Environmental Governance within the United Nations System" (JIU/REP/2008/3). Geneva: Joint Inspection Unit, United Nations.

IOM. 2009. *Migration, Environment and Climate Change: Assessing the Evidence*. Geneva: IOM.

IPCC. 2007. *Climate Change 2007: The Fourth Assessment Report of the Intergovernmental Panel on Climate Change*: *Synthesis Report*: *Summary for Policymakers.* Cambridge, United Kingdom: Cambridge University Press.

Jensen, E., and D. Ahlburg. 2004. "'Why Does Migration Decrease Fertility? Evidence from the Philippines." *Population Studies* 58(2): 219-231.

Karanja, I. 2010. "An Enumeration and Mapping of Informal Settlements in Kisumu, Kenya, Implemented by Their Inhabitants." *Environment and Urbanization* 22(1): 217-239.

Kovats, R. S., and S. Hajat. 2008. "Heat Stress and Public Health: A Critical Review." *Annual Review of Public Health* 29: 41-55.

Martine G 2009. "Population Dynamics and Policies in the Context of Global Climate Change." Pp. 9-30 in: *Population Dynamics and Climate* Change, edited by J. M. Guzmán, et al. New York and London: UNFPA and IIED..

Massey, D. 1990. "Social Structure, Household Strategies, and the Cumulative Causation of Migration." *Population Index* 56(1): 3-26.

Mayor of London. 2010. *The Draft Climate Change Adaptation Strategy for London: Public Consultation Draft*. London: Greater London Authority. Website: http://www.london.gov.uk/climatechange/strategy, last accessed 6 September 2012.

McGranahan, G., D. Balk, and 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): 17-37.

Mehrotra, S., et al. 2009. "Framework for City Climate Risk Assessment." Concept paper presented at The World Bank's Fifth Urban Research Symposium, Marseille, France, 28-30 June 2009.

Mitchell, T., and M. van Aalst. 2008. "Convergence of Disaster Risk Reduction and Climate Change Adaptation." Review for the Department for International Development (DFID). London: United Kingdom

Mohan, G. 2002. "Participatory Development." Pp. 49-53 in: *The Companion to Development Studies*, edited by V. Desai. and R. Potter. 2002. London: Arnold.

Montgomery, M. 2009. "Urban Poverty and Health in Developing Countries." *Population Bulletin* 64(2).

Nelson, D., W. N. Adger, and K. Brown.2007. "Adaptation to Environmental Change: Contributions of a Resilience Framework." *Annual Review of Environmental Resources* 32: 395-419.

Newell, P 2004. "Climate Change and Development: A Tale of Two Crises." *IDS Bulletin* 35(3): 120-126.

Nicholls, R. J., et al. 2008. *Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates*. OECD Environment Working Paper. No. 1. Paris: OECD.

O'Brien, G, et al. 2008. "Climate Adaptation from a Poverty Perspective.' *Climate Policy* 8(2): 194-201.

Patt, A. G., A. Dazé, and P. Suarez. 2009. "Gender and Climate Change Vulnerability: What's the Problem, What's the Solution?" Pp. 82-102 in: *Distributional Impacts of Climate Change and Disasters: Concepts and Cases*, edited by M. Ruth and M. E. Ibarraran, 2009.. Cheltenham, United Kingdom: Edward Elgar Publishing Inc.

Renaud, F., and R. Perez. 2010. "Climate Change Vulnerability and Adaptation Assessments." *Sustainability Science* 5(2): 155-157.

Satterthwaite, D. 2004. *The Under-estimation of Urban Poverty in Low- and Middle-income Nations.* Human Settlements Working Paper, Poverty Reduction in Urban Areas Series. No. 14. London: IIED.

Schipper, L., and M. Pelling. 2006. "Disaster Risk, Climate Change and International Development: Scope for, and Challenges to, Integration." *Disasters* 30(1): 19-38.

Schneider, S., et al. 2007. "Assessing Key Vulnerabilities and the Risk from Climate Change." Pp. 779-810 in: *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by M. Parry et al. 2007. Cambridge: Cambridge University Press.

Semenza, J. C., et al. 1996. "Heat-related Deaths during the July 1995 Heat Wave in Chicago." *New England Journal of Medicine* 335(2): 84-90.

Stern, N. 2006. *The Stern Review: the Economics of Climate Change*. London: HM Treasury.

Tacoli, C. 2009. "Crisis or Adaptation? Migration and Climate Change in a Context of High Mobility." Pp. 104-118 in: *Population Dynamics and Climate* Change, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Thomalla F., et al. 2006. "Reducing Hazard Vulnerability: Towards a Common Approach between Disaster Risk Reduction and Climate Adaptation." *Disasters* 30(1): 39-48.

Tilly, C. 1990. "'Transplanted Networks." Ch. 3 in: *Immigration Reconsidered: History, Sociology, and Politics*, edited by V., Yans-McLaughlin, ed. 1990. Oxford: Oxford University Press.

United Nations. 2005. *Report of the World Conference on Disaster Reduction, Kobe, Hyogo, Japan, 18-22 January 2005* (A/CONF.206/6). Geneva: United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UN/ISDR).

UKCIP. 2012. *The UKCIP Adaptation Wizard* v 2.0. Oxford: UKCIP. Website: www.ukcip.org.uk/wizard, last accessed 7 September 2012.

UNFCCC. 2008. *Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 Addendum Part Two: Action Taken by the Conference of the Parties at its Thirteenth Session* (FCCC/CP/2007/6/Add.1). New York: United Nations.

UNFPA. 2009. *The State of World Population: Facing a Changing World: Women, Population and Climate*. New York: UNFPA.

________. 2007. *The State of World Population 2007: Unleashing the Potential of Urban Growth*. New York: UNFPA.

UNISDR. 2008. "Links between Disaster Risk Reduction, Development and Climate Change." Paper commissioned by the Commission on Climate Change and Development. Geneva: UNISDR Website: http://www.ccdcommission.org/Filer/pdf/pb_disaster_risk_reduction.pdf, last accessed 7 September 2012.

van Aalst, M. K., T. Cannon, and I. Burton. 2008. "Community Level Adaptation to Climate Change: The Potential Role of Participatory Community Risk Assessment." *Global Environmental Change* 18(1): 165-179.

The World Bank. 2010.*World Development Report 2010: Development and Climate Change*. Washington, D. C.: The World Bank.

The World Bank /UNISDR. 2008. *Climate Resilient Cities: 2008 Primer: Reducing vulnerabilities to Climate Change Impacts and Strengthening Disaster Risk Management in East Asian Cities.* Washington, D. C.: The World Bank Global Facility for Disaster Reduction and Recovery and United Nations International Strategy for Disaster Reduction.

WWF. n.d. *Mega-Stress for Mega-Cities: A Climate Vulnerability Ranking of Major Coastal Cities in Asia*. Gland, Switzerland: WWF. Website: http://assets.panda.org/downloads/mega_cities_report.pdf, last accessed 7 September 2012.

CHAPTER 2

Fair and Effective Responses to Urbanization and Climate Change: Tapping Synergies and Avoiding Exclusionary Policies

Gordon McGranahan, Deborah Balk,
George Martine and Cecilia Tacoli

Introduction

Over the first half of this century, the urbanization level of Asia is expected to increase from about 37 to 64 per cent, while that of Africa is expected to grow from 36 per cent to 58 per cent (United Nations, 2012). Together with Asia's overall increase in population from 3.7 to 5.2 billion and Africa's from 0.8 billion to 2.0 billion, their combined urban population will increase by almost 2.9 billion, and by 2050 half of the people in the world will be living in the cities and urban towns of Africa and Asia–up from about a quarter in 2000. Despite considerable uncertainty in projections, this urban transition is bound to be among the most striking demographic trends of our time.

Meanwhile, the effects of climate change are likely to increase. Despite even greater uncertainty as to its exact form and outcomes, climate change must be the most striking environmental trend of our time. The dominant view in scientific circles is that the negative impacts of climate change over the course of the century will be large but unevenly distributed both spatially and socially. The contributors to climate change are likely to remain concentrated in wealthier parts of the world, though some of the largest increases in emissions are apt to be in urbanizing and industrializing Asia. The worst impacts, however, are expected to be in relatively poor countries, including many in Africa and Asia that are experiencing rapid urban growth.

The focus of this chapter is on how urbanization and climate trends will interact, how cities will react, how potentially vulnerable groups will be affected and the challenges that these changes pose to political equity and urban governance. Urban policy regimes already disadvantage many urban and rural dwellers, and their prospects could be further threatened by climate change. These groups are likely to be put at risk by physical hazards brought on by climate change, and in principle ought to be the key beneficiaries of climate change mitigation and adaptation. However, particularly if urban policy regimes become more exclusionary in response to climate change, they could end up doubly burdened—by climate change itself and by the inequitable responses to it.

This chapter is structured around the shift in population from rural to urban settlements (i.e., urbanization), the location of receiving urban centres and population density and distribution within those settlements. Each of these issues relates quite differently to climate change and poses different political and governance challenges. Except in passing, differences between small versus large settlements, mono-centric versus polycentric settlements or cities versus city-regions are not considered. While these differences could well relate to the broader question of how urbanization and climate change trends will combine, and how this will affect the most vulnerable groups, the evidence is too ambiguous to justify the sort of brief summary that could be included in this chapter.

Understanding the environmental, economic and social implications of urbanization requires getting its definition straight. The definition of urbanization used in this chapter is the standard demographic one: The level of urbanization is the share of the population living in urban rather than rural settlements, and the rate of urbanization is the annual rate at which this urban population share increases (Poston and Bouvier, 2010). Urbanization is sometimes used loosely to refer to urban population growth or to the conversion of land to urban use. This is statistically incorrect, since urban population growth rates in urbanizing countries are typically about twice the rate of urbanization, the difference being the country or region's overall population growth rate (United Nations, 2010b). Moreover, with urban population densities declining around the world, urban land areas are expanding far faster than the urban population growth rate (Angel et al., 2010).

Defining urbanization in terms of the growth of urban areas or populations is also misleading conceptually in that urbanization is a shift from rural to urban and not a purely urban phenomenon. It involves a relative reduction in the number of people in dispersed rural areas, as well as an increase in comparatively dense urban locations. Increasing the level of urbanization involves a shift towards greater settlement density. The implications of this shift are not at all the same as those of overall population growth and the declining density of urban settlement (or urban sprawl), which together are driving most urban spatial expansion. In particular, the shift has very different implications for greenhouse gas emissions and adaptive capacities.

Rural-urban Migration, Exclusion and Climate Adaptation

Some widely cited estimates suggest that climate change will result in hundreds of millions of climate refugees migrating out of the global South, looking for safer places to live (Myers, 2005). This crisis narrative has proved to be an effective means of stirring up press and public concern in the North. Similar estimates could be constructed to stir up fears about climate migrants leaving the countryside and overwhelming the cities of the global South. In both cases, such crisis narratives are in danger of being used to justify tightening controls on migration and diverting attention from the sources of climate change and from the positive role that migration can play in adapting to climate change.

The high estimates of international climate migrants have been largely dismissed as unfounded by migration researchers (Black et al., 2008; Piguet, 2010; Tacoli, 2009). It has also been pointed out that this crisis narrative is ideologically rooted and obscures more legitimate concerns about how the burdens of climate change are being distributed (Hartmann, 2010). What is really striking about this narrative, however, is that it takes a pathway that relatively disadvantaged groups may need to follow in order to adapt to climate change and presents it as one of the major negative consequences of climate change (Black et al., 2011). This reflects a more general issue: One person's climate adaptation can be another person's climate-induced hazard. Indeed, to take the iteration forward one more step, for aspiring "economic" migrants it is possible that one of the negative consequences of climate change will be stricter limits on mobility.

While the climate-led migration crisis narrative relates primarily to international migration, it has important parallels in rural-urban migration. Internationally, borders are used to try to control population movements, and the distinction between the authorized and unauthorized migrant is at least rhetorically central and is used to justify various forms of legal and illegal discrimination (Adepoju et al., 2010; Donato and Armenta, 2011).

Intra-nationally, border controls are the exception, and regulations explicitly limiting the rights of rural people to move to urban locations—such as the hukou household registration system in China, once used to place strict limits on migration and still used to limit migrants' rights—are comparatively rare. Nevertheless, concerns about excessive rural-urban migration are widespread and motivate an array of questionable responses by governments. People intuitively perceive the advantages of urban life, but policymakers see only added burdens to urban management. The latest United Nations data show that 72 per cent of developing countries implement policies aimed at lowering rural-to-urban migration. The proportion is highest (81 per cent) in Africa where current urbanization levels are still low, but it is also high in the Latin America and Caribbean region, which is well on its way to completing its urban transition (United Nations, 2010, Table 16).

Such policies reflect a failure to accept the rights of poor migrants to settle in the city and a tendency to conflate poverty with rurality. Although they rarely have a significant and lasting impact on the reduction of migration, these policies do strengthen the anti-urbanization stances that inhibit pragmatic and pro-active approaches to inevitable urban growth. They also help to explain why an increasingly large share of urban settlement in most low- and many middle-income countries is informal and deficient in public services.

Underpinning these negative views is the assumption that rural migrants are responsible for "uncontrolled" urban growth. However, natural increase—the excess of births over deaths in the urban population—is in most cases a more important factor than rural-urban migration (United Nations, 2008). This is especially true in countries where fertility rates in both rural and urban areas remain high and in nations that have reached high levels of urbanization. Economic growth can also be a factor. China, with its rapid economic growth, is among the countries where rural-urban migration dominates urban growth (China ceased to use the hukou system to curb migration severely once it became clear that urbanization was necessary for economic growth). In contrast, the levels of urbanization were stagnating in some sub-Saharan African countries, probably as a result of declining economic opportunities in urban areas (Potts, 2009).

Rural migrants are also often held responsible for increasing urban poverty. Indeed, the estimated urban share of poor people living on less than US$1 a day has increased from 19 per cent in 1993 to 25 per cent in 2002 (Chen and Ravallion, 2007). While income-based measurements underestimate the real extent of urban poverty (Satterthwaite, 2004), there is no evidence to suggest that rural migrants are the majority or even a substantial proportion of the urban poor, and comparisons of migrant and non-migrant groups in urban centres show mixed results and, perhaps more important, comparatively small differences (United Nations, 2008). Moreover, even where rural migrants are worse off than other urban dwellers, they are usually better off than rural non-migrants.

Will climate change increase rural-urban migration?

It is impossible at this time to predict more than roughly what environmental impact climate change will have in different localities, let alone how this impact will influence migratory flows (Kniveton et al., 2008; Tacoli, 2009). Not only will climate change have its effect on migration in combination with a range of other economic and political factors, but actions taken in response to climate change may have just as large an effect on migration as the direct physical impacts of climate change. Thus, for example, rural biofuel plantations promoted to mitigate climate change could accelerate rural-urban migration by displacing rural smallholders. Similarly, the construction of infrastructure to produce renewable energy, such as dams, and infrastructure to protect against floods and other extreme weather events could have significant impacts on local livelihoods and displace large numbers of people (de Sherbinin et al., 2011). Also, urban building regulations promoted to reduce carbon emissions could inhibit rural-urban migration by increasing the cost of urban living, although their effects on carbon emissions may end up being rather minimal. The extent to which such measures, which harm already disadvantaged groups, will dominate over more positive measures will depend on how much influence such groups have in the policy arena.

Perhaps a more fruitful way to assess the impacts of climate change on population distribution is to focus on livelihood opportunities rather than mobility *per se* (see Chapter 3). From this perspective, mobility is a form of diversification of income sources. This, in turn, helps explain mobility's diversity, especially with regard to destinations, duration of stay and the composition of migrant flows, all of which are central to developing appropriate support policies.

Overall, there is a growing consensus among urban economists that urbanization and mobility are integral to economic growth (World Bank, 2009), in clear and increasingly sharp contrast with policymakers' pessimistic views. This does not mean, of course, that simply increasing urbanization and mobility will increase economic growth or productivity (Bloom, Canning, and Fink, 2008). However, arbitrary attempts to curb urbanization or interfere with mobility are not only likely to reduce economic growth, but are also apt to interfere with people's attempts to diversify their livelihoods, cope with uncertainty and achieve resilience in the face of climate change.

What can be done?

The current focus on migration and displacement in the context of climate change tends to limit the debate to issues of measurement and, perhaps inevitably, to discussions on whether mobility is good or bad. To simplify, mobility is and will be, an increasingly fundamental feature of livelihoods, economies and settlement. Policy discussions should more usefully focus on understanding how and when mobility can lead to poverty reduction and adaptation and when it can lead to increased vulnerability. Acting to support positive outcomes and reduce negative ones will then be a logical next step.

This involves moving the focus to livelihoods—to income generating opportunities and their locations and to the living conditions and associated risks in places where such economic activities are concentrated. As mentioned earlier, an obvious adaptive response to climate change is to reduce the dependence of livelihoods on natural resources – for example, by expanding non-farm income activities. Income diversification that includes farming as well as non-farming activities and perhaps (but not necessarily) some form of mobility has long been shown to reduce vulnerability to shocks and stresses and to foster farming innovation (Bah et al., 2003; Hoang et al., 2008; Tiffen, 2003). All of these are relevant in the context of climate change.

A focus on living conditions brings to the fore the need to locate urban poverty in its context of socioeconomic, cultural, political and environmental transformations. From this perspective, urban poverty is as diverse as the characteristics of each urban centre—e.g., its size, economic base, rate of growth and migration patterns, administrative and political setup and ecological and geographic characteristics.

Urban Location and Climate-related Hazards

One of the dangers of urbanizing in a changing climate is that the receiving urban centres may be in locations that are or will be susceptible to climate-related hazards. The location and size of urban centres are path-dependent (Arthur, 1988; Martin and Sunley, 2006). Small differences in infrastructure investment or public policy in the present can, in some cases, result in large differences in the future spatial and size distribution of cities. Urban development is to some degree locked in by the interdependence of locational decisions: Industrial enterprises, services and the residents themselves locate where they do largely because of the other people and enterprises located nearby. Shifting established urban spatial patterns can be costly as well as socially disruptive. But current policies are also establishing the cities of tomorrow under the influence of climate conditions set to change.

As such, an obvious adaptive strategy might be to steer new urban development away from locations likely to be prone to future climate hazards. This could be especially important in Africa and Asia, where urban populations are growing rapidly as the result of both urbanization and natural population growth. Unfortunately, it is difficult to predict where and how severe climate-related hazards are apt to occur and difficult to change settlement patterns on the basis of predicted hazards. Moreover, attempts to shift populations away from climate-vulnerable locations could easily be hijacked by less noble-minded attempts to exclude "undesirable" residents.

This section focuses on low-elevation coastal cities and water-scarce cities, particularly in Africa and Asia. In both cases, the analysis starts with an overview of the character of the physical burdens and the size of the potentially exposed urban populations and ends by examining how land-based exclusionary practices, potentially aggravated by climate change policies, could create special problems for disadvantaged groups.

Low-elevation coastal cities

Coasts have long provided attractive urban locations, particularly in trading economies, but many coastal areas are periodically threatened by storms and flooding. Climate change is expected to result in sea level rise, more extreme tropical cyclones and more intense episodes of precipitation (Alley et al., 2007; Nicholls and Cazenave, 2010). This will increase longstanding coastal hazards and undermine protective measures designed around historical weather patterns. Local specificities will play a major role in determining the risks people face, but generally those living near the coast at a low elevation will be likely to bear the brunt of these increasing coastal hazards.

In 2000, about 630 million people lived in the Low Elevation Coastal Zone (< 10 meters elevation contiguous to the coast), of which about 360 million were urban (McGranahan, Balk, and Anderson, 2007). The average population density in this zone was about five times the world average, and the urban share was about 60 per cent, compared to a world average of less than 50 per cent. While low- and lower-middle income countries generally had less urbanized coastal zones than upper-middle and high-income countries, the share of their urban populations in the zone were actually higher. Most of the countries with large populations in the zone were large countries with heavily populated delta regions, predominantly in Asia, and almost two thirds of the cities with populations over 5 million were located at least partly in the zone.

In a more detailed look at the hazards faced by port cities of over 1 million, a study by Nicholls and colleagues for the Organisation for Economic Co-operation and Development (OECD) (2008) estimated that, in 2005, about 40 million inhabitants (about a tenth of the total population in these port cities) were exposed to one-in100 year coastal flood events. They estimated that, by 2070, climate change, subsidence, population growth and urbanization would increase this figure to about 150 million. In 2005, the top 10 cities, in terms of exposed population, were almost evenly split between “developed” and “developing” countries, with most of the latter in Asia. They estimated that, by 2070, nine of the top 10 cities would be in Asia, largely because of rapid urban growth. They also looked at the exposure of assets and found, not surprisingly, that asset exposure was considerably higher in wealthier countries. For any given exposure, however, risks were generally found to be lower for port cities in wealthier countries, as these had more protection. This was not always the case: Shanghai, for example, was found to have a higher level of protection than New York.

With coastal risks on the increase and ocean shipping in relative decline, this might seem like a good time to shift urban development away from exposed coastal locations. Indeed, this might seem like a priority, given that some have suggested on the basis of the estimates of low-elevation coastal population summarized above that in the foreseeable future hundreds of millions of people will be forced to migrate from their coastal homes anyway (Brown, 2010). However, while there is good reason to be concerned, such deductions are unfounded and potentially pernicious, in part for the reasons given in the previous section and also because they deflect attention from the adaptive measures that are needed in coastal areas.

As of yet, there is little sign of any movement of population away from coastal settlements, except temporarily in the wake of disasters, and there is insufficient evidence to justify promoting such a move. Ocean shipping remains vital to the global economy and is far less carbon intensive than air freight (Hoen et al., 2010, Table 6), though it brings its own environmental burdens. In most coastal areas, slight changes in location can reduce flood risks substantially. Protective measures can be taken. There are hazards to be found in non-coastal areas as well. Movement away from the coast should ideally emerge out of a negotiation that takes these and many other considerations into account.

Climate change does call into question policies that favour coastal areas, for example, by creating special economic zones in coastal areas, as the Chinese did from the 1970s to the 1990s (Demurger et al., 2002). However, from the perspective of this article, the major concern is how to prevent climate hazards and anti-urbanization policies from combining to place some of the most vulnerable urban dwellers in Africa and Asia at risk.

If populations in poorer coastal cities are generally at greater risk because of a lack of protection, poorer groups in these cities are likely to be at still greater risk. The vulnerability of certain racial and economic groups to the flooding brought on by Hurricane Katrina, for instance, and the lack of assistance for them in the wake of the disaster, has been well documented (Craemer, 2010; Logan, 2006). This reflects a broader tendency for disadvantaged groups within cities to be both more exposed and more vulnerable to disasters (Satterthwaite et al., 2009). As Aromar Revi describes in relation to climate risks in Indian cities, risk is often more closely associated with vulnerability than with exposure, making it particularly important to consider the changing landscape of vulnerability, since this will determine how exposure is translated into risk (Revi, 2008). In the urban coastal cities of the global South, a key part of this vulnerability will be the changing political economy of land, informal settlements and "slums", and how urbanization is handled.

Flood plains and other exposed locations are, in a sense, "natural" sites for the informal settlements that characterize so much low-income housing in the global South (UN-HABITAT, 2003a). The land in these locations is comparatively unattractive because of the flood hazards, so prices are low. They can be particularly attractive in coastal cities, which tend to be long established and comparatively densely settled.

Construction in flood plains may be formally prohibited, but informal development (instigated by occupiers or by developers) is only loosely controlled. Inhabitants may be well aware that there are flood hazards and, indeed, may have to cope with flooding several times a year, but still be willing to take a risk in return for an affordable and central location. It may not be impossible to estimate how many people live in such conditions, but the character of informal settlement suggests that it could be a major problem to do so.

There is a growing literature on adaptation in coastal cities, including case studies in low-income countries (e.g., Awuor, Orindi, and Adwera, 2008; Dossou and Glehouenou-Dossou,2007). These case studies have begun to document the special difficulties that low-income coastal inhabitants face (for example, Douglas et al., 2008; Revi, 2008). There are also case studies demonstrating considerable scope for shifting people away from the more exposed areas of cities (for example, Kebede et al., 2012). For the most part, it is assumed that adaptation programmes will benefit the poorest groups most, as they are the most vulnerable. Unfortunately, this is not necessarily the case.

If programmes for adaptation to climate change focus narrowly on preventing settlement in exposed areas, there is a real danger that they will protect formal housing and leave the informal settlements exposed to rising physical hazards or harsh evictions. Moreover, if adaptation programmes generate conflict between the residents of informal settlements and their governments, the local collective action that is likely to be critical to local adaptation efforts could be undermined (Adger, 2003).

Indeed, unless the urban land issues that exclude low-income households from formal housing are addressed, it is difficult to see how equitable adaptation efforts can be mounted in coastal cities. The urban land question is, in turn, closely linked to how urbanization and urban population growth are handled.

Water-short cities

Climate change is expected to alter precipitation patterns and increase the aridity of many of the world's drylands. From the perspective of climate adaptation, the question of whether dryland populations should be concentrated in urban areas is quite different from that of whether urban centres should be concentrated in drylands. All other things being equal, it is preferable if urban populations are not located in drylands where they may be exposed to water shortages and be forced to compete for scarce water supplies. On the other hand, there are various water-related reasons why it may make sense for rural dryland populations to move to local urban centres, particularly when population densities are high and agriculture is causing environmental degradation. Especially where there is a risk of desertification, it may also make sense for a government to encourage urban development rather than agricultural intensification in drylands (Portnov and Safriel, 2004).

In China, there are large areas where urbanization is being promoted as a response to dryland degradation. The situation in Ordos, a municipality in Inner Mongolia with a population of about 1.6 million, provides an extreme example of some of the issues involved. This water-scarce and energy-rich city-region is urbanizing extremely rapidly, spurred on by both the booming energy-based economy and ambitious efforts to protect rural ecosystems which involve substantial government subsidies for many of those who move from rural to urban locations in the drylands. The rural population in Ordos declined from 935,000 in 2000 to about 500,000 at the end of 2009, with commensurate increases in the urban population (Han and McGranahan, 2011). This government-promoted "ecological migration" may indeed reduce pressures on rural environments. However, from a narrow environmental perspective, it would probably make more sense to allow urban investment and rural-urban migration to flow to alternative locations, away from these fragile drylands. This would nevertheless raise very serious political concerns, as it would entail not only pushing local farmers and herders, including many ethnic Mongolians, out of the rural areas, but out of their homelands as well.

Most drylands are far less arid than Ordos, and outside of China government-led "ecological urbanization" is rare. All drylands are characterized by low rainfall relative to evaporation, however, which constrains agriculture and biological productivity generally (Safriel et al., 2005) and can make it difficult to secure sufficient water for domestic purposes. Overall, drylands cover 40 per cent of the world's land area and, in 2000, contained about a third of the world's urban population and also about a third of its rural population (McGranahan et al., 2005). More recent estimates for the same year suggest that, in Asia, about 0.54 billion out of 1.49 billion urban dwellers lived in drylands, while in Africa it is about 0.13 billion out of 0.28 billion (Balk et al., 2009).

A recent assessment of water resource shortages in cities in Africa, Asia and Latin America with populations greater than100,000 estimated that, in 2000, 150 million city dwellers faced perennial water resource shortages (less than 100 litres per capita per day) within their urban extents, and this figure is projected to grow to 993 million by 2050 (McDonald et al., 2011, pp. 6312-6313). Most cities divert water from rural sources, however, and even in Africa these distances have been increasing substantially (Showers, 2002). In recognition of this, the assessment also estimated the population that would still face water shortage if the city could obtain water from within 100 kilometres. Under this measure, only 24 million faced water shortage in 2000, rising to 162 million in 2050 (McDonald et al., 2011). In these projections, urban population growth is the main driver, but climate change is a contributing factor and is growing in importance.

All such estimates are highly uncertain, but they do point to what could potentially be extremely severe problems. One of the biggest urban dangers, alongside that of severe ecological and agricultural disruptions, is that water scarcity will prevent people from securing adequate water to meet their basic needs.

As with coastal settlements, it needs to be recognized that not all groups will be burdened equally and that adaptation efforts that try to prevent people from living in "exposed" cities could make matters worse. The water scarcity estimates above relate to water resource availability, and, in many cities, low-income residents, especially those in informal settlements, cannot secure access to improved water supplies even when local water resources are plentiful (UN-HABITAT, 2003b). Such households often lack access to the urban piped water network and depend on less reliable, less convenient, less healthy and sometimes considerably more expensive supplies. Some informal settlements are far from the piped network, while others may be refused access because they are on land that they do not own or on which residential development is not formally allowed. In some cities, there are fears that if informal settlements are provided with services such as piped water more migration and illicit settlement will be encouraged. In effect, exclusionary policies are actually helping to create the hazards, and using them to shift people away from hazards is likely to be counterproductive.

Almost a third of the urban households in Africa and Asia rely on groundwater from wells in or around their homes (Grönwall, Mulenga, and McGranahan, 2010). A disproportionate share of these are low-income households, who are more likely to depend on shallow wells affected by local rainfall patterns and surface water flows and to be unable to draw on distant supplies should local water resources be depleted. At the same time, there are often high levels of water being wasted by a small number of consumers and high shares of unaccounted-for water. Such conditions make it both particularly important and particularly difficult to develop more efficient urban water systems that are more equitable within urban areas, as well as between rural and urban areas.

As in relation to coastal hazards, unless urban land issues are addressed, it is difficult to see how an equitable adaptation effort could be mounted. In particular, if discouraging settlement in dryland cities were to become part of an adaptation strategy, the water-supply problems faced by the most vulnerable households could be compounded. As with the settlement of flood plains, the use of vulnerable water supplies is already linked to a form of exclusion.

An objection could be raised that resolving land issues in exposed cities will attract people to these cities. Moreover, if the measures are funded centrally rather than locally, the cost differentials that might otherwise help to drive people and enterprises away from hazardous cities will be attenuated (see Kahn, 2010 for a simple treatment of this sort of effect). It is true that, like many measures that help cities in hazardous locations adapt to climate change, resolving land issues will also make these cities more attractive to live in. The effect on migration is difficult to predict, however. In any case, with respect to land issues, the obvious response is to fund the measures locally, or, better still, to resolve land issues in less hazardous locations as well, rather than to let them continue to fester in exposed cities.

Climate Regimes, Urban Density and Finding a Safe Place in the City

The density and size of urban settlement provide the proximities that are key to the growth of industry, trade, and services. They also provide the basis for many of the environmental and social advantages that well-managed cities can provide (relative to dispersed rural settlements at comparable income levels). Environmentally, density can help people both to reduce carbon emissions and to protect themselves from the effects of climate change, provided it is part of a broader low-carbon strategy (Dodman, 2009). Residential density also reduces land costs and is often central to the struggles of low-income groups to gain a foothold in the city.

The effects of settlement size and density are contingent on other factors, however, and there can be conflicts as well as complementarities between economic, environmental, and social improvements. Density lowers carbon emissions from transport if it lowers trip distances and facilitates efficient public transport, but not if it simply concentrates unrelated people and activities. It protects people from climate change if it diverts settlement from unsafe locations and makes use of returns to agglomeration in adaptation, but not if it concentrates people and activities in unsafe locations. Density helps to provide a viable foothold for the urban poor if it creates the basis for healthy and friendly neighbourhoods where people can ply their trades, but not if it forces people into overcrowded and under-serviced squatter settlements or into high-rise apartments.

Advocating compact cities

Declining urban density is a longstanding phenomenon in North America, and it has been documented at lower levels in European and Japanese cities. Recent evidence suggests that urban density is declining in most of the world. A study of a global sample of cities found that densities in the built-up urban areas declined at about 2 per cent a year, though with a small but significant decline in urban fragmentation; densities within larger urban agglomerations declined somewhat more slowly (Angel et al. 2011). While cities outside of North America are higher in density (see also Schneider and Woodcock, 2008), there does appear to be a broad tendency for urban densities to decline in all parts of the world however urban is defined (Angel et al., 2011). This is only in part because urban advantages can now be achieved at lower densities.

In recent decades, urban environmentalists as well as public health experts have tended to favour more compact cities (Frumkin, Frank, and Jackson, 2004; Jenks and Burgess, 2000; Van der Waals 2000) pursued through "Smart Growth" (Filion, 2010) or more effective urban planning (Dulal, Brodnig, and Onoriose, 2011). According to their proponents, compact cities build over less land, require shorter trip distances, increase the share of pedestrian, bicycle and public transport trips, and provide a better basis for cogeneration and other low-carbon measures. Compact urban development can also be designed to interweave densely settled urban land with green spaces, enabling urban dwellers to tap local ecosystem services.

Neither "compact" nor "sprawl" are well-defined concepts (Frenkel and Ashkenazi, 2008), and environmental burdens take a wide variety of forms, making it difficult to demonstrate empirically that compact cities are environmentally preferable (Batty, 2008; Vella and Morad, 2011). The serious challenge to the compact city concept as a means of mitigating climate change comes from the claim that policies designed to promote more compact cities may nevertheless increase carbon emissions indirectly.

Measures designed to increase density in one city may inadvertently—or under pressure from vested interests—have side-effects that increase emissions in that city or increase carbon emissions elsewhere. For example, it has been argued that policies promoting compactness may favour inefficient mono-centric cities, and that, if such measures are to reduce carbon emissions, they may need to be supplemented by others to decentralize jobs and create poly-centric cities (Gaigné, Riou, and Thisse, 2010). It has also been argued that in the United States land use regulations in compact low-carbon cities have been pushing development to sprawling high-carbon cities (Glaeser and Kahn, 2010).

Despite such arguments, it is widely accepted that, at least within the existing range of densities, more densely settled cities are likely to emit less carbon than otherwise comparable low-density cities. Concentrated settlements also create opportunities for increasing resilience to climate change. Even when density is not adaptive in itself, concentrating people and activities in particular locations may be so, particularly if protective area-specific measures are taken.

Thinking back to the issues of water-short cities and coastal cities threatened with flooding, the challenges are quite different, but similar patterns emerge. In drylands, as elsewhere, water resources are distributed unevenly, and some locations will be closer than others to more ample water supplies. It is also generally more economical to distribute water to a few concentrations of urban population than to a large number of scattered rural settlements. Similarly, intra-settlement water distribution tends to be less costly in dense rather than in sprawling cities and less costly in urban than rural areas. Of course, if lower costs translate into lower prices, this will also result in higher demand. Thus, urbanization can help reduce the burden of increasing water scarcity, but requires more water resource management, both on the supply and the demand side.

In low-elevation coastal zones, some locations are less exposed to flooding than others, and some are more easily protected with barriers or other flood prevention measures. Even within a coastal urban centre, it is possible to concentrate urban populations and vulnerable assets in less exposed areas. Alternatively, assuming protection costs are proportional to the area protected, it is more economical to protect people when they are concentrated in small areas. There is a danger that measures to protect flood-prone locations will attract population and assets away from inherently safer locations, and, indeed, this is often an integral part of the means through which such measures are funded—as when private funding for flood protection is secured in return for planning permission to allow dense residential and commercial construction in the protected area. Generally, while urbanization can help reduce the burden of coastal risks, this is not an automatic outcome of urbanization and requires that the risks be addressed explicitly.

More generally, successful climate regimes in and for coastal cities could, in principle, create compact settlements both low in carbon emissions and better protected against climate-related hazards. Land values are likely to be high in these settlements with high residential and commercial densities and open land managed to provide ecosystem services. As with highly designed ecological cities, this raises questions about the urban dwellers who now live in informal settlements, with limited rights to the city.

Density, informal settlement and accommodating rapid urban population growth in a changing climate

Yet again, the foregoing section places land issues, already central to the challenge of contemporary urban population growth, at the centre of urban climate challenges. Particularly in rapidly urbanizing Africa and Asia, there is a distinct danger that a combination of climate change, climate change policies and reactions to inadequately accommodated urban population growth will reinforce exclusive forms of urban development, leaving the groups that now live in informal settlements exposed to climate-related hazards, compounding the many risks that they already face.

Nevertheless, there have been positive experiences, some in relation to accommodating rapid urban population growth and some in relation to upgrading or relocating informal settlements. China, for example, has in recent decades been very positive and pro-active about urbanization and expanding urban construction, which compensates to at least some degree for its authoritarian attitude to informal settlements and evictions. In Thailand the Government's Community Organizations Development Institute (CODI) has supported hundreds of community-driven upgrading schemes. In many nations, federations of slum dwellers now work with city governments to map and plan needed improvements (Boonyabancha, 2009).

For the most part, however, these positive experiences remain the exception, and in most growing cities a disproportionate share of the growth is in poorly served and badly located informal settlements. Moreover, well-located informal settlements are often in need of upgrading, and inhabitants are under growing pressure to move. This is particularly evident in Asia (see the International Institute for Environment and Development

(IIED) and UNFPA Website: www.urbandensity.org and associated publications). Informal settlements established decades ago in peripheral locations have been surrounded by urban development and are now in valuable central locations. In a market economy, low-income residents can only remain in such locations by achieving very high densities. Unfortunately, conventional upgrading cannot comfortably achieve high densities, and most high density options are ill suited to the lifestyles and livelihoods of the low-income residents of informal settlements.

Programmes such as CODI's Baan Mankong have nevertheless achieved high densities while retaining a high level of community control over both the location and form of the upgrading (Boonyabancha, 2009). The Baan Mankong programme has also found ways of identifying well-located urban land for this low-income residential development. This has required very active and innovative government support for low-income housing. It is difficult to imagine how this sort of approach can succeed where governments are actively trying to discourage urban growth and fear that if low-income housing is readily available undesirable rural migrants will be attracted to it.

It is possible to envisage how the low-income settlements now emerging on the periphery of rapidly growing cities could be encouraged to locate in safe sites and to develop incrementally towards high, but livable, densities. Settlement on the urban periphery is attracted by infrastructure development, which can in principle be used to steer greenfield development, including that of low-income housing, provided this is done strategically (for a proposed strategy for intermediate cities in Ecuador, building on such an approach, see Angel, [2008]).

In principle, it is also possible to support low-income housing development to achieve high density, applying the lessons of successful urban upgrading, but transferring them to high–density, low-rise developments. It is difficult for residents and their organizations to retain control of upgrading when this involves the construction of multi-story buildings (for an example from Sri Lanka, see D'Cruz, McGranahan, and Sumithre, 2009). However, using examples from Karachi, Arif Hasan and colleagues (2010) have illustrated how it is possible, at least in principle, to achieve densities above what local by-laws allow (1,250 persons per hectare), while meeting the needs and priorities of low- and middle-income residents. Their examples are based on small residential plots that can be developed incrementally by the residents themselves, with technical assistance to ensure that the initial construction is sufficiently solid to add more floors as the families expand.

Such construction is not generally favoured by urban authorities aspiring to create "world-class" cities, with "investment friendly architecture and iconic architecture" (Hasan, Sadiq, and Ahmed, 2010, p. 1). Nor is it favoured by developers interested in securing profits from large construction contracts. Nevertheless, such approaches can help overcome uncontrolled low-income settlement, without imposing regulations that make it more difficult for poor groups to secure their place in the city. This will be critical in those parts of the world where urbanization is the dominant demographic trend and climate change a leading environmental trend.

Conclusion

A tendency to treat urbanization as a driver of climate change—and of mal-adaptation—diverts attention from the variety of forms urbanization can take and the ways it can become a means of addressing the risks of climate change. Thus, for example, compact urban settlement, suitable to efficient public transport, can both reduce emissions and prevent development from sprawling over flood prone areas.

In addition, a tendency to assume that measures that reduce climate risks are inherently pro-poor diverts attention from the range of different measures and policy regimes that can be justified in terms of climate change, some of whose consequences could greatly increase poverty and inequality. Thus, for example, carbon-related standards could become a means of excluding aspiring low-income residents from formal settlements, while prohibitions on settling flood plains could be used to justify harsh evictions of the residents of informal settlements.

While urbanization can contribute to both climate change mitigation and adaptation, it can only achieve this equitably with a far more proactive approach to rural-urban migration and urban expansion than now prevails. This is not an issue of shifting the balance between markets and planning, that obsession of 20th century geo-politics that still plagues us today. Nicholas Stern (2007) has described climate change as "the greatest market failure the world has ever seen". After the debacle of the Copenhagen Conference of Parties in 2009, it is tempting to predict that it will also become "the greatest government failure the world has ever seen". Yet, to address the challenges described in this chapter will clearly require better markets, better planning and, just as important, a transformation in the politics of place.

References

Adepoju, A., F. van Noorloos, and A. Zoomers. 2010. "Europe's Migration Agreements with Migrant-sending Countries in the Global South: A Critical Review." *International Migration* 48(3): 42-75.

Adger, W. N. 2003. "Social Capital, Collective Action, and Adaptation to Climate Change." *Economic Geography*79(4): 387-404.

Alley, R. B., et al. 2007. "Summary for Policymakers." Pp. 1-18 in: *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom, and New York, N.Y.: Cambridge University Press. Website: www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf, last accessed 16 August 2012.

Angel, S. 2008. "Preparing for Urban Expansion: A Proposed Strategy for Intermediate Cities in Ecuador." Pp. 115-129 in: *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century*, edited by G. Martine, et al. London: Earthscan.

Angel, S., et al. 2011. *Making Room for a Planet of Cities.*, Policy Focus Report. Cambridge, MA: Lincoln Institute of Land Policy.

Angel, S. et al. 2010. *A Planet of Cities: Urban Land Cover Estimates and Projections for All Countries, 2000-2050*. Working Paper. Cambridge, MA: Lincoln Institute of Land Policy.

Arthur, W .B. 1988. *Urban Systems and Historical Path-dependence*. Paper No. 0012. Stanford, CA: The Stanford Institute for Population and Resource Studies.

Awuor, C. B., V. A. Orindi, and A. O. Adwera. 2008. "Climate Change and Coastal Cities: The Case of Mombasa, Kenya." *Environment and Urbanization* 20(1): 231–242.

Bah, M., et al. 2003. "Changing Rural-urban Linkages in Mali, Nigeria and Tanzania." *Environment and Urbanization* 15(1): 13-23.

Balk, D., et al. 2009. "Mapping Urban Settlements and the Risks of Climate Change in Africa, Asia and South America." Pp. 80-103 in: *Population Dynamics and Climate Change* edited by J. M. Guzmán, et al., New York and London : UNFPA and IIED.

Batty, M. 2008. How Tall Can We Go? How Compact Can We Get? The Real Questions of Urban Sustainability." *Environment and Planning B-Planning & Design* 35(1): 1-2.

Black, R., et al. 2011. "Climate Change: Migration as Adaptation." *Nature* 478(7370): 447-449.

Black, R., et al. 2008. *Demographics and Climate Change: Future Trends and Their Policy Implications for Migration.* Working Paper. No. T-27. Brighton, United Kingdom.: Development Research Centre on Migration, Globalisation and Poverty.

Bloom, D. E., D. Canning and G. Fink. 2008. "Urbanization and the Wealth of Nations." *Science* 319(5864): 772-775.

Boonyabancha, S. 2009. "Land for Housing the Poor—by the Poor: Experiences from the Baan Mankong Nationwide Slum Upgrading Programme in Thailand." *Environment and Urbanization* 21(2): 309-329.

Brown, L. R. 2010. *World on the Edge: How to Prevent Environmental and Economic Collapse.* London: Earthscan.

Chen, S., and M. Ravallion. 2007. "Absolute Poverty Measures for the Developing World, 1981–2004." *Proceedings of the National Academy of Sciences* 104(43): 16757-16762.

Craemer, T. 2010. "Evaluating Racial Disparities in Hurricane Katrina Relief Using Direct Trailer Counts in New Orleans And Fema Records." *Public Administration Review* 70:(3): 367-377.

D'Cruz, C., G. McGranahan, and U. Sumithre. 2009. "The Efforts of a Federation of Slum and Shanty Dwellers to Secure Land and Improve Housing in Moratuwa: From Savings Groups to Citywide Strategies." *Environment and Urbanization* 21(2): 367-388.

de Sherbinin, A., et al. 2011. "Preparing for Resettlement Associated with Climate Change." *Science* 334(6055): 456-457.

Démurger, S., et al. 2002. "The Relative Contributions of Location and Preferential Policies in China's Regional Development: Being in the Right Place and Having the Right Incentives." *China Economic Review* 13(4):, 444-465.

Dodman, D. 2009., "Urban Form, Greenhouse Gas Emissions and Climate Vulnerability. Pp. 64-79 in: *Population Dynamics and Climate Change*, edited by J. M Guzmán, et al. New York and London: UNFPA and International Institute for Environment and Development.

Donato, K. M., and A. Armenta. 2011. "What We Know about Unauthorized Migration." *Annual Review of Sociology* 37(1): 529-543.

Douglas, I., et al. 2008. "Unjust Waters: Climate Change, Flooding, and the Urban Poor in Africa." *Environment and Urbanization* 20(1): 187–205

Dossou, K. M. R., and B. Glehouenou-Dossou. 2007. "The Vulnerability to Climate Change of Cotonou (Benin): The Rise in Sea Level." *Environment and Urbanization* 19(1): 65-79.

Dulal, H. B., G. Brodnig, and C. G. Onoriose. 2011. "Climate Change Mitigation in the Transport Sector through Urban Planning: A Review." *Habitat International* 35(3): 494-500.

Filion, P. 2010. "Reorienting Urban Development? Structural Obstruction to New Urban Forms. *International Journal of Urban and Regional Research* 34(1): 1-19.

Frenkel, A., and M. Ashkenazi. 2008. "Measuring Urban Sprawl: How Can We Deal with It?" *Environment and Planning B: Planning and Design* 35(1): 56-79.

Frumkin, H., L. Frank, and R. Jackson. 2004., *Urban Sprawl and Public Health: Designing, Planning and Building for Healthy Communities.* Washington D. C.: Island Press.

Gaigné, C., et al. 2010. *Are Compact Cities Environmentally Friendly? Groupe D'Analyse et de Théorie Èconomique* (GATE) Working Paper Series. No. 1001. Lyon, France: GATE

Glaeser, E. L., and M. E. Kahn. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67(3): 404-418.

Grönwall, J. T., M. Mulenga, and G. McGranahan. 2010., *Groundwater, Self-supply and Poor Urban Dwellers: A Review with Case Studies of Bangalore and Lusaka.* Human Settlements Working Paper Series. Water and Sanitation. No. 26. London: IIED.

Han, G., and G. McGranahan. 2011. "Urbanizing in the Name of the Environment: The Radical Transformation of Ordos, China." Draft paper. London: IIED.

Hartmann, B. 2010. "Rethinking Climate Refugees and Climate Conflict: Rhetoric, Reality and the Politics of Policy Discourse." *Journal of International Development* 22(2) 233-246.

Hasan, A., A. Sadiq, and S. Ahmed. 2010. *Planning for High Density in Low-income Settlements: Four Case Studies from Karachi.* Human Settlements Working Paper Series. Urbanization and Emerging Population Issues. No. 3. London and New York: IIED and UNFPA.

Hoang, X., et al. 2008. *Urbanization and Rural Development in Vietnam's Mekong Delta: Livelihood Transformations in Three Fruit-growing Settlements*. Working Paper Series on Rural-Urban Interactions and Livelihood Strategies. No. 14. London: IIED.

Hoen, K. M. R,. et al. 2010. "Effect of Carbon Emission Regulations on Transport Mode Selection in Supply Chains." BETA Publicate Working Paper. No. 308. Eindhoven, The Netherlands: Eindhoven University of Technology. Website: http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/Beta_wp308.pdf, last accessed 15 August 2012.

IIED and UNFPA. n.d. Website: www.urbandensity.org, last accessed 18 August 2012.

Jenks, M., and R. Burgess (eds.). 2000. *Compact Cities: Sustainable Urban Forms for Developing Countries*. Oxon, United Kingdom: Spon Press.

Kahn, M. E. 2010. *Climatopolis: How Our Cities Will Thrive in the Hotter Future*. New York: Basic Books.

Kebede, A. S., et al. 2012. "Impacts of Climate Change and Sea-level Rise: A Preliminary Case Study of Mombasa, Kenya." *Journal of Coastal Research*, 28(1A): 8-19.

Kniveton, D., et al. 2008. *Climate Change and Migration: Improving Methodologies to Estimate Flows*. Geneva: International Organization for Migration and University of Sussex.

Logan, J. R. 2006.. *The Impact of Katrina: Race and Class in Storm-damaged Neighborhoods*. Providence, RI: Brown University.

Martin, R., and P. Sunley. 2006. "Path Dependence and Regional Economic Evolution." *Journal of Economic Geography* 6(4,): 395-437.

McDonald, R. I., et al. 2011. "Urban Growth, Climate Change, and Freshwater Availability." *Proceedings of the National Academy of Sciences of the United States of America* 108(15): 6312-6317.

McGranahan, G., D. Balk, and 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)17-37.

McGranahan, G. et al. 2005. "Urban Systems." Pp. 795-825 in: *Ecosystems and Human Well-being: Current State and Trends.* Vol. 1 of The Millennium Ecosystem Assessment, edited by R. Hassan, R. Scholes, and N. Ash. Washington, D.C.: Island Press

Myers, N. 2005. "Environmental Refugees: An Emerging Security Issue." Paper presented at the 13th Economic Forum, Organization for Security and Co-operation in Europe, Prague, Czech Republic, 23-27 May 2005.

Nicholls, R. J., and A. Cazenave. 2010. "Sea-level Rise and Its Impact on Coastal Zones." *Science* 328(5985): 1517-1520.

Nicholls, R. J., et al. 2008. *Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates*. OECD Environment Working Paper. No. 1. Paris: OECD.

Piguet, E. 2010., "Linking Climate Change, Environmental Degradation, and Migration: A Methodological Overview." *Wiley Interdisciplinary Reviews: Climate Change* 1(4): 517-524.

Portnov, B. A., and U. N. Safriel. 2004. "Combating Desertification in the Negev: Dryland Agriculture vs. Dryland Urbanization." *Journal of Arid Environments* 56(4): 659-680.

Poston, D. L., and L. F. Bouvier. 2010. *Population and Society: An Introduction to Demography*. Cambridge, United Kingdom: Cambridge University Press.

Potts, D. 2009. "The Slowing of Sub-Saharan Africa's Urbanization: Evidence and Implications for Urban Livelihoods." *Environment and Urbanization* 21(1): 253–259.

Revi, A. 2008. "Climate Change Risk: An Adaptation and Mitigation Agenda for Indian Cities. *Environment and Urbanization* 20(1): 207-229.

Safriel, U., et al. 2005. "Dryland Systems." Pp. 623-662 in: *Ecosystems and Human Well-being: Current Status and Trends*, edited by R. Hassan, R. Scholes, and N. Ash. Washington, D. C.: Island Press.

Satterthwaite, D. 2004. *The Under-estimation of Urban Poverty in Low- and Middle-income Nations.* Human Settlements Working Paper. Poverty Reduction in Urban Areas Series. No. 14. London: (IIED).

Satterthwaite, D., et al. 2009. "Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-income Nations. Pp. 3-47 in: *Adapting Cities to Climate Change: Understanding and Addressing the Development Challenges*, edited by J. Bicknell, D. Dodman, and D. Satterthwaite. London: Earthscan.

Schneider, A., and C. E. Woodcock. 2008. "Compact, Dispersed, Fragmented, Extensive? A Comparison of Urban Growth in Twenty-five Global Cities Using Remotely Sensed Data, Pattern Metrics and Census Information. *Urban Studies* 45(3): 659-692.

Showers, K. B. 2002. "Water Scarcity and Urban Africa: An Overview of Urban-rural Water Linkages." *World Development* 30(4): 621–648

Stern, N. 2007. "Climate Change, Ethics and the Economics of the Global Deal." Royal Economic Society's 2007 Annual Public Lecture. Manchester, England, 29 November 2007.

Tacoli, C. 2009. "Crisis or Adaptation? Migration and Climate Change in a Context of High Mobility." *Environment and Urbanization* 21(2)" 513-525.

Tiffen, M. 2003. "Transitions in Sub-saharan Africa: Agriculture, Urbanization and Income Growth." *World Development* 31(8): 1343-1366.

UN-HABITAT. 2003a. *Slums of the World: The Face of Urban Poverty in the New Millennium?* Nairobi: UN-HABITAT.

________. 2003b. *Water and Sanitation in the World's Cities: Local Action for Global Goals*. London: Earthscan.

United Nations. 2012. *World Urbanization Prospects: The 2011 Revision* (POP/DB/WUP/Rev.2007). New York: Population Division, Department of Economic and Social Affairs, United Nations.

________. 2010a., *World Population Policies 2009* (ST/ESA/SER.A/293). New York: Population Division, Department of Economic and Social Affairs,United Nations.

________. 2010b. *World Urbanization Prospects: The 2009 Revision* (POP/DB/WUP/Rev.2007). New York: Population Division, Department of Economic and Social Affairs, United Nations.

________ 2008. *An Overview of Urbanization, Internal Migration, Population Distribution and Development in the World* . New York: Population Division, Department of Economic and Social Affairs, United Nations.

Van der Waals, J. F. M. 2000. "The Compact City and the Environment: A Review." *Tijdschrift Voor Economische En Sociale Geografie* 91(2): 111-121.

Vella, A., and M. Morad. 2011. "Taming the Metropolis: Revisiting the Prospect of Achieving Compact Sustainable Cities." *Local Economy: The Journal of the Local Economy Policy Unit* 26(1): 52-59.

The World Bank. 2009. *World Development Report 2009: Reshaping Economic Geography.* Washington, D. C.: International Bank for Reconstruction and Development, The World Bank.

CHAPTER 3

Migration as a Response to Local and Global Transformations: A Typology of Mobility in The Context of Climate Change

Cecilia Tacoli

Introduction

Environmental change has long been identified as a driver of migration. It is, however, one among several factors shaping population movement, and its relative importance remains open to debate (Black and Sward, 2008; Castles, 2002; Jäger et al., 2009). In the past decade, the growing concern about the impacts of climate change has re-ignited discussions on their implications for population distribution and mobility (see, for example. Brown, 2008; Morrissey, 2009; Piguet, 2008 for reviews of the arguments and evidence). The widely differing views highlight the conceptual differences in the understanding of migration, with one side describing it as essentially a failure to adapt to environmental degradation, resulting in flows of impoverished displaced people (Myers, 2005; Stern, 2006) and the alternative depiction of mobility and migration as key adaptive strategies that require policy support (Barnett and Webber, 2009; GECHS, 2008; McLeman and Smit, 2004).

These differences have resulted in increased efforts to improve the understanding of the impacts of environmental change in shaping migration and mobility. Hence, earlier catastrophic predictions have given way to a greater attention to migration as one of the main adaptive responses to the impacts of climate change by vulnerable populations. A recent global review of current knowledge suggests that migration will offer opportunities as well as challenges, and that the population contingents at greatest risk will actually be those who are unable or unwilling to move. Moreover, the lack of mobility may be exacerbated by policies that aim to prevent migration (Black et al., 2011a; The Government Office for Science [UK], 2011).

There is still much that remains to be done to change the prevailing negative perceptions of migration and mobility among policymakers, as reflected in the high proportion of governments that implement policies to stem migration (United Nations, 2010). A first step is a better understanding of how environmental degradation as a driver of mobility interacts with other factors—socioeconomic, cultural, demographic and political (Black et al., 2011b). A better grasp of these admittedly complex dynamics is necessary to achieve a better sense of what can be done to support and accommodate migration in a changing climate.

Information on mobility patterns is also essential for local governments that, in both areas of origin and destination, are responsible for providing basic services to local residents whose numbers and composition may swell and shrink at different times of the year, and who may include children who require health and education services, or be composed mainly of young adults who require employment and training services. Most local authorities have limited access to relevant population data, and census data is in many cases of limited use. Moreover, circular and seasonal mobility generally tends to be "invisible".

More accurate information is also needed to dispel misconceptions that are often at the root of discriminatory policies against migrants. Migrants are typically thought to be poor and to move mainly from rural areas to cities, and therefore contribute substantially to urban population growth and the increase in urban poverty. The reality, however, is far more complex. For instance, much migration, especially in Africa, remains short-distance and temporary (Potts, 2012), and large urban centres are not always primary destinations. This reflects the large share—over half—of the total world's urban population living in urban centres that are classed as "small", that is, with less than one million residents. Between 1975 and 2005, small urban centres accounted for 48 per cent of the increase in the world's urban population, a share that is expected to remain largely unchanged in the next decade (United Nations, 2008).

The assumption that much, if not most, movement is from rural to urban areas is also in many cases an over-generalization. Rural-rural migration, often seasonal or temporary, remains prevalent in countries with a predominantly agricultural economic base, and this is the case for most low-income nations in Africa and Asia. While climate change and environmental degradation are likely to prove an additional factor spurring mobility, there is little evidence that it will change its direction. One important reason for this is that rural-rural migration is dominated by the poorest groups who lack the skills, financial capital and social networks to move to towns and cities. At the same time, however, the continuing reliance of these migrants on natural resource-based livelihoods is likely to increase their vulnerability to environmental degradation, either in their home areas or at their destinations.

Cultural, as well as socioeconomic factors, account for differences in the directions and destinations of migrants according to their gender and age. While women's movements are still often determined by marriage, growing numbers of women relocate to urban centres where they can find employment opportunities in sectors of the urban labour market where they are disproportionately represented, such as domestic service, export factory work and the urban informal sector (Chant, 2011; Tacoli, 2012). Again, it is likely that, while environmental degradation will increase the numbers of migrants, destinations will largely remain the same, as they are determined primarily by non-environmental factors.

A more accurate understanding of the wide range of destinations, duration of movements and composition of migratory flows is a necessary first step towards the formulation of policies relevant to population mobility. Drawing on the findings of recent empirical research, this chapter proposes a typology of mobility that takes into account the interrelations between slow-onset climate change and socioeconomic and cultural transformations. The main purpose of this typology is not to suggest fixed, universal categories, but rather to highlight the diversity of migration and to identify the ways in which its drivers—environmental, socioeconomic and cultural—overlap and result in different mobility patterns. Groups whose livelihoods rely almost exclusively on natural resources are most likely to move if there are no local employment and income-generating alternatives. The spatial location of opportunities for income diversification is therefore essential to the understanding of mobility. Just as important is the ability of migrants to take advantage of these opportunities. Hence, the key argument of this chapter is that supporting migration as adaptation to climate change can only be successful if the context-specific links between migration and vulnerability are also addressed. This is a precondition to ensure that migration is not just a coping strategy but will ultimately increase resilience to the impacts of environmental degradation.

The Multiple and Cumulative Drivers of Migration and Mobility

Although the term "environmental refugees" was first used in the late 1970s, it is only recently that it has become a relatively common notion, in the wake of the emergent understanding of the impacts of climate change on natural ecosystems. A growing body of evidence suggests that environmental change, including flooding, changes in rainfall patterns, higher temperatures and more frequent extreme weather events, will almost certainly influence migration and mobility increasingly (Black et al., 2011a). However, contrary to earlier predictions, it is unlikely to result in mass movements across borders and from low-income countries to wealthier ones. While extreme weather events will cause displacements, current evidence suggests that these may be short-term and short-distance, depending primarily on the capacity of communities and local institutions to provide effective coping support. In turn, slow-onset global environmental change is predicted to affect migration indirectly through its impact on the key socioeconomic and political drivers of mobility. The majority of these movements are likely to take place within national borders, reflecting the general patterns of migration worldwide, with international migrants estimated to account for only about 3 per cent of the world's population against almost 11 per cent of internal migrants (UNDP, 2009).

It is hardly surprising that future decades will see growing mobility, as this reflects current trends which will intensify with economic transformations, sociocultural change and greater access to information technology. Together, these will strengthen the social networks that underpin people's ability to move. Going beyond this general acknowledgement, however, will require improved information and a better understanding of locally-specific processes. Predicting with any precision the impacts of climate change at the local level is still relatively difficult, despite vast scientific improvements. There are still high levels of uncertainty on the speed of the environmental transformations linked to climate change, especially in regions likely to be most affected, such as West Africa (ECOWAS/SWAC, 2008). Moreover, there is a lack of comprehensive data on internal migration, especially in its temporary and seasonal forms. Again, this is particularly the case in the low-income nations that are likely to bear the brunt of environmental degradation linked to climate change (Kniveton et al., 2008).

Extreme weather events such as hurricanes, floods and landslides increasingly force people to move away from their home areas. However, it is the poorest groups, those who in many cases have no option but to reside in dangerous locations, such as steep slopes or "informal" urban settlements, who suffer the most. In urban centres of low-income countries, very large proportions of the population live in settlements that have little, if any, provision for storm drainage, are distant from health centres and have limited access to emergency services, and whose housing is overcrowded and inadequate. It is when extreme events affect people with high levels of vulnerability that these events become disasters. With regard to mobility, in most cases people return as soon as possible to reconstruct their homes and livelihoods. Whether and how rapidly they are able to do so, however, depends largely on the level of support they receive from governments and civil society (Paul, 2005; Perch-Nielsen and Bättig, 2005).

Slow-onset impacts of climate change, such as drought, desertification and land degradation, are related mainly to rises in average temperatures and changes in rainfall patterns. Research in the Sahel following the droughts of the early 1970s and 1980s suggests that people in affected rural areas are likely to move temporarily to local destinations. On the other hand, permanent migration to urban centres appears to be relatively unaffected by environmental conditions. This is explained by the fact that these migrants are often better-educated (and hence often wealthier) and are less likely to rely on natural resources for their livelihoods (Findley, 1994; Henry et al., 2004). Research in Nepal shows similar patterns (Massey et al., 2007).

Recent research in environmentally fragile rural areas in Bolivia, Senegal and the United Republic of Tanzania goes further in exploring the impacts of environmental degradation on migration and mobility patterns (Balderrama Mariscal et al., 2011; Sall et al., 2011; Tacoli, 2011). It shows that desertification, soil degradation and disrupted rainfall patterns do indeed deeply affect the livelihoods of rural people who rely primarily on natural resources. In addition, the research suggests that in many cases it is possible to identify "precipitating events", such as unusually harsh droughts and epidemics of livestock disease, which have a long-lasting impact on local economies and livelihoods. What is crucial in making these events so catastrophic is a socioeconomic context which restricts people's ability to rely on well-tested strategies and diversify their activities within both the agricultural and non-farm sectors. The undermining of the local opportunities that have traditionally ensured resilience in areas where the environment is fragile and subject to cyclical disruptions has resulted in growing climate sensitivity and deeper impacts of specific climate hazards.

In Bolivia, for instance, the extremely severe El Niño-related drought of 1982-1983 had a dramatic impact on the population of the relatively remote Norte Potosi province. This is one of the poorest areas of the country and of the continent, with 71 per cent of its land affected by desertification and 98 per cent of its population classified as poor. Out-migration from the province is high, with an average of 15 per cent and peaks of 50 per cent in some communes. The drought of 1982-1983 is widely perceived as marking the beginning of a downward spiral of environmental change and out-migration. Since then, more than 100 hectares have been lost to land degradation exacerbated by irregular rainfall and milder weather. This coincided with the implementation of a structural adjustment programme in the mid-1980s that involved the closure of mines in the Andes region and resulted in a massive loss of jobs for miners and workers in associated industries. In areas such as Norte Potosi, this deeply affected the local economic base and curtailed opportunities for seasonal employment in the mines, a traditional alternative income-generating activity for farmers. Migration in this area is thus best understood as the result of combined environmental and socio-economic factors. A substantial proportion of migrants from Norte Potosi have moved to urban centres, including the capital, La Paz, but they are increasingly moving to smaller centres where expansion and economic growth are largely fuelled by investments of international migrants. Others have moved to the lowlands areas, a movement that was initially encouraged by state-sponsored resettlement programmes in the 1960s (Balderrama Mariscal et al., 2011).

In the United Republic of Tanzania, Maasai pastoralists describe the prolonged dry season of 1997 that was followed by El Niño-related floods in 1998 as a turning point in their traditional way of life. The related outbreaks of Rift Valley Fever between 2000 and 2002 decimated cattle already weakened by scarce rainfall. Drought returned in 2009-2010, making it difficult to find water and good pasture. The cattle death rate was so high that, in the words of the Maasai, it was not unusual to wake up in the morning and find that five to 10 animals had died overnight. This resulted in a glut in the market, with pastoralists anxious to sell their animals before disease and malnutrition killed them all. At the same time, conflicts of interest between different land users in Maasai areas, linked to increasing land value, continued to escalate. Under the Land Act of 1999, traditional pasture land was in many cases classed as unoccupied or unused and, thus, fell under the exclusive control of the central Government, which was then able to allocate it to private or foreign investors for large-scale commercial farming. This obliged Maasai pastoralists to move further away looking for water and pasture, thus undermining their traditional responses to environmental degradation; as a result, many of them turned to sedentary farming, while growing numbers of young men migrated to the cities (Tacoli, 2011).

Senegal has a long tradition of international migration, both within the region and to European and North American destinations. The severe droughts of the 1970s and early 1980s are remembered as events that introduced significant changes in local livelihoods. Rainfall is estimated to have declined by 30 to 40 per cent in the last decades, and desertification and deforestation are substantial. The areas where infrastructure allows irrigated farming are concentrated in the north of the country along the River Senegal, while in the poorest rain-fed farming areas migration has long been a way of life to make ends meet during the dry season. The main cash crop in these areas is groundnut, promoted by export-oriented agricultural policies and long seen as the engine of the Senegalese economy. The dismantling of heavily indebted marketing parastatal organizations under a structural adjustment programme in the mid-1980s and the subsequent decline and volatility of producer prices for groundnut since the 1990s (Mortimore and Tiffen, 2004) have drastically reduced the role of groundnut production in the national economy and in rural livelihoods in the so-called "groundnut basin". These transformations, combined with soil degradation and the lack of local alternative income-generating activities in many rural areas, are widely seen by residents as a main reason for the increase in migration. At the same time, the expansion of social networks and opportunities for (often undocumented) international migration have attracted increasing numbers of young men, resulting in labour shortages in areas with more prosperous commercial farming which have therefore become destinations for internal seasonal migrants (Sall et al., 2011).

In all three cases, mobility has long been a traditional coping strategy for people living in fragile environments. While there is little doubt that environmental degradation has become more severe and extreme events such as droughts have become more frequent, their impact has also become more severe as non-environmental factors have undermined alternative local economic opportunities. As a result, migration and mobility have become much more widespread and diverse. Perhaps more important, they have become a crucial part of local livelihoods: In all the case study locations in Bolivia, Senegal and the United Republic of Tanzania, the most vulnerable households were unanimously identified as those who do not migrate or receive remittances from migrant relatives.

Duration, Destinations and Composition of Migrant Flows

Understanding who moves, where to and for how long is essential to identifying the impact of migration on vulnerability. In many cases, and especially for groups with limited assets and social networks and with limited voice and representation, there are likely to be trade-offs associated with migration. For instance, moving may increase access to economic opportunities which help improve resilience to the impacts of climate change in home areas. It may also, however, expose migrants to harsh working conditions and personal insecurity. This is especially the case for the growing numbers of young boys and girls and for women migrating independently without relatives (Tacoli and Mabala, 2010), but also more generally for poor migrants, including wage agricultural labourers. Similarly, the expansion of smaller urban centres is important for rural migrants from surrounding areas as it provides much-needed opportunities for income diversification. However, local authorities in such centres often lack the technical and financial resources to ensure that urban growth does not contribute to environmental problems. Weak governance systems may also result in social polarization and the marginalization of poorer groups, which often include temporary migrants.

Based on the findings from the case studies in Bolivia, Senegal and the United Republic of Tanzania, as well as on the wider literature, the rest of this section explores a possible typology of migration and mobility from environmentally fragile rural areas. The main purpose of this exercise is to identify the key factors that overlap with environmental change in shaping migration types and outcomes. It does not intend to be exhaustive, but rather to point to the important intersections and trade-offs that need to be addressed if mobility and migration are to be an adaptive and not merely a coping strategy in response to environmental change.

Seasonal mobility between rural areas and the transformations in family farming

In remote rural areas where livelihoods rely primarily on rain-fed agriculture, seasonal migration of adult men can be crucial for food security or simply to help make ends meet (van der Geest, 2009). In Senegal, seasonal migration between rural areas involves primarily adult men from impoverished remote areas where rain-fed agriculture prevails, who move to coastal areas to work on irrigated farms and family farms specializing in horticulture. These agricultural labourers tend to earn very low wages and, in some cases, work on a sharecropping basis which increases their financial risk if the harvest is poor (Sall et al., 2011). This kind of arrangement means that mobility does not necessarily reduce the exposure of migrants to the impacts of environmental change, but simply changes its location.

Three factors are important in understanding seasonal rural-rural mobility. The first is the lack of local alternative employment opportunities. The second is that farming remains an important element of livelihoods, despite the need to supplement incomes. This is well illustrated by the case of the Bolivian Andes, where farmers who have access to mountain land (over 3,500 metres above sea level) where environmental change has, for the time being, resulted in greater opportunities for farming are likely to move temporarily and on a seasonal basis. In contrast, farmers whose land is located in the valleys (at an altitude of between 1,650 and 3,000 metres) have been more affected by land degradation and are more likely to move away permanently (Balderrama Mariscal et al., 2011).

The third important factor is that these migrants also respond to the growing demand for seasonal labourers from family farms in areas with different agricultural cycles. Such demand, in turn, is the result of labour shortages due to widespread out-migration, especially of younger generations, to urban and international destinations, which is compensated for by their remittances which enable households to hire labourers. This out-migration is the result not only of the generally low incomes from farming, but also of higher expectations, often linked to better education and economic well-being. In other words, migration is not only a response to local poverty but also to improved local livelihoods (Deshingkar, 2004).

It is difficult to understand rural-rural migration and assess its likely future patterns without taking into account such a profound transformation in family farming, whereby family labour is replaced by waged labour and where remittances play an increasingly important role. Moreover, this transformation is not confined to areas affected by environmental degradation and has been documented in several other places, including those with a prosperous agricultural sector in locations as diverse as northern Tanzania and Viet Nam's Mekong Delta (Diyamett et al., 2001; Hoang et al., 2008). In all these very different locations, it is not only large-scale commercial farming that attracts migrant workers, but increasingly it is family farms, where mobility has become an integral part of production systems. Remittances from employment in non-farm activities are essential to secure the financial resources needed to innovate and intensify production to respond to changing demand, especially where farmers can access urban markets. Remittances are also crucial to hire the necessary labour, often on a seasonal basis.

Temporary rural-urban movement as income diversification

Unlike seasonal mobility, temporary migration is not linked to agricultural calendars and is, therefore, more often directed towards urban centres. This movement is important for people living in areas where natural resource-based livelihoods are made increasingly insecure by environmental change, in many cases exacerbated by socioeconomic factors such as limited access to markets, low prices and so on. At the same time, while environmental degradation in home areas is a key "push" factor, destinations and composition of the flows are largely determined by non-environmental factors such as labour markets, intra-household divisions of labour and gender relations. It is also increasingly influenced by patterns of urbanization and urban growth and the related sociocultural transformations.

Women are more likely to engage in temporary rural-urban migration to work in non-farm sectors, especially in domestic service and small-scale trade, provided the nature of their responsibilities in farming households allows them to move (Massey et al., 2007; Balderrama Mariscal et al., 2011). Young people also tend to move to towns, with boys going to work in construction and security sectors (e.g., as watchmen) and girls going to work in domestic service. In this type of movement, social networks have an important role in ensuring access to jobs and accommodation. Social networks also provide some protection and social control, thus replacing the traditional roles of older relatives, especially males. In part, this helps explain the social acceptability of the independent (unaccompanied) movement of young people and women (Tacoli and Mabala, 2010).

As with seasonal rural-rural migration, transformations in labour markets in destination areas are important in understanding and assessing possible future patterns of temporary rural-urban migration. One important aspect is the increasing demand for women workers in domestic service, often at a very young age. This movement may be relatively long-term, but can still be understood as temporary given employment insecurity, low wages and the financial obligations towards relatives in home areas.

Domestic work is a major category of employment for women in urban areas of low- and middle-income countries. In South Africa, domestic work was the second-largest sector of employment for black women in 2004, employing some 755,000 workers, with a large proportion of internal migrants from rural areas (Peberdy and Dinat, 2005). Work in private households is also a major source of employment for rural-urban migrant women in Viet Nam (Hoang et al., 2008) and in the United Republic of Tanzania (Mabala and Cooksey, 2008). In Latin America, 7.6 million people are employed as domestic workers, the majority of whom are women and many of whom are migrants (Tokman, 2010). Clearly, the growing demand for domestic workers is related to socioeconomic and cultural transformations rather than environmental impacts (Tacoli, 2012); at the same time, it is impossible to ignore the opportunity domestic work represents for women living in environmentally fragile areas for whom it may well be described as a 'pull' factor.

A similar point can be made for another significant transformation taking place in a growing number of small- and medium-sized urban centres in low- and middle-income countries, where investment from internal and especially international migrants results in a rapid expansion of the built-up areas and of new non-farm economic activities. A key reason for this is that, as land prices in large cities increase, the growing numbers of international migrants switch their investments to smaller cities where land is more affordable (Balderrama Mariscal et al., 2011; Sall et al., 2011). This, in turn, attracts rural migrants from surrounding areas and provides alternative destinations to the large cities where the cost of living is higher. In Bolivia and the United Republic of Tanzania, young boys and sometimes women find employment in construction work and other activities that are owned by migrants and their relatives, to whom they are often linked through social networks.

Permanent rural-urban and urban-urban movement

Education and skills are important drivers of migration, as they tend to increase people's expectations and in many cases spur a move out of farming. Social mobility is often related to migration to urban centres and from small to larger urban centres. There is strong evidence that decisions to migrate by better educated, wealthier groups are not affected by environmental conditions (Henry et al., 2004; Massey et al., 2007; van der Geest, 2009). In general terms, rural-urban migrants are better educated and have more economic resources than those who stay behind in rural areas or who move to other rural areas and to local small towns. Indeed, migrants are typically not the majority of the urban poor, despite widespread misconceptions (Tacoli et al., 2008).This does not mean, of course, that the urban poor are not especially exposed to and vulnerable to the impacts of climate change (see Chapter 1 and 2).

It is difficult to assess whether environmental degradation will, in the long run, result in increased permanent migration to cities and larger urban centres. Current evidence from the three case studies in Bolivia, Senegal and the United Republic of Tanzania largely corroborates the findings from other studies in environmentally fragile areas in Nepal (Massey et al., 2007), Burkina Faso (Henry et al., 2004) and Ghana (van der Geest, 2009), as well as earlier studies of the impacts of drought in the Sahel in the 1980s (Findley, 1994). That is, the poorest rural groups, who are also in many cases the ones more likely to be affected by environmental degradation, tend to move locally and whenever possible on a temporary basis. The latter depends largely on whether there are still sufficient assets such as farmland in home areas that are worth maintaining. Such mobility can be defined primarily as a form of income diversification. Clearly, in some areas, this is not a viable option, and permanent migration is likely to be the most rational decision. Whether mobility-based income diversification can increase resilience to climate change or whether multi-local strategies are only a transitional phase towards permanent migration to urban centres, which—being pushed by rural poverty and lack of opportunities—will inevitably affect urban poverty, will depend not only on the severity of environmental change but also on socioeconomic factors.

It is, however, important to keep in mind that migration in itself is neither positive nor negative but rather an essential element of population dynamics and economic change. Even in the most dynamic settlements, in-migration typically goes hand-in-hand with out-migration (Hasan and Raza, 2009; Hoang et al., 2008; Li and An, 2009). This is perhaps the clearest indication that migration is not always the result of a failure to adapt to the impacts of climate change and other socioeconomic transformations.

Indeed, initiatives that encourage non-farm activities in rural settlements are in many cases intended as a way to slow down out-migration. In actual fact, however, improved livelihoods often lead to higher expectations and increased out-migration (Deshingkar 2004).

The Importance of Local Governance Systems in Linking Adaptation and Mitigation

Voluntary migration in its many forms is, and will become, increasingly important as an element of strategies of adaptation to the impacts of climate change and other transformations. Local-level organizations and the establishment of systems of governance that allow voice and influence to poorer groups is without doubt the most important element of any successful policy that aims to support adaptation to climate change. Remarkably, the role of local governments and local governance systems is systematically overlooked in current discussions of migration and climate change. However, there are several reasons why this should be a priority.

The first reason is the high levels of diversity in migration and mobility patterns, both between and within areas. It would be difficult, if not impossible, for national governments to take into account and accommodate the sometimes wide differences in duration, destinations and composition of flows. Moreover, local governments in both sending and receiving areas need such information in order to better plan for the provision of services and basic infrastructure to populations that may shrink or grow at different times. But local governments in many cases lack the capacity and financial means to gather basic information on their existing populations, let alone on migrant flows.

Second, wealthier migrants from areas with a declining agricultural sector tend to invest in towns and cities, while migrants from areas where farming offers employment and incomes are more likely to invest in rural areas. In many cases, such investments are very small because of migrants' low earnings, but they can still have a significant impact on local economies. Paradoxically, however, this can result in further environmental degradation. Construction in urban centres often contributes to environmental problems, especially in smaller towns where migrants' investments tend to concentrate, because they may be within their area of origin and because costs are lower than in large cities (Klaufus, 2010). These impacts may be at the local level (within the municipal boundaries), the regional level (affecting the surrounding rural region) or the global level (from increased emissions). Smaller urban centres are often neglected in debates on climate change, although they are critical for both mitigation and adaptation initiatives and policies. But local governments in small towns often lack the technical capacity and administrative authority to ensure that their growth does not contribute to the problem more than to the solution (Sall et al., 2010; Satterthwaite and Tacoli, 2003).

It is also important to note that migration often has important implications for social polarization and power relations. In their home areas, financially successful international migrants often become important players in local affairs, with increasing access to, and control over, resources such as land for themselves and their relatives. The emergence of this new powerful interest group can thus result in the further marginalization of poorer residents (Serageldin et al., 2005; Sall, 2010). On the other hand, declining access to land is often a major reason for migration. Local governance systems that include (in the sense of giving voice and influence to) all groups, including non-migrants, in-migrants and out-migrants are a first, essential step towards accommodating migration in climate change adaptation and broader development goals and in making local governments more accountable.

This does not mean that regional, national and international levels should be overlooked. Indeed, it is difficult for local governments to be effective without national government support. Investment in education and better skills for new, often non-farm, activities enhances opportunities for income diversification, whether or not it is linked to migration; however, such investments are often beyond the capacity and revenue of local governments. At the same time, national economic strategies, often linked to regional and international actors, have an important role in determining the locations of investment. Such locations, in turn, attract migrants through the creation of employment opportunities, but also negatively affect environmental conditions for those living in surrounding areas and thus contribute to out-migration. Moreover, the construction of infrastructure to reduce the use of fossil fuels is certainly likely to increase in the next decades, but its impact on local livelihoods and thus on migration is hardly ever considered. It is very difficult for poor groups to be heard at those levels, let alone influence them.

Conclusion

There is little doubt that environmental change does, and increasingly will, contribute to growing mobility and migration. While it is difficult to assess how this will affect population movement and distribution in the long term, current evidence suggests that socioeconomic factors affect the impact of climate hazards. In Bolivia, Senegal and the United Republic of Tanzania, for example, the reduced ability to rely on traditional responses to environmental variability increases the climate sensitivity of specific groups, usually the ones with the least assets and representation. Income diversification as the key adaptation strategy to environmental degradation increasingly involves some form of mobility.

This chapter has highlighted the need to move from a general acknowledgement of the links between migration and climate change to a more refined typology of the different flows based on their duration, direction and composition. This is an initial step, and it does not claim to be exhaustive due to the small number of case studies on which it draws—which to a large extent reflects limitations in the available evidence.

However limited, the evidence nevertheless clearly points to the centrality of socioeconomic factors in determining the duration, direction and composition of the flows. Seasonal rural-rural mobility and temporary movement to local urban centres are the main forms of migration for poorer groups. However, these options do not necessarily lift them out of poverty or decrease their vulnerability to the impacts of environmental change or to social and economic discrimination and exploitation. In other words, they can easily remain only coping strategies rather than become mechanisms to increase resilience and effective adaptation to the impacts of climate change as well as to other socioeconomic transformations.

More detailed information is essential for policymaking. Supportive policies that recognize mobility as an important element of adaptation need to take into account the context-specific links between vulnerability and migration for different groups in different locations. These links also need to be positioned within wider transformations which include but are not limited to climate change, and ensure that the trade-offs inherent to migration are minimized.

References

Balderrama Mariscal, C., et al. 2011. *Rural Migration in Bolivia: The Impact of Climate Change, Economic Crisis and State Policy*. Rural-urban Working Paper Series. No. 31. London: International Institute for Environment and Development (IIED).

Barnett, J., and M. Webber. 2009. "Accommodating Migration to Promote Adaptation to Climate Change." Melbourne: Department of Resource Management and Geography, The University of Melbourne.

Black, R., et al. 2011a. "Climate Change: Migration as Adaptation." *Nature* 478(7370): 447-479.

Black, R., D. Kniveton, and K. Schmidt-Verker. 2011b. "Migration and Climate Change: Towards an Integrated Assessment of Sensitivity". *Environment and Planning A* 43(2): 431-450.

Black, R., and J. Sward. 2008. *Measuring the Migration-Development Nexus: An Overview of Available Data*. Briefing Paper. No. 13. Brighton, United Kingdom: Development Research Centre on Migration, Globalisation and Poverty, Sussex Centre for Migration Research, University of Sussex.

Brown, O. 2008. *Migration and Climate Change*. IOM Migration Research Series. No. 31. Geneva: International Organization for Migration.

Castles, S. 2002. *Environmental Change and Forced Migration: Making Sense of the Debate*. New Issues in Refugee Research Working Paper. No. 70. Geneva: UNHCR.

Chant, S. 2011. "Introduction." In: *State of Women in Cities 2012/13: Gender and the Prosperity of Cities*. First draft. Nairobi: UN-HABITAT.

Deshingkar, P. 2004. "Improved Livelihoods in Improved Watersheds: Can Migration Be Mitigated?" Paper presented at the International Workshop on Watershed Management Challenges, New Delhi, India, organized by the Indian Council of Agricultural Research, International Water Management Institute and International Crops Research Institute for the Semi-arid Tropics, 3-4 November 2004.

Diyamett, B., et al. 2001. *The Case of Himo and its Region, Northern The United Republic of Tanzania*. Rural-Urban Working Paper. No. 01. London: IIED.

ECOWAS/SWAC/OECD. 2008. *Climate and Climate Change*. Atlas on Regional Integration in West Africa Environment Series. Abuja and Paris: Economic Community of West Africa, and Sahel and West Africa Club/ Organisation for Economic Co-operation and Development.

Findley, S. 1994. "Does Drought Increase Migration? A Study of Migration from Rural Mali during the 1983-1985 Drought." *International Migration Review* 28(3): 539-553.

GECHS (Global Environmental Change and Human Security). 2008. *Disaster Risk Reduction, Climate Change Adaptation and Human Security*. Report No. 2008:3. Oslo: University of Oslo.

The Government Office for Science (UK). 2011. *Migration and Global Environmental Change: Future Challenges and Opportunities*. Final Project Report. London: The Government Office for Science, United Kingdom.

Hasan, A., and M. Raza. 2009. *Migration and Small Towns in Pakistan*. Rural-Urban Working Paper. No. 15. London: IIED.

Henry, S., B. Schoumaker, and C. Beauchemin. 2004. "The Impact of Rainfall on the First Out-Migration: A Multi-level Event-History Analysis in Burkina Faso." *Population and Environment* 25(5): 423-460.

Hoang, X., et al. 2008. *Urbanization and Rural Development in Vietnam's Mekong Delta: Livelihood Transformations in Three Fruit-growing Settlements*. Rural-Urban Working Paper. No. 14. London: IIED

Jäger, J., et al. 2009. "EACH-FOR: Environmental Change and Forced Migration Scenarios: Synthesis Report." Website: www.each-for.eu/documents/EACH-FOR_Synthesis_Report_090515.pdf, last accessed 19 September 2012.

Klaufus, C. 2010. "Watching the City Grow: Remittances and Sprawl in Intermediate Central American Cities." *Environment and Urbanization* 22(1): 125-137.

Kniveton, D., et al. 2008. *Climate Change and Migration: Improving Methodologies to Estimate Flows*. IOM Migration Research Series. No. 33. Geneva: International Organization for Migration.

Li, B., and X. An. 2009. *Migration and Small Towns in China: Power Hierachy and Resource Allocation*. Rural-Urban Working Paper. No. 16. London: IIED.

Mabala, R., and B. Cooksey. 2008. "Mapping Adolescent Vulnerability to HIV/AIDS in Dar es Salaam: Results of an Exploratory Study." Joint Learning Initiative on Children and AIDS.

Massey, D., W. Axinn, and D. Ghimire. 2007. *Environmental Change and Out-Migration: Evidence from Nepal.* Population Studies Center Research Report. No. 07-615. Ann Arbor, MI: Institute for Social Research, University of Michigan.

McLeman, R., and B. Smit. 2004. *Commentary No. 86: Climate Change, Migration and Security.* Ottawa: Canadian Security Intelligence Service.

Morrissey, J. 2009. *Environmental Change and Forced Migration: A State of the Art Review.* Oxford: Refugee Studies Centre, Oxford Department of International Development, University of Oxford.

Mortimore, M., and M. Tiffen. 2004. "Introducing Research into Policy: Lessons from District Studies of Dryland Development in Sub-Saharan Africa." *Development Policy Review* 22(3): 259-285.

Myers, N. 2005. "Environmental Refugees: An Emerging Security Issue." Paper presented at the 13th Economic Forum, Organization for Security and Co-operation in Europe, Prague, Czech Republic, 23-27 May 2005.

Paul, B. K. 2005. "Evidence against Disaster-induced Migration: The 2004 Tornado in North-central Bangladesh." *Disasters* 29(4): 370-385.

Peberdy, S., and N. Dinat. 2005. "Migration and Domestic Workers: Worlds of Work, Health and Mobility in Johannesburg." SAMP Migration Policy Series. No. 40. Cape Town: Southern Africa Migration Project.

Perch-Nielsen, S., and M. Bättig. 2005. "Exploring the Link between Climate Change and Migration." Paper presented at the 6th Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Bonn, 9-13 October 2005.

Piguet, E. 2008. *Climate Change and Forced Migration.* New Issues in Refugee Research Series. Research Paper. No. 153. Geneva: UNHCR.

Potts, D. 2012. *Whatever Happened to Africa's Rapid Urbanisation?* Africa Research Institute Counterpoints. London: Africa Research Institute.

Sall, M. 2010. "Straightforward Critics or Would-be Candidates? International Migrants and the Management of Local Affairs and Development: The Case of the Senegal River Valley." *Environment and Urbanization* 22(1): 81-89.

Sall, M., et al. 2011. "Climate Change, Adaptation Strategies and Mobility: Evidence from Four Settlements in Senegal." Rural-urban Working Paper. No 33, London: IIED.

Sall, M., et al. 2010. *International Migration, Social Change and Local Governance in Ourossogui and Louga, Two Small Urban Centres in Senegal*. Rural-Urban Working Paper. No 23, London: IIED.

Satterthwaite, D., and C. Tacoli. 2003. *The Urban Part of Rural Development: The Role of Small and Intermediate Urban Centres in Rural and Regional Development and Poverty Reduction.* Rural-Urban Working Paper. No 9. London: IIED.

Serageldin, M., et al. 2005. "Migratory Flows, Poverty and Social Inclusion in Latin America." Ch. 7 in: *Urban Futures: Economic Growth and Poverty Reduction*, edited by N. Hamdi with J. Handal. Rugby, United Kingdom: ITDG Publishing.

Stern, N. 2006. *The Stern Review: the Economics of Climate Change*. London: HM Treasury.

Tacoli, C. 2012. *Urbanization, Gender and Urban Poverty: Paid Work and Unpaid Carework in the City.* Urbanization and Emerging Population Issues Working Paper. No. 7. London and New York: IIED and UNFPA.

________. 2011. *Not Only Climate Change: Mobility, Vulnerability and Socio-economic Transformations in Environmentally Fragile Areas of Bolivia, Senegal and Tanzania*. Rural-UrbanWorking Paper. No. 28. London: IIED.

Tacoli, C., and R. Mabala. 2010. "Exploring Mobility and Migration in the Context of Rural-urban Linkages: Why Gender and Generation Matter." *Environment and Urbanization* 22(2): 389-395.

Tacoli, C., G. McGranahan, and D. Satterthwaite. 2008. "Urbanization, Poverty and Inequity: Is Rural-Urban Migration a Poverty Problem, or Part of the Solution." Pp. 37-53 in: *The New Global Frontier: Urbanization, Poverty and Environment in the 21st Century*, edited by G. Martine, et al. 2008. London: Earthscan.

Tokman, V. E. 2010. *Domestic Workers in Latin America: Statistics for New Policies*. WIEGO Working Paper. No. 17. Cambridge, MA: Women in Informal Employment: Globalizing and Organizing (WIEGO).

United Nations. 2010. *World Population Policies 2009* (ST/ESA/SER.A/293). New York: Population Division, Department for Economic and Social Affairs, United Nations.

________. 2008. *An Overview of Urbanization, Internal Migration, Population Distribution and Development in the World.* New York: Population Division, Department of Economic and Social Affairs,United Nations.

UNDP. 2009. *Human Development Report 2009: Overcoming Barriers: Human Mobility and Development*. New York: Palgrave MacMillan.

van der Geest, K. 2009. "Migration and Natural Resources Scarcity in Ghana." Case Study for the EACH-FOR: Environmental Change and Forced Migration Scenarios Project. Bonn and Vienna. Website: www.each-for.eu/documents/CSR_Ghana_090126.pdf, last accessed 19 September 2012.

CHAPTER 4

Understanding Vulnerability and Adaptation Using Census Data

José Miguel Guzmán, Daniel Schensul and Sainan Zhang

Introduction

Vulnerability is generally divided into physical, social, economic or environmental vulnerability (UNDP, 2004). The Intergovernmental Panel on Climate Change (IPCC) describes vulnerability as the susceptibility of a system to climate change and its inability to cope with the consequences (IPCC, 2001; Adger, 2006; Chapter 1). Based on the IPCC's definition, vulnerability has three components: hazard exposure, sensitivity and adaptation capacity. As this book argues and a wide range of literature agrees, investigating the potential impacts of climate change on populations in vulnerable areas is crucial for adaptation policies and sustainable development and can be widely used for vulnerability assessments and the development of vulnerability indicators (McCarthy et al., 2001; Locatelli et al., 2008; Bolin et al., 2010).

Hazard exposure, as one component of vulnerability, can be identified by using simulations, Geographic Information Systems (GIS) and remote sensing techniques on environmental data, such as climate change projections, precipitation and surface temperature (see, for example, Vrieling, 2006; van Westen et al., 2008). Vulnerability assessment, which builds on the interaction between humans and the environment (Turner et al., 2003; Turner, 2010), is more complex and requires the integration of large demographic, environmental and other datasets, as well as information related to adaptive capacity, such as social networks, technology and emergency practices (UNEP, 2002; Adger et al., 2004).This chapter addresses how to integrate the different dimensions of vulnerability and, in particular, how to maximize the analysis of population data—namely, census data—in mapping vulnerabilities and adaptive capacity.

Vulnerability and adaptive capacity can be evaluated at multiple levels, from individual and household levels in relation to self-protection, awareness, household leadership, income and so forth, to community, city, country and regional levels in relation to economy, technology and population characteristics. This chapter proposes a framework that illustrates vulnerability and adaption at different administrative levels (layers) and suggests how to apply population data for each level. Early adaptation strategies adopted a "top-down" approach (van Aalst et al., 2008), but with the emergence of community-based vulnerability assessments and participatory adaptation planning, a more "bottom-up" approach to the reduction of climate change impacts is being applied (CARE, 2012). A better understanding of the different adaptation levels and of the higher granularity available in census data helps support community, household and individual "bottom-up" adaptation strategies.

This chapter focuses on a set of population data that is available in most countries today: census data. Forty per cent of sustainability indicators can be derived from census data (Guzmán, 2009). Vulnerability is one of the major themes in sustainability science and is highly associated with human settlement (Turner et al., 2003; Turner, 2010). For example, the Environmental Vulnerability Index (EVI), developed by the South Pacific Applied Geosciences Commission (SOPAC) and the United Nations Environment Programme (UNEP) (Environmental Vulnerability Index, n.d.) includes 50 indicators covering weather and climate, geology, geography, resource and services and human populations. The Global Risk and Vulnerability Trends Index developed by UNEP (UNEP, 2002) defines vulnerability factors in eight categories: (1) economy; (2) environment; (3) demography; (4) health and sanitation; (5) politics; (6) infrastructure, early warning and capacity of response; (7) education; and (8) development. A new "climate vulnerability index" developed by the Pacific Institute combines data from 19 different social and economic factors at the census-tract level, including air-conditioner ownership, childhood obesity, percentage of tree cover, pre-term births and workers in outdoor occupations (Cooley et al., 2012). The Water Poverty Index (WPI), developed by the Centre for Ecology and Hydrology in Wallingford, United Kingdom (Sullivan, 2002), is a weighted average of water availability that provides a means of linking water issues to poverty. Its components include many variables that can potentially be derived from or supplemented with census data, such as percentage of households having a piped water supply, education levels and percentage of households receiving a pension.

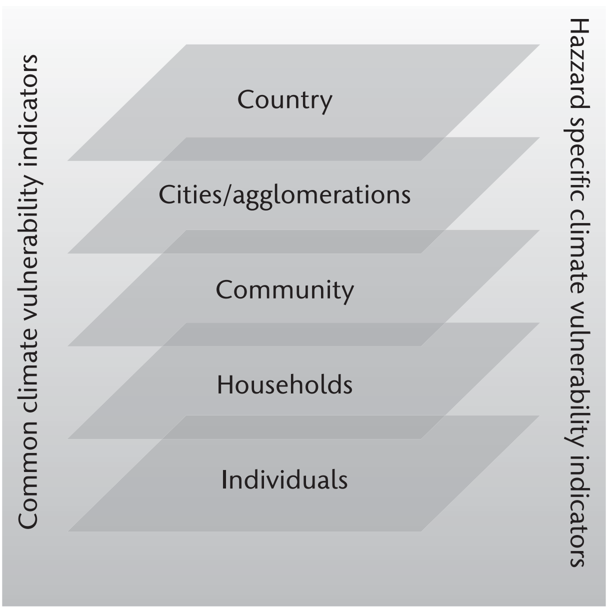
Given their breadth, coverage and flexibility, census data can have an important role in vulnerability assessment. Close to 90 per cent of the world's population was enumerated in the 2010 round of censuses, representing the largest data collection endeavour on population and housing characteristics ever undertaken. The substantial amount of data provided is invaluable for understanding and acting on vulnerability and adaptation, while the technological ramp-up in the use of GIS with census data in developing countries greatly increases the value of these data in climate analysis. The level of granularity of census data is low in some of the topics included in vulnerability assessment, but very high in terms of the geographical coverage. However, until now, they have been an underutilized tool in climate change adaptation analyses; outside of a few developed countries or cities, their potential has never been fully realized.

The first section of this chapter situates population-related data in the conceptual framework of vulnerability assessment. The second presents the analysis process in some detail, from the preparation of census-based indicators for climate analysis to the range of substantive analyses that can be done using the data. The final section presents conclusions and recommendations and includes a table elaborating a wide range of climate-vulnerability indicators that have components linked to the census. Chapter 5 uses this chapter as a starting point and focuses on processing of census data and integration with other relevant geographic layers.

Conceptual Framework

In order to define indicators related to vulnerability and adaptive capacities, this chapter presents an approach that considers three complementary conceptual parts. The first is based on the fact that vulnerability and adaptive capacities have different layers. As can be seen in Figure 4.1, at least five layers have been identified: individual, household, community, cities or agglomerations and country. Other intermediary layers could be added.

Figure 4.1: Layers of Vulnerabilities/ Adaptive Capacity



The advantage of census data is that they provide information from the two lowest layers that can be aggregated to intermediate and higher layers in accordance with the objectives of analysis. Existing vulnerability assessments tend to target the community level or above. Census data allow for the targeting of individual and household levels, both as objects of analysis and as inputs into a better understanding at higher levels. The census provides data on small geographic areas used to collect the data, which can then serve as building blocks for exposure geography. This is critical because exposure geography rarely coincides with the official boundaries of administrative entities, which are more common units of census reporting. Because of their high geographic granularity, census data based on building blocks can be aggregated to any higher geographic level to meet the needs of vulnerability and adaptive capacity assessments at different layers.

A second part focuses on the identification of the human and social dimensions of climate vulnerability and adaptive capacity as a function of two sets of components: The first is the set of characteristics that affect vulnerability and adaptation and that are shared across all climate change hazards, herein called *common* climate vulnerability indicators (CCVIs). The second set comprises the specific characteristics associated with different climate change hazards, herein called *hazard-specific* vulnerability indicators (HSVIs). Both of these categories of indicators share the same set of layers defined in Figure 4.1.

The third part relates to indicators, both common and specific, which are defined when measuring vulnerability/adaptive capacities in each of the layers. Taking into account the kind of information that is usually collected in a census, three components can be identified: First, there is a *demographic* component, which includes spatial location and distribution of the population, as well as a set of demographic factors, such as the proportion of youth and elderly, the proportion of households headed by women, the proportion of migrants and population density. Such demographic characteristics may have a clear and independent positive or negative impact on vulnerability, but they can also by exacerbated by other factors and resources of the population, such as social capital and hazard exposure, among others (see Chapter 1).

The second component is the *built environment*, in particular housing and service access. Most population and housing censuses ask whether houses are permanent or temporary and what materials their roofs, walls and floors are made of. Key services include water access, energy available for cooking and lighting and toilet facilities, as well as other sanitation infrastructure. These services can be an essential bulwark for households in the face of climate-hazards, and in turn can be seriously compromised by hazard-related damage, with long term consequences for individuals, households and communities. Finally, there is a *human and economic capital* component, focusing on the resources people and communities have at their disposal to adjust to changing circumstances. These can include such indicators as poverty, level of education, employment and occupation and access to and use of new technologies.

The census provides data on all of these components and, indeed, is the only source of comprehensive data available at a small-area level. All components may be relevant for generalized assessments of vulnerability and adaptive capacity based on CCVIs. However, only some will be relevant for hazard-specific analyses based on HSVIs.

Developing and Analyzing Census-Based Vulnerability Indicators

Developing and analyzing the indicator set for vulnerability assessment from the census involves a series of steps starting with more general indicators and moving towards greater specificity. Table 4.1 elaborates a wide range of potential indicators. The following explication of steps uses some of these indicators as a way of mapping out the indicator production and analysis path.

Step 1: Defining the Common Climate Vulnerability Indicators

In the first round of analysis, CCVIs can be used to construct generalized assessments of vulnerability and adaptive capacity across space. At a minimum, this involves developing key proxies from census items as inputs to the framework described above.

In relation to the demographic component, interest is centred on the location of the population in space, in terms of number of people, population density (not just total population, but also, for example, density of older persons, density of young people, etc.) and population composition according to age and sex. This can be assessed using a standard set of GIS methods, essentially mapping the population at the small-area level. It can be carried out across social and administrative spaces or across sector-specific geographies such as catchment areas, and it can also be done with respect to specific climate geographies, for instance, flood plains, temperature bands, low elevation coastal zones and others using census units as building blocks (a process described in Chapter 5).

With regard to the built environment component, mapping common indices of housing and service access will provide the most consistent and comparable results. One particularly useful index in this regard may be the Secure Tenure Index (STI) (Herr and Guenter, n.d.), which has been part of tracking progress on Millennium Development Goal (MDG) 7.10 on slum dwellers. The STI has five inputs: access to water, permanency of housing, regulatory compliance of housing, connection to sewers and connection to electricity. Four of these five inputs (the exception being regulatory compliance) can be taken from the census, and these four provide a strong approximation of the STI. 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, all of which are inputs to other indices as well.

With respect to the human and economic capital component, the census collects information on employment (though the data are less sophisticated and are not comparable to labour-force surveys), occupation, education and literacy. Even the less refined census-based employment and occupation data, however, can provide a proxy of relative economic vitality as it is distributed across space. Literacy and school completion can be used as broad-spectrum inputs to adaptive capacity (Brooks et al., 2005), and mapped as stand-alone data. Access to new technologies can be also considered part of human and social capital.

Poverty modeling can be undertaken using census data in combination with other sampled datasets. Information from censuses that can be used for poverty modeling includes some consumption indicators (for example, bedrooms per residents of households, refrigerators, radio or TV ownership), household characteristics and headship status, as well as other demographic characteristics. Poverty mapping can be an important tool for vulnerability analysis; however, full implementation of this kind of analysis is methodologically complex and requires integration with survey data. Explanation of this method is covered in chapter 6.

As discussed in Chapter 3, migration is an important part of the adaptation toolkit, and the census can provide basic information on the history of migration within households. Sending households may have more networks, more resources and more options in the event of emergencies, but they could also have additional new strains on livelihoods. New migrants may not yet be integrated into their receiving communities, and therefore may be particularly likely to lack secure livelihoods or may not be familiar with the history of disasters in the areas.

Step 2: Hazard Specific Vulnerability Indicators

Results from CCVIs are essential for generating a basic understanding of climate vulnerability, but a better understanding needs to integrate the HSVIs to tie the analysis to contextually specific climate hazards. One aspect of this, as mentioned earlier, is conducting analyses within geographically exposed areas. This is important, but it is by no means the only necessary analytical geography, given that climate impacts will not be geographically isolated: Migration of people and goods constitutes a critical part of both vulnerability and adaptation. Nonetheless, as described in Chapter 5, identifying climate geography and integrating it with census data is at the core of successful analysis of this type.

Beyond hazard geographies, HSVIs involve the identification of specific census-based variables and their relationship to specific hazards. Climate hazards vary significantly in type, time frame and severity, as well as in the strategies required to prepare for and respond to them. As a result, a large part of census-based climate analysis must be tailored to specific hazards, as well as to the CCVIs which also apply to the capacity to adapt to the threat of specific hazards. Some examples follow of hazards and the census-based additions to vulnerability analyses that they invite.

Flood vulnerability

Once flood-exposure geography has been identified and overlaid onto census data, and basic demographics within the exposed areas have been summarized, analysis should be directed to the census-based components of flood vulnerability. The first point to be considered is housing characteristics, and in particular the combination of *materials for walls and floors* and the presence of *pit latrines or unimproved toilets*, which are particularly vulnerable to rising water levels and can exacerbate the risk of cholera and other communicable diseases during flooding. These features can be combined to produce a measure of vulnerability in the event of a flood.

In addition, escape routes are extremely important in flood prone areas. Lack of public spaces, including open street routes, housing on steep slopes prone to landslides, and areas lacking infrastructure such as staircases for escape are important aspects of flood vulnerability. While the census alone cannot provide such information, data on *population distribution* and *population density* from the census can be combined with an analysis of aerial photography or remote sensing data, and eventually with data provided by the community itself, to identify the ratio of public space to population density. This ratio could be used as a proxy for ease of escape. In this case, the analysis moves from the layer of individuals and households to the community layer. Application of CCVIs and HSVIs related to flood plains and to low elevation coastal zones may be sufficient to understand human and social vulnerability as well as the adaptive capacity specific to sea level rise.

Heat wave vulnerability

Temperature increase will lead to more frequent and severe instances of heat waves. Heat island effects in urban areas may exacerbate this problem. The geography of temperature increases and heat wave risk is often derived from remote sensing of nighttime temperatures (see, for example, Streutker, 2003; Weng et al., 2004). This geography can be combined with data on housing materials and water access—piped water into or outside of the home, for instance—to identify households that are particularly vulnerable. Access to electricity and air-conditioning, and other similar indicators derived from censuses, can be used to calculate the correspondent HSVIs.

Declining agricultural output

Due to changing precipitation patterns, shortened growing seasons and more variation in weather, agricultural output in many places is expected to decline. Because agricultural outputs are not constrained to where they are grown, the specific geography of farming is less critical than identifying the areas that rely heavily on agriculture for livelihoods. The *proportion of the population employed in agriculture* can be derived from the census and can provide a proxy for this reliance. It is better to examine this indicator within urban or rural areas only, rather than comparing the two, given that rates will inevitably be much higher in rural areas. However, reliance on agriculture is hardly confined to rural areas, given the increasing importance of urban and peri-urban agriculture to livelihoods; in many urban areas, the proportion of agricultural employment will actually be quite high.

Local deforestation

While deforestation at the global or regional level is generally associated with large-scale industry and consumption, there are increasing instances of local deforestation driven by local fuel needs. The geography of local deforestation can be determined through remote sensing techniques, particularly the analysis of time series land-use/land-cover layers. Most censuses in developing countries ask about *sources of energy for lighting and cooking*, with the use of wood or charcoal very common. To the extent that climate change enhances deforestation, and local energy use does the same, this leaves households relying on biomass increasingly vulnerable to energy insecurity and reinforces the poverty-environment trap.

Step 3: Refining the analysis

The complete database of the census provides the ability not just to analyse and display data for small areas, but to do so with different kinds of relevant subsets and combinations of variables within these areas. In other words, the analysis need not be limited to the proportion of older persons, or women-headed households, or houses with earth floors or semi-permanent structures, but can look at various pertinent combinations. This is critical because when doing a geographically based analysis, in which data are aggregated from individual and household records to a given spatial extent, the results can be open to ecological fallacy.

For instance, when looking at two important variables (for example, proportion of female-headed households and proportion of households lacking water access) with counts aggregated to the level of a census enumerator area, there may be a correlation between the summary values of the two at the level of the enumerator area—perhaps a negative one, in which the higher the proportion of women-headed households, the lower the proportion of households with access to water. However, this correlation cannot clarify whether it is in fact only the women-headed households, rather than all the households in the area, that actually lack water access. To find out, new aggregates of household-level records to enumerator area are necessary. These new aggregates, representing important crosstabs, can significantly deepen a census-based analysis of vulnerability, as well as help to uncover the mechanisms—and not just the correlates—driving it. Some examples of relevant crosstabs follow.

Crosstab 1: Female-headed households

Differences between male and female-headed households are very commonly cited in the literature on poverty, food security, disaster impacts and climate change (Alwang et al., 2001). Female headship is almost universally considered a component of vulnerability, partly due to assumptions derived from either the ecological fallacy or other inferences that may or may not be found in the data. Running both the CCVIs and the HSVIs above, disaggregated by household headship, is relatively simple to do once the data have been aggregated to a small-area level in an appropriate way. Important results could emerge from crosstabs of headship with each of the three main components of the CCVI analysis and could also help to inform specific hazard-related vulnerability. For instance, it has often been reported that women had higher mortality in the 2004 tsunami (Doocy et al., 2007). In an analysis of flood plains and low elevation coastal zones, it may therefore be important to generate and map enumerator-area level tallies of, for instance, housing materials by headship. (At the same time, such disaggregation does not make sense in an analysis population density, which is a characteristic at the spatial level, not the individual or household level.)

Crosstab 2: Elderly-only or adolescent-headed households

Certain household types may leave the residents more vulnerable simply on the basis of household composition. Two examples are households composed of only elderly people, a factor commonly associated with heat-wave vulnerability (see, for example, Sheridan and Dolney, 2003; Harlan et al., 2006) and those households where there are only adolescents or children, who may have fewer choices and fewer resources at their disposal. While there are not likely to be large numbers of such households in many countries, their identification, which involves the combination of multiple census items (hence the crosstab), can illuminate a vulnerable and often hidden component of the population.

Crosstab 3: Migrant sending and receiving households

As Chapter 3 discussed in detail, the nature of climate vulnerability and adaptive capacity among both sending and receiving households continues to be a puzzle, with relatively few sources of data and essentially none that can be mapped outside of censuses. Crosstabbing migrant sending and receiving households with some of the CCVIs and HSVIs to generate comparisons to non-sending or non-receiving households in climate exposed areas, as well as more broadly, would provide a significant source of information on the links between climate change and migration.

Step 4: Integration with climate- or environment-specific questionnaires linked to the census

Censuses are increasingly being recognized for their capacity to enable cross-cutting analysis of the type described in this chapter. Some National Statistical Offices have also added secondary data collection efforts, linked to census geography, that provide deeper, key-informant based information on related subjects. Although examples remain rare, two important ones are the climate/environment questionnaire implemented by the Dominican Republic in their last census, and the Indonesian "Village Potential Survey", or PODES. Given overlaps in common geography, it is possible to link these comprehensive surveys with traditional census data. Information contained within these surveys will vary heavily, though, meaning common analytical processes are difficult to describe and comparability across countries is nearly impossible. Further, this type of information has not been widely used as of yet for climate change purposes, so its potential remains unknown.

Step 5: Using results to feed back to base geography and link to policy

As with any policy-relevant analysis, the final outputs should be structured to have meaning for the policies to be affected. Climate change responses can be stand-alone climate policies, or they can be a part of efforts to mainstream climate change into development and poverty reduction programmes, infrastructure projects and the like. Depending on the policy in question and how the analysis is structured, the geography of results is critical. Chapter 5 focuses expressly on the processing and integration of census data with other kinds of climate-relevant geographic data. Using the right geography in this process is essential.

For instance, as concerns a climate-specific response, the right output geography could be climate-exposed areas. This means ensuring that census analysis results are delivered according to the geography of exposure. Analyses like the ones suggested above should, therefore, be done for these geographies, rather than for the enumerator areas, and outputs should be structured as population size, composition and vulnerability variation in exposed areas. Similarly, for sectoral responses, for instance, access to water, which comes with its own geography of catchment areas, the analysis should be reported within that geography.

However, for a wide range of development policies, the geography that matters may be administrative boundaries or social ones such as neighbourhoods. In these instances, identifying the most vulnerable enumerator areas according to the analysis suggested above might be the best choice. Alternatively, aggregating enumerator areas back into administrative or budget-relevant polygons could ensure the greatest policy relevance.

These decisions depend largely on the purpose of the analysis and local decisions about the best means of getting the results integrated into policy discussions. One of the key points of this type of analysis is that each option is possible within the framework of current technology.

Conclusion and Recommendations

If census data are fully utilized, and if the methods proposed in this paper are, in fact, adopted on a broad scale, only the very start of possible advances will have been made. Indeed, one of the biggest challenges at this point is a lack of research and the fact that census data in many places is not fully utilized for high-resolution analysis, particularly in relation to climate change.

One feature that has restricted the use of census data is the fact that the data are not always available at the necessary level of geographic resolution. Many variables important for climate adaptation, such as income, race, health, incidence of diabetes, homelessness and citizenship status, are either not available or not accessible with fine geographic granularity due to issues of confidentiality (Cooley et al., 2012). Because the variation of population distribution characteristics within the census geographic area is averaged out, thereby lowering the granularity, larger errors can occur when linking with environmental data. Researchers are therefore looking for methods that will allow for better use of census data. For example, Boone (2008) raised a dasymetric approach, through which census tracts are re-delineated by overlaying original census tracts on inhabited areas derived on the basis of impervious surfaces.

Another challenge comes from cross-site comparative studies. Vulnerability analysis can be conducted on the basis of aggregated data related to climate change hazards; however, the indicators are different from one country to the other, and the standards of variables are not uniform. For example, the temperature criteria in the definition of "extreme heat" in a humid continental city are not the same as that in a subtropical desert city. Similarly, the standards of poverty levels also vary among countries. For such reasons, Adger et al. (2004) argued that developing standardized, aggregated hazard vulnerability indices at the global level has limited value.

Monitoring change over time constitutes another challenge. Vulnerability is dynamic and changes over time. Moreover, the variables that would be essential to monitoring long-term vulnerability often undergo change from one census to another or the historical data are simply unavailable for given census dates (Cutter and Finch, 2008). Similarly, the boundaries of census geographic areas, e.g., census tracts, also change over time. This is critical since many recent vulnerability analyses are conducted on the basis of aggregating the areal units (building blocks) that are available in the census rather than on the basis of existing administrative areas (see, for example, Reid et al., 2009; and Chapter 7).

Despite such challenges, the kind of analyses proposed in this chapter can have powerful impacts through the integration of demographic information with development research, policy and practice, which the strong substantive overlaps and the long history of census analysis in those fields make possible. In this regard, the list in Table 4.1 which contains examples of indicators that can be derived from census data, both CCVIs and HSVIs, is just a starting point in the definition of more standardized sets of indicators that can be developed or combined using the census as a data source.

Table 4.1: Examples of Indicators of Adaptive Capacity by Layer and Type

Layer: Individual	
Common Climate Vulnerability Indicators (CCVI)	**Component**
Number, proportion or density of population by age, e.g., 0-4; 65+ [1] [2] [16]	Demography
Number, proportion or density of population by ethnic groups [16] [5], e.g. Percentage of population who listed a race other than white [18]	Demography
Number, proportion or density of population by gender, e.g., females[2] [16]	Demography
Number, proportion or density of population living alone/socially isolated [1] [3]	Demography
Number, proportion or density of migrants by duration of residence, e.g., less than 1 year; 1-4 years; 5-9 years; 10 years or more	Demography
Number, proportion or density of pregnant or nursing mothers and very young children [1]	Demography
Number, proportion or density of the total population [14] [16]	Demography
Number, proportion or density of population whose primary language is not local language [18]	Demography
Number and proportion of population with sense of efficiency and social participation [3]	Demography
Number and proportion of the population by international migration characteristics, e.g., Proportion of immigrants by period of arrival, country of origin, etc.	Demography
Number, proportion or density of population with disability; Number and proportion of population with disabilities by age	Demography
Education by gender [11] [12], e.g., Percentage of women and men over age 25 lacking a high school diploma [18]	Demography by Human and Economic Capital
Literacy rate by age, e.g., Literacy rate for population 15-24 years old	Demography by Human and Economic Capital
Proportion of population by combining employment/occupation[2] and age, e.g., unemployed population by age	Demography by Human and Economic Capital
Proportion of population with low socio-economic status [1], e.g., Percentage of population living below the poverty line	Human and Economic Capital
Proportion of population without health insurance [11]	Human and Economic Capital
Proportion of population with access to health service [12]	Resources and Services
Proportion of population with access to information	Resources and Services
Proportion of population by geography, e.g., Proportion of urban population; Proportion of rural population	Geography

(continued)

Table 4.1- continued

Hazard Specific Vulnerability Indicators (HSVI)	
Flood	**Component**
Number and proportion of population employment in agriculture [12]	Human and Economic Capital
Number and proportion of population by geography: Location in areas exposed to coastal flooding; susceptibility areas under rising sea level scenarios [17]	Geography
Proportion of population by geography: Location in the areas exposed to flood susceptibility, areas measured by annual precipitation, incidence of extreme precipitation, type of soil, slope, proximity to catchments, elevation, etc. [10] [12] [14]	Geography

Heat wave/extreme temperature	Component
Number and proportion of population with illness, e.g., chronic illness: cardiovascular, respiratory, diabetes, nervous system disorders, mental illness, and certain medications.	Demography
Number and proportion of population by geography: Location in areas exposed to heat stress, measured by Average Soil-adjusted Vegetation Index, % asphalt; % tile; % wood, etc. [5] [10]	Geography
Proportion of population by geography: Location in areas susceptible to heat waves, measured by, e.g., the number of days exceeding the local “high-heat threshold” per year (Note: “local high-heat threshold” is defined as the temperature that is exceeded 5 per cent of the time during the summer months, determined through the historical record) [10] [17]	Geography

Drought	Component
Average per capita water consumption [4]	Demographic
Number and proportion of population employed in agriculture	Human and Economic Capital
Number and proportion of population living in poverty	Human and Economic Capital
Proportion of population by geography: Location in areas exposed to drought, measured by, e.g., historical frequency of droughts; duration of historical droughts; average annual rainfall; inter-annual variability and seasonality; occurrence [8]	Geography

Landslide	Component
Proportion of population by geography: Location in wave/surge susceptibility areas measured by land use/ cover, topographic position, e.g., slope. [12]	Geography

Wave and surge	Component
Proportion of population by geography: Location in wave/surge susceptibility areas measured by average wind speed, breaking waves, etc. [16]	Geography

Windstorm (cyclones)	Component
Proportion of population by geography: Location in areas exposed to windstorms measured by wind speed, average storm surge, etc. [16] [17]	Geography

Layer: Household/Family	
Common Climate Vulnerability Indicators (CCVI)	**Component**
Number and proportion of households by headship characteristics, e.g., female headship, elderly-only or adolescent headship [11]	Demography
Number and proportion of single-mother households [16]	Demography
Number and proportion of one-member households [16]	Demography
Number and proportion of households by household size [12]	Demography
Number and proportion of households by ownership [18] [16], e.g., Percentage of occupied housing units designated as rental units, Percentage of vacant housing units	Human and Economic Capital
Number and proportion of households living in poverty [11] [2] [1] [5]	Human and Economic Capital
Number and proportion of households by income [2] [5]	Human and Economic Capital
Number and proportion of households supported by public assistance [18]	Human and Economic Capital
Number and proportion of households by production type: Land, water, animal, capital and other means of production [11]	Human and Economic Capital
Number and proportion of households by consumption, e.g., Percentage of households without a vehicle; Percentage of households without a radio [18]	Human and Economic Capital
Number and proportion of households by education [12]	Human and Economic Capital
Number and proportion of households by access to health services [12]	Human and Economic Capital
Proportion of households by number of rooms	Human and Economic Capital
Proportion of households by housing conditions, e.g., age of housing [2] [15]	Built Environment
Proportion of households by physical infrastructure, e.g., materials of walls and roofs [7] [9] [11] [15]	Built Environment
Number and proportion of households by size of house [12]	Built Environment
Number and proportion of households by number of rooms/ bedrooms per household	Built Environment
Adjusted Secure Tenure Index (STI) calculated by census variables	Built Environment
Number and proportion of households by access to roads [11]	Built Environment
Number and proportion of households by water and energy access [4] [11] [12]	Resources & Service
Number and proportion of households with poor natural resources and ecosystems [7] [9]	Resources & Service
Number and proportion of households with technical capacity [7] [9]	Resources & Service

(continued)

Table 4.1- continued

Layer: Household/Family (continued)	
Common Climate Vulnerability Indicators (CCVI)	**Component**
Number and proportion of households with access to information [9]	Resources & Service
Proportion of households by geography: Location in areas with low equity [9]	Geography
Proportion of households by geography: Location in areas with a lack of institutions, governance and social capital [7] [9]	Geography

Hazard Specific Vulnerability Indicators (HSVI)	
Flood	**Component**
Number and proportion of households with pit latrines/unimproved toilets [10]	Built Environment
Number and proportion of households without piped system connected to a public sewage disposal plant	Built Environment
Number and proportion of households with unimproved sanitation systems	Built Environment
Number and proportion of households where occupants dispose of solid waste into a river, creek or pond	Built Environment
Number and proportion of households where occupants dispose of solid waste in a local dump not supervised by authorities	Built Environment
Number and proportion of households with staircases for escape	Built Environment
Number and proportion of households dependent on agriculture [7]	Human and Economic Capital
Proportion of households by geography: Location in areas exposed to floods measured by annual precipitation, incidence of extreme precipitation, type of soil, slope, proximity to catchments, elevation, etc. [10] [12] [14]	Geography
Proportion of households by geography: Location in areas exposed to coastal flooding under rising sea level scenarios [17]	Geography
Proportion of households by geography: Location in areas that lack services/open street routes [10]	Geography
Number and proportion of households with substandard housing material, by headship characteristics	Demographic by Built Environment
Number and proportion of households with substandard housing material, by migrant status	Demographic by Built Environment

Heat wave	**Component**
Proportion of households by geography: Location in areas exposed to heat stress, measured by Average Soil-Adjusted Vegetation Index, % asphalt; % tile; % wood, etc. [5] [10]	Geography
Proportion of households by geography: Location in areas exposed to heat waves, measured by, e.g., the number of days exceeding the local "high heat threshold" per year [10] [17]	Geography
Number and proportion of households with air-conditioning [1] [5]	Human and Economic Capital

Hazard Specific Vulnerability Indicators (HSVI) (continued)	
Heat wave	**Component**
Number and proportion of households with open space [5]	Built Environment
Number and proportion of households with swimming pools [5]	Built Environment
Number and proportion of households living on the top floor [1]	Built Environment
Number and proportion of households with low roof reflectivity [5]	Built Environment

Drought	**Component**
Number and proportion of households by non-farm income [6] [7]	Human and Economic Capital
Number and proportion of households by machine use [6]	Human and Economic Capital
Number and proportion of households by water supply system [4], e.g., Number and proportion of households using well water	Human and Economic Capital
Number and proportion of households by water consumption [4]	Human and Economic Capital
Number and proportion of households (or headship) by access to resources, e.g., machinery and equipment, insurance, technical assistance, information, social networking, public support programmes, crop and livestock management practices, risk mitigation practices [6]	Resources and Services
Proportion of households by geography: Location in areas by biological conditions (e.g., locusts)	Geography
Proportion of households by geography: Location in areas exposed to drought, measured by, e.g., historical frequency of drought; duration of historical droughts; average annual rainfall, inter-annual variability and seasonality [8]	Geography
Proportion of households by geography: Location in groundwater overdraft areas [4]	Geography

Landslide	**Component**
Proportion of households by geography: Location in wave/surge susceptibility areas measured by land use/cover, topographic position, slope, etc. [12]	Geography

Wave and surge	**Component**
Proportion of households by geography: Location in wave/surge susceptibility areas measured by average wind speed, breaking waves, etc. [16]	Geography

Windstorm (cyclones)	
Proportion of population by geography: Location in areas exposed to windstorms measured by wind speed, average storm surge, etc. [16] [17]	Geography

(continued)

Table 4.1- continued

Indicators that are particular to a city (and above) level:
Population density [5] Household density [16]
Indicators at certain geographic area:
National wealth: GDP per capita [3]; GNI Inequality: GINI coefficient Water infrastructure [2] Landmarks [2] Oil and gas infrastructure [2] Housing age [2] Nuclear facilities [2] Urban density [2] Economic well-being; Per capita GDP [3] [8, pp. 81-82] Human Development Index (HDI) [8] Environmental Performance Index (EPI) by World Economic Forum [8] Global Risk and Vulnerability Index by UNEP [8] Social Ties Index [5] Highest Elevation [13] Agricultural Produce [13]

Sources for this table:

[1] Ibrahim and McInnes, 2008.
[2] Cutter et al., 2003.
[3] Dwyer et al., 2004.
[4] Bolin et al., 2010.
[5] Harlan et al. 2006.
[6] Eakin et al., 2006.
[7] Adger, 1999.
[8] Adger et al. 2004.
[9] NeWater, 2005.
[10] Warner, 2007.
[11] Cannon, Twig and Rowell, 2003.
[12] López, 2009.
[13] Forkuo, 2011.
[14] Wheeler, 2011.
[15] Castellanos Abella and van Westen, 2007.
[16] Wu et al., 2002.
[17] Cooley et al., 2012.
[18] Shepard et al., 2012.

References

Adger, W. N. 2006. "Vulnerability." *Global Environmental Change* 16(3): 268–281.

Adger, N. 1999. "Social Vulnerability to Climate Change and Extremes in Coastal Vietnam." *World Development* 27(2): 249–269.

Adger, W. N., et al. 2004. *New Indicators of Vulnerability and Adaptive Capacity*. Tyndall Centre Technical Report. No. 7. Norwich, United Kingdom: Tyndall Centre for Climate Change Research, University of East Anglia.

Alwang, J., P. B. Siegel, and S. L. Jorgensen. 2001. "Vulnerability: A View from Different Disciplines." Social Protection Discussion Paper Series. No. 0115. Washington, D. C.: The World Bank.

Bolin, B., M. Seetharam, and B. Pompeii. 2010. "Water Resources, Climate Change, and Urban Vulnerability: A Case Study of Phoenix, Arizona." *Local Environment* 15 (3): 261–279.

Boone, C. G. 2008. "Improving Resolution Of Census Data in Metropolitan Areas: A Dasymetric Approach: Applications for the Baltimore Ecosystem Study." *Cities and the Environment* 1(1): Article 3. (Online open access journal.)

Brooks, N., W. N. Adger, and P. M. Kelly. 2005. "Determinants of National Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation." *Global Environmental Change* 15(2): 151-163.

Cannon, T., J. Twig, and J. Rowell. 2003. "Social Vulnerability, Sustainable Livelihoods and Disasters." Report to DFID. London: Conflict and Humanitarian Assistance Department (CHAD) and Sustainable Livelihoods Office, Department for International Development.

CARE. 2012. *Participatory Monitoring, Evaluation, Reflection and Learning for Community-based Adaptation*. PMERL Manual. Unknown location: CARE International. Website: www.careclimatechange.org/files/adaptation/CARE_PMERL_Manual_2012.pdf, last accessed 7 November 2012.

Castellanos Abella, E. A., and C. J. van Westen. 2007. "Generation of a Landslide Risk Index Map for Cuba Using Spatial Multi-criteria Evaluation. *Landslides* 4(4): 311-325.

Cooley, H., et al. 2012. "Social Vulnerability to Climate Change in California." A White Paper from the California Energy Commission's California Climate Change Center. Oakland, CA: Pacific Institute. Website: www.energy.ca.gov/2012publications/CEC-500-2012-013/CEC-500-2012-013.pdf, last accessed 5 November 2012.

Cutter, S. L. 2007. "The Social Vulnerability Index: A County-Level Assessment of Communities and Implications for Preparedness Planning." Presentation at the First Annual DHS Network Summit on Research and Education, Washington, D. C., March 15-16 2007.

Cutter, S. L., and C. Finch. 2008. "Temporal and spatial changes in social vulnerability to natural hazards." *Proceedings of the National Academy of Sciences* 105(7): 2301-2306.

Cutter, S. L., B. J. Boruff, and W. L. Shirley. 2003. "Social Vulnerability to Environmental Hazards." *Social Science Quarterly* 84(2): 242-261.

Downing, T. E., and A. Patwardhan. 2003. "Vulnerability Assessment for Climate Adaptation." Oxford, United Kingdom: Stockholm Environment Institute.

Doocy, S., et al. 2007. "Tsunami Mortality in Aceh Province, Indonesia." *Bulletin of the World Health Organization* 85(4): 273-278.

Dwyer, A., et al. 2004. *Quantifying Social Vulnerability: A methodology for Identifying Those at Risk to Natural Hazards*. Canberra, Australia: Geoscience Australia, Australian Government.

Eakin, H., et al. 2006. *A Comparison of the Social Vulnerability of Grain Farmers in Mexico and Argentina*. AIAAC Working Paper. No. 29. Washington, D. C.: Assessments of Impacts and Adaptations to Climate Change.

Ebert, A., N. Kerle, and A. Stein. 2009. "Urban Social Vulnerability Assessment with Physical Proxies and Spatial Metrics Derived from Air- and Spaceborne Imagery and GIS Data." *Natural Hazards* 48(2): 275-294.

Environmental Vulnerability Index. n.d. "Environmental Vulnerability Project." Suva, Fiji: Environmental Vulnerability Project. Website: www.vulnerabilityindex.net, last accessed 5 November 2012.

Forkuo, E. K. 2011. "Flood Hazard Mapping using Aster Image data with GIS." *International Journal of Geomatics and Geosciences* 1(4): 932-950.

Guzmán, J. M. 2009. "The Use of Population Census Data for Environmental and Climate Change Analysis." Pp. 192-205 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and the International Institute for Environment and Development (IIED).

Harlan, S. L., et al. 2006. "Neighborhood Microclimates and Vulnerability to Heat Stress." *Social Sciences and Medicine* 63(11): 2847-2863.

Herr, H., and K. Guenter. n.d. "Estimating Global Slum Dwellers: Monitoring The Millennium Development Goal 7, Target 11." Website: http://unstats.un.org/unsd/accsub/2002docs/mdg-habitat.pdf, last accessed 14 November 2012.

Ibrahim, J. E., and J. McInnes. 2008. "Reducing Harm to Older Persons in Victoria from Extreme Hot Weather." Final Report to the Department of Human Services, Victoria, Australia. Caulfield East, Australia: Monash University. Website: www.health.vic.gov.au/environment/downloads/reducing_harm_monash.pdf, last accessed 5 November 2012.

IPCC. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press.

Kuriakose, A. T., L. Bizakova, and C. A. Bachofen. 2009. "Assessing Vulnerability and Adaptive Capacity to Climate Risks: Methods for Investigation at Local and National Levels." Social Development Working Papers. No. 116. Washington, D. C.: The World Bank. Website: http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1164107274725/sdp116.pdf, last accessed 10 November 2012.

Locatelli, B., et al. 2008. *Methods and Tools for Assessing the Vulnerability of Forests and People to Climate Change: An Introduction*. Working Paper. No. 43. Bogor, Indonesia: Center for International Forestry Research.

López L., D. 2009. "Spatial Analysis and Modeling to Assess and Map Current Vulnerability to Extreme Weather Events in the Grijalva–Usumacinta Watershed, México." *IOP Conference Series: Earth and Environmental Science* 8(1): 012021.

McCarthy, J. J., et al. (eds.) 2001. *Climate Change 2001: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press.

NeWater. 2005. "Integrating Social Vulnerability into Water Management." NeWater Working Paper No. 5. New Approaches to Adaptive Water Management under Uncertainty. Stockholm: Stockholm Environment Institute.

Peduzzi, P., et al. 2009. "Assessing Global Exposure and Vulnerability Towards Natural Hazards: The Disaster Risk Index." *Natural Hazards and Earth System Sciences* 9(4): 1149-1159.

Reid, C. E., et al. 2009. "Mapping Community Determinants of Heat Vulnerability." *Environmental Health Perspectives* 117(11): 1730-1736.

Shepard, C. C., et al. 2012. "Assessing Future Risk: Quantifying the Effects of Sea Level Rise on Storm Surge Risk for the Southern Shores of Long Island, New York." *Natural Hazards* 60(2): 727-745.

Sheridan, S. C., and T. J. Dolney. 2003. "Heat, Mortality, and Level of Urbanization: Measuring Vulnerability across Ohio, USA." *Climate Research* 24: 255-265.

Simelton, E., et al. 2009. "Typologies of Crop-drought Vulnerability: An Empirical Analysis of the Socio-economic Factors that influence the Sensitivity and Resilience to Drought of Three Major Food Crops in China (1961–2001)." *Environmental Science and Policy* 12(4): 438-452.

Skelton, S., and S. S. Panda. 2009. "Geo-spatial Technology use to Model Flooding Potential in Chestatee River Watershed." Ch. 6.5.2 in: *Proceedings of Georgia Water Resources Conference*, University of Georgia, Athens, Georgia, 27-29 April 2009. Website: www.gwri.gatech.edu/uploads/proceedings/2009/6.5.2_Skelton.pdf, last accessed 16 November 2012.

Streutker, D. R. 2003. "Satellite-measured Growth of the Urban Heat Island of Houston, Texas." *Remote Sensing of Environment* 85(3): 282-289.

Sullivan, C. 2002. "Calculating a Water Poverty Index." *World Development* 30(7): 1195-1210.

Turner, B. L. 2010. "Vulnerability and Resilience: Coalescing or Paralleling Approaches for Sustainability Science?" *Global Environmental Change* 20(4): 570-576.

Turner, B. L., et al. 2003. “A Framework for Vulnerability Analysis in Sustainability Science.” *Proceedings of the National Academy of Sciences of the United States* 100(14): 8074–8079.

UNDP. 2004. *Reducing Disaster Risk. A Challenge for Development*. A Global Report. New York: Bureau for Crisis Prevention and Recovery, UNDP. Website: www.disaster-info.net/watermitigation/i/publications/RedDisaster-Risk/index, en.html, last accessed 7 November 2012.

UNEP. 2002. “Global Risk and Vulnerability Index Trends per Year: Phase II: Development, Analysis and Results.” Geneva: The “Gravity-Team”, UNEP. Website: www-fourier.ujf-grenoble.fr/~mouton/Publis_HDR_applis/ew_gravity2.pdf, last accessed 5 November 2012.

van Aalst, M. K., et al. 2008. “Community Level Adaptation to Climate Change: The Potential Role of Participatory Community Risk Assessment.” *Global Environmental Change* 18(1): 165-179.

van Westen, C. J., E. A. Castellanos Abella, and L. K. Sekhar. 2008. “Spatial Data for Landslide Susceptibility, Hazard, and Vulnerability Assessment: An Overview.” *Engineering Geology* 102(3-4): 112-131.

Vrieling, A. 2006. “Satellite Remote Sensing for Water Erosion Assessment: A Review.” *Catena: An Interdisciplinary Journal of Soil Science, Hydrology, Geomorphology Focusing on Geoecology and Landscape Evolution* 65(1): 2-18.

Warner, K. (ed.) 2007. *Perspectives on Social Vulnerability*. SOURCE. No. 6/2007. Bonn, Germany: United Nations University Institute for Environment and Human Security (UNU-EHS) and Munich Re Foundation.

Wheeler, D. 2011. *Quantifying Vulnerability to Climate Change: Implications for Adaptation Assistance.* Center for Global Development Working Paper. No. 240. Washington, D. C.: Center for Global Development.

Weng, Q., D. Lu, and J. Schubring. 2004. “Estimation Of Land Surface Temperature: Vegetation Abundance Relationship for Urban Heat Island Studies.” *Remote Sensing of Environment* 89(4): 467-483.

Wu, S. Y., B. Yarnal, and A. Fisher. 2002. “Vulnerability of Coastal Communities to Sea-level Rise: A Case Study of Cape May County, New Jersey, USA.” *Climate Research* 22(4): 255-270.

CHAPTER 5

Harnessing Census Data for Environment and Climate Change Analysis

Deborah Balk, José Miguel Guzmán
and Daniel Schensul

Introduction

One of the driving purposes of this book is to address a significant gap in the climate change response in consideration of population dynamics and their links to the human and social components of vulnerability assessment and adaptation planning. This chapter aims to help meet that goal by showcasing how processing and linking population data to climate data can be used to develop and monitor effective adaptation policies and practices.

Data on population distribution and dynamics are largely omitted from the current dialogue on climate adaptation. Yet, understanding the contribution of population processes is vital for both climate mitigation and adaptation scenarios (Guzmán et al., 2009). While climate mitigation is often thought of in a global way and therefore can rely on global models and national-level demographic data, the impacts of climate change will be borne on particular localities, and the evidence base for it draws largely on local and regional case studies (e.g., Agrawal, 2010). In order to understand and prepare for climate adaptation, however, a better understanding of demographic dynamics, including population distribution and composition, is necessary at a subnational level, particularly in climatically vulnerable regions.

To take one example of a climate-related hazard, the effects of floods that cause human mortality, morbidity and forced displacement are already considerable. The IPCC has estimated that, by the 2080s, many millions more people will face floods each year as a result of sea level rise and storm surges. It is increasingly recognized that understanding and responding to climate risk will require better integration of physical and socioeconomic data, including information on population vulnerability, sectoral economic risk and critical infrastructure, as well as an understanding of how vulnerability changes over time (Few et al., 2003).

Since strategies to prepare for disaster management differ in localized settings, disaggregated demographic data must be available to help lay a solid foundation upon which climate-related vulnerability can be evaluated and addressed. Critically, these data must be geo-referenced so that they can be mapped and linked to the geography of climate hazards. The need for subnational and local geo-referenced demographic data is especially significant for Africa and Asia, where future population growth is likely to continue at high rates for coming decades, primarily in towns and cities.[1] Population and housing censuses[2] are the only data sources that can provide comprehensive, geo-referenced population and socioeconomic data at the high levels of resolution necessary to make the links to climate geography.

National Statistic Offices (NSOs) collect and report information in many different ways (Guzmán, 2009). Yet, while NSOs produce reports, tables and maps of population characteristics by administrative units (such as provinces or districts), they do not produce them tallied by flood zone or other ecological features. To address this gap, much remains to be done to reorient census data producers and users and to improve the capacity to make demographic data relevant for use in climate models, studies and policies. The benefit of making progress in this area is that census data take common form across contexts, yet the results of analyses are highly specific to the places of focus, meaning that common methods can produce context-specific results. This chapter, along with the broader guide to census analysis for climate adaptation produced by UNFPA on which it is based (Balk et al., forthcoming), can help to bring population data to climate interventions by guiding NSOs, relevant ministries and local planning agencies in producing and using these data in relevant ways for environmental and related applications.

Reorientation in the Use of Census Data for Climate Change Policies

In order to facilitate a more in-depth analysis for climate change vulnerability, census data must be processed for very small areas in such a way that they effectively match the geographic distribution of hazards. This can be done in a number of ways, but the key is that the smallest geographic units should be useable as "building blocks" that can be joined into a range of larger geographies. Climate hazards, such as storm surges, cyclones, flooding, drought and temperature changes, will occur in different geographic extents and may disproportionately affect only some population subgroups in the affected area. While these localities belong to larger administrative areas—such as states or provinces and, of course, countries—often these hazards are very limited in geographic distribution.

In the past 10-20 years, the spatial capacities of national censuses have improved dramatically, though huge variability exists in the spatial rendering of censuses. By the end of January 2012, 77 per cent of all countries in the world had conducted their 2010 round of census, meaning that 87 per cent of the global population had been enumerated. Most censuses are also now geo-referenced; that is, some information on the location of each household is recorded by the census taker, and that information is reported in administrative units that can be rendered to show the boundaries of those units. While individual locations are never publicly revealed by census takers—since census taking upholds the principles of confidentiality—censuses combine locational information into a variety of reporting units. These units vary widely by country, with some making available only the coarsest levels of aggregation—national boundaries and/or first-order subdivisions, such as regions, provinces or states—while others make available the very finest units of aggregation necessary to maintain the confidentiality of census respondents, such as enumeration areas (EAs). These very fine units are sometimes called "building blocks" (Champion and Hugo, 2003) because they can be combined to create a variety of larger units, whether administrative units or other kinds of geographies like flood plains.

NSOs and the capacity for climate-related analysis

Despite the increased availability of spatial information and its importance for adapting to and preparing for climate change-related hazards, as well as the rise in the use of geographic information systems (GIS) in census enumerations during the 2010 round of censuses, few countries have put their censuses to use in this way. One of the major stumbling blocks to the use of census data for climate change is the lack of capacity and skills in NSOs. In the poorest countries, NSOs often run their censuses and major survey programmes with the technical (and financial) assistance of international experts largely because sufficient domestic expertise is lacking. Furthermore, like academic disciplines, NSOs tend to specialize. Agencies, or departments within agencies, often have one set of experts for population data collection and analysis and another for geographic data. This means that, in order to integrate climate and population data, agencies or parts of agencies that have traditionally not worked together will increasingly need to cooperate.

The lack of skills and capacity in NSOs is exacerbated by the lack of established best-practices for the production, distribution and use of spatial data in climate change and vulnerability applications. The remainder of this chapter is therefore intended as a guide for national researchers, analysts, NSO staff and others in understanding the nature of this analysis by providing guidance and tools that can help them in linking population to climate change and to other environmental issues.

Types of Census Data that Can Be Used for Climate Change and Environmental Analysis

> [Population and housing censuses] provide a powerful tool for assessing the impact of population on the environment, for example, on drainage basins and on water resource management systems. The spatial units for such a study may combine a group of local administrative areas. In this situation, the availability of census databases with mapping capability … is of great importance (United Nations, 2008, p. 241).

Fundamentally, a census provides data on the number, location and characteristics of households and dwellings. This basic information is directly relevant for determining the risks associated with environmental and climate hazards, yet it is all too often left out of vulnerability assessments. Population and housing censuses contain, at a minimum, information on sex, age, household composition and, usually, information on education and where individuals previously lived. Many censuses also collect data on occupation, fertility and mortality, among other variables. Censuses, therefore, provide information on the size, composition and characteristics of the population, which allows for the study of situation and trends in the composition, age structure and spatial distribution of the population. Their usefulness with respect to climate change and environmental analysis, however, will largely be affected by the availability of disaggregated and geo-referenced data, as well as on the types of questions included in the census.

Like any method of data collection, censuses vary in their quality and have some limitations. Censuses are conducted, in the best case, every 10 years, so the data are at risk of becoming outdated relatively quickly. Some countries have adopted intercensal data collection and estimation, though those estimates tend to be available for coarser spatial units only or for population size only. Also, the information collected in censuses is not as detailed as in surveys. For instance, there are no direct measures of poverty, a critical component for adaptation, in many censuses, meaning that links between survey and census data are required to model poverty across census geography. In spite of these limitations, when used alone or combined with data from surveys or administrative data, most of the information obtained in a census can be useful for environment and climate change analysis.

Demographic data from sources other than the census

Many NSOs or national institutions collect additional information through periodic surveys. Such surveys are run by the countries themselves or by major international survey programmes, such as Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS) and Living Standards Measurement Surveys (LSMS). These surveys are based on sampling frames derived from the decennial census and are nationally representative. They often ask many more questions than are possible in a census, since they are conducted through extensive in-person interviews. They also usually include more information on social, environmental and demographic issues—such as child well-being and survival, fertility, household assets and disease—and this information could be very useful in many climate-related applications.

However, the level of spatial disaggregation of these surveys is typically the first-order administrative unit (such as provinces), or even higher levels of aggregation. These surveys are typically sampled using geographic clusters of households, and new efforts have involved collecting geographic coordinates for these survey clusters. Even so, there are limitations in the geography of the clusters and the extent to which they represent small areas. Nevertheless, such data can be harnessed in creative ways by associating environmental characteristics with the survey clusters (see, for example, Balk et al., 2004, and Ch. 6 in this volume). The triangulation of information from different sources—censuses, household surveys and administrative statistics—is probably the most useful way to extract the best of these sources; i.e., it provides broad coverage from censuses and administrative records and better quality and details from surveys. This is the case for poverty mapping, which uses the links between household surveys and census data to model poverty over space.

Linking Population to Climate Data

Linking population data to the geography of exposure seems to be an easy task. However, it is made difficult because censuses publish or distribute information by administrative areas that rarely coincide with environmental areas (see: Balk and Yetman, 2004). McGranahan et al. (2007) assessed the distribution of human settlements in Low Elevation Coastal Zones (LECZs) around the world. In order to calculate the population at risk and their international distribution in LECZs, the authors integrated spatially constructed global databases of population distribution and urban extent and elevation data and, by overlaying gridded geographic data, derived totals of national populations in LECZs. While the authors were able to calculate exposure of coastal areas to sea level rise, they recognized that this analysis was just a first appraisal and that further disaggregation is needed.

Because survey data are typically rendered in fairly coarse spatial terms, their value in identifying climate risks for low-lying coastal zones is fairly limited. In contrast, census data have much greater intrinsic spatial flexibility. Estimations of populations at risk have to date relied heavily on using population counts for small-areal units (sometimes transformed as described below). These units are the backbone of the census. Any census variable that is reported at the level of very fine areal units can be combined with GIS tools into geographically identified regions. In some countries, only population counts are made available at the finest level, whereas additional variables may be available for coarser units. Census data are typically not used as microdata, but rather as attributes of small administrative units in order to maintain confidentiality.

This type of aggregation—while very powerful in some respects, particularly for policy applications—can be misleading. For example, if one were to find that the population of the coastal zone was more urban than the population living outside the coastal zone, and that the population of the coastal zone is also more likely to report fishing as an occupation (by nature of their proximity to the sea), one might infer that urban dwellers fish for a living. But this type of inference arises through an "ecological fallacy"—assigning characteristics of an area to individuals within it—and is quite possibly false. To properly make inferences, one would need to return to the microdata, identify occupations in urban and rural households, and then re-aggregate them to the small administrative units. Similarly, when survey data are used in this way as summaries at the subnational regional level, they, too, fall prey to potential ecological fallacy. In addition, coarse units often result in under or over estimations of populations at risk, as illustrated with Viet Nam later in this chapter.

This raises an important point about preparing census data for environment and climate analysis. Because the end result will inevitably be geographically organized units, aggregation from microdata will always be necessary. This aggregation will always leave analysis open to the ecological fallacy, unless the analyst selects and analytically organizes the right combination of data from the microdata (such as in crosstabs). For example, an analysis of dwelling type and service access of women-headed households must begin with the aggregation of microdata on dwelling type and service access by household headship. It is essential to carefully think through the combination of data needed for the analysis ahead of time. Once aggregation is done, it may be too timeconsuming to go back to the microdata, or even impossible depending on the nature of access.

Because geographic zones (apart from administrative units, such as watersheds, flood zones or even urban agglomerations) have not been commonly used in the past, census analysts have not prepared summaries of census data for those zones from the micro-data themselves. Existing technology makes the construction of different geographies aggregated from microdata very possible by NSOs or their enclaves for protected data (electronic or otherwise), though at the present time this is not common practice.

What does it mean to make demographic data relevant to climate change?

Climate change is a spatial phenomenon. To make population data relevant, they must also be rendered spatially. This means that small-area spatial unit data and key indicators on population distribution and composition are both necessary. Spatial data formats vary, and the tools for working with them vary accordingly. Administrative data are typically vector-format polygons. Once population data are rendered in small spatial units (enumeration areas, blocks, etc.), it is important that they be integrated with spatially-specific climate change data. Climate data are almost always raster format or grids. Some form of correspondence between any two spatial units that are not identical is required. When linking population data with climate data, that integration takes place in a spatial framework, and, depending on what is being integrated, may require that population data are transformed from irregularly-shaped census units (usually, in vector format) to a uniform grid (or raster format). Transformation to a grid helps reduce data loss and facilitates consistency in the generation of estimates.

Another option may involve summarizing climate data in raster form according to small-area polygons of administrative data. A key decision to be made in this type of analysis involves when to use a grid as the basis of analysis or when to use polygons such as enumerator areas or administrative units. Some guidelines for this decision are as follows:

- Enumerator areas or administrative boundaries often are constructed to have social meaning, be they neighbourhoods, blocks, communities, municipalities, provinces or even national boundaries. Depending on the reasons for the analysis, it may be important to retain this social meaning in the results. In such circumstances, it is best to retain the census unit as the base.
- Sometimes several different types of geography are important to the analysis: For instance, water catchment areas, urban boundaries, flood plains and low elevation coastal zones. In these instances, it may be more important to be able to move among these geographies quickly and easily, and transforming the population data to a grid is likely to be the best choice.
- Comparisons between censuses with different units—either across years when the units have been changed or between countries—require a consistency of unit that cannot be delivered by polygons that do not match in size or time. Under these circumstances, transformation to a grid provides the most consistent base for analysis.

Using a polygon base ultimately works in much the same way as transforming to a grid when either developing new geographies or summarizing statistics from raster to polygon. Similarly, raster areas can be outlined and transformed to polygons, and these polygons can be matched with census polygons to determine the proportion of overlap, which in turn determines proportional allocation.

Alternatively, analysts can maintain the census unit, and then identify the average value of a set of pixels within a particular polygon quite easily in standard mapping software (often referred to as zonal statistics). This is common for remotely observed variables like temperature. In the end, if the result is to be a level of exposure for a neighbourhood, zonal statistics to summarize raster-form climate data are the best choice. If the result is to be the population size and composition of a geographic unit of risk, either gridding or maintaining the census unit may work.

Coastal population distribution provides a strong example of the benefits of gridding. To date, among the many climate-related or environmental risks to population, only coastal population distribution has been systematically estimated in an integrated fashion. Until recently, coastal proximity was not a consideration in demographic analysis; for example, even in the United States, a country with much flexibility in how it could repackage its demographic estimates, the initial estimates of coastal population have been greeted with some scepticism (Crowell et al., 2007).

Fortunately, increasing data availability and the development of new methods over the past decade are making estimation possible even in low-income countries. One of the first studies to systematically identify global population distribution with respect to coastal proximity was that of Small and Cohen (2004). They defined coastal proximity as residence "within 100 km" of a coast line, this distance being the best that could be done at the time, given the coarse spatial resolution of the population data then available. Small and Cohen found that one third of the global population lives within 100 km of a coast. McGranahan et al. (2007) used a more refined measure of coastal proximity—10-metre elevation—and were able to disaggregate between urban and rural population and land areas. These advances were largely made possible by investments in finer resolution population data (used by the GRUMP project, CIESIN et al., 2004) and improvements in satellite measures of elevation that allow for refinements in estimates of coastal elevation.

In less-developed countries, the lack of spatially detailed data has been a limitation for all types of locations, not only coastal areas. Outside of high-income countries—which hold regular censuses and have statistical systems capable of collecting, mapping and analysing spatially-specific population data—very little is known about a given population's demographic features that does not conform to regular and, usually, coarse reporting units. Such limitations are not easily overcome. It can be quite difficult to convert population data organized by administrative units into estimates of population distribution. Census data are typically reported for administrative units such as provinces, states or, in some cases, municipalities. Very often the spatial boundaries associated with these administrative units, even at this level of disaggregation, are not made publicly (or at least not freely) available. Even within NSOs, data may not be available to all units within the agency. In many NSOs, boundary data are the domain of geographers and population data are the domain of demographers, and efforts to combine data are sometimes limited to the most basic, coarse-level reporting units.

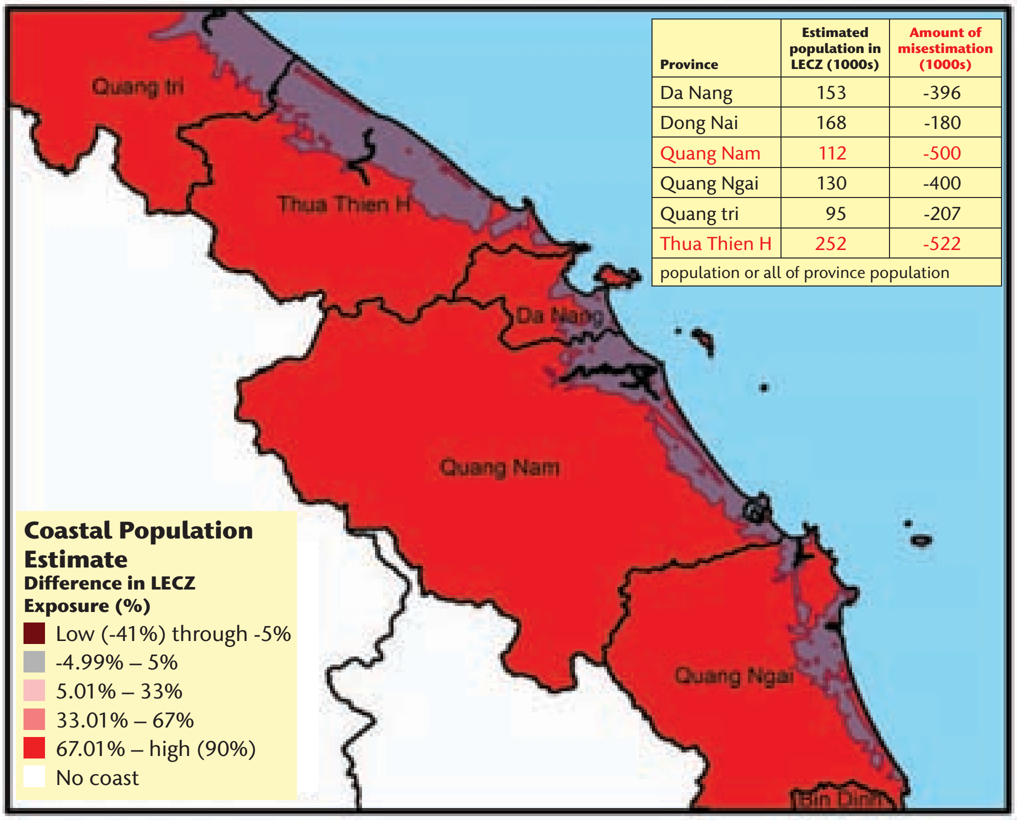
Even when spatial units that match census reporting data are available, the spatial and administrative data are seldom linked, leaving the user to grapple with the challenges of manipulating and reconciling conventional tabular data with spatial data. Some specialized knowledge and training are necessary in order to work with these different data effectively. This is an important challenge, especially at the local level where expertise in the many areas required by interdisciplinary analysis would be hard to come by. Therefore, NSOs should make every effort to maintain linkages between disparate types of data. For example, data tables of demographic characteristics that are organized by geographic regions should retain the name and complete code of that region. Similarly, geographic data should retain not only the codes and names of the smallest possible unit, but also the hierarchical information that allows smaller units to be matched to other administrative or political geographic units.

A methodological issue that is of particular concern for spatially defined areas such as coastal areas or flood zones is the spatial resolution of units. These types of zones are not unique. Many ecologically defined zones are irregular and cut across many administrative units. The finer the unit of interest—for example, the finest grained units that might border a coast line or river—the more difficult the data are to acquire. This creates an inherent problem when the objective is to estimate population characteristics in a narrow geographic area such as a strip of coastal land. Even when the coastal band is sizeable, its area will usually not generally conform to the formal boundaries of administrative units.

Using Viet Nam[3] as an example, it is clear why the resolution of population data matters for estimating populations facing coastal hazards, i.e., those living in a LECZ (McGranahan et al., 2007). Figure 5.1 shows a close-up of several first-order administrative units (provinces) in Viet Nam. The finely detailed boundaries shown—fourth-order administrative units—are termed communes, as can be seen in Figure 5.2. Viet Nam is unusual for a developing country in that the resolution of its spatial data is high. These data are fine-grained enough that the native data format (i.e., vector) may be overlaid with data on the LECZ to estimate the population living at risk of coastal hazards.

Overlaying data in this way brings a number of analytic problems to the fore. For any commune that intersects the LECZ (rather than being fully covered by it), an assumption must be made about how to estimate the population in that unit. For some purposes, one might want to include the entire population in any administrative unit that intersects the LECZ. For example, if flooding were to occur in a limited area, the economic burden to prepare for or respond to the flooding would, in some part, be shared by the entire population of a given municipality, so the population of the unit as a whole may be the best estimate. For other purposes, one might want to assume that the population of a given unit is distributed evenly throughout that unit so that only the proportion exposed to the LECZ would be counted. This approach is preferable when estimating the number of individuals or households in flood zones or who require evacuation for coastal storms. When there are many adjacent units, all with partial exposure, the estimates for the partially exposed areas may then be added together to get an estimate of total

Figure 5.1: Provincial Boundaries, Overlaid by the 10m Low Elevation Coastal Zone, Viet Nam



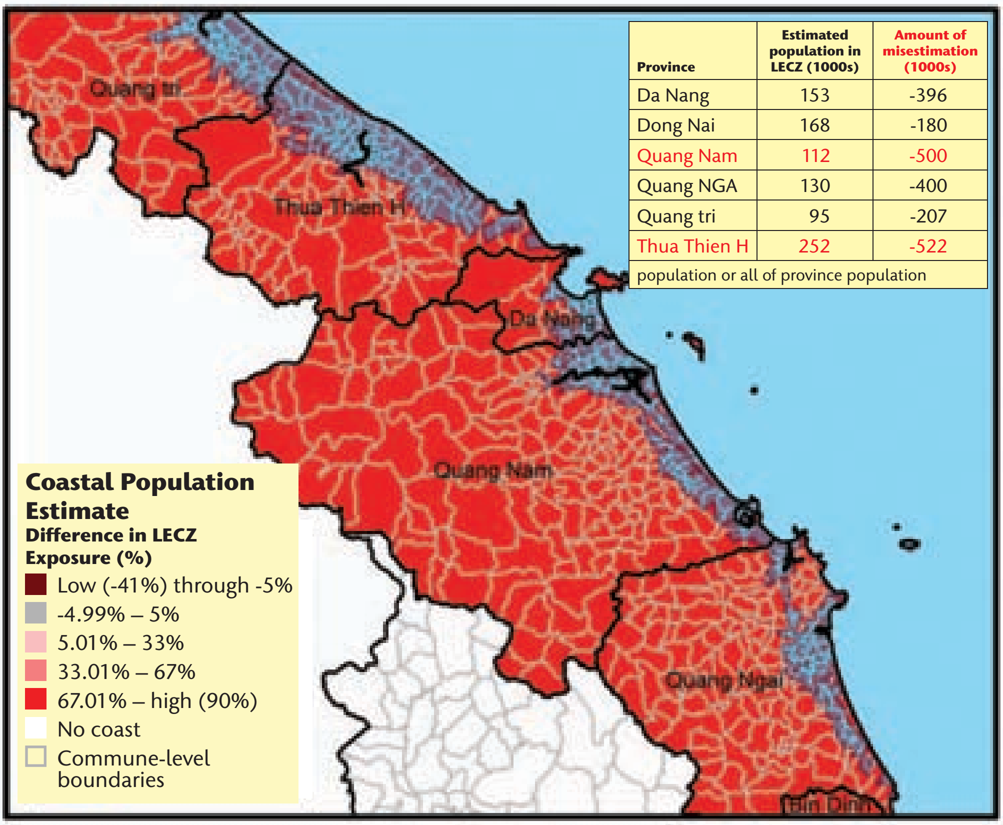
Province	Estimated population in LECZ (1000s)	Amount of misestimation (1000s)
Da Nang	153	-396
Dong Nai	168	-180
Quang Nam	112	-500
Quang Ngai	130	-400
Quang tri	95	-207
Thua Thien H	252	-522
population or all of province population		

exposure within the flood zone (rather than for larger administrative units), which would give more accurate estimates of exposure.

There are also more complicated rules about how to estimate population exposure based on assumptions about the uneven distribution of population within spatial units. Because the answers depend on the assumptions used, it is essential to make the assumptions explicit. A common example of this type of assumption would be to use aerial photography or satellite imagery to identify the built environment and density and then to apply proportions of the population to these areas.

Historically, few countries have collected and reported fine-grained details on census units. This is only partly because reporting is seen as only necessary for politically or administratively viable units. Another reason is because it has been difficult in the past to process, manage, analyse and disseminate many more variables for many more units. However, with increasing computational power and capacity, this limitation no longer applies even in poor countries. Another concern (and one which remains quite real) is the need to preserve the confidentiality of individuals who have completed the census. As the reporting unit becomes finer—for example, down to the smallest enumeration area—the breadth of information that is used for analysis internally and reported by NSOs typically diminishes, in part so that individuals may not be identified through "attribute disclosure". For the smallest units, it is common for very limited information

Figure 5.2: Provincial and Commune Boundaries, Overlaid by the 10m Low Elevation Coastal Zone, Viet Nam



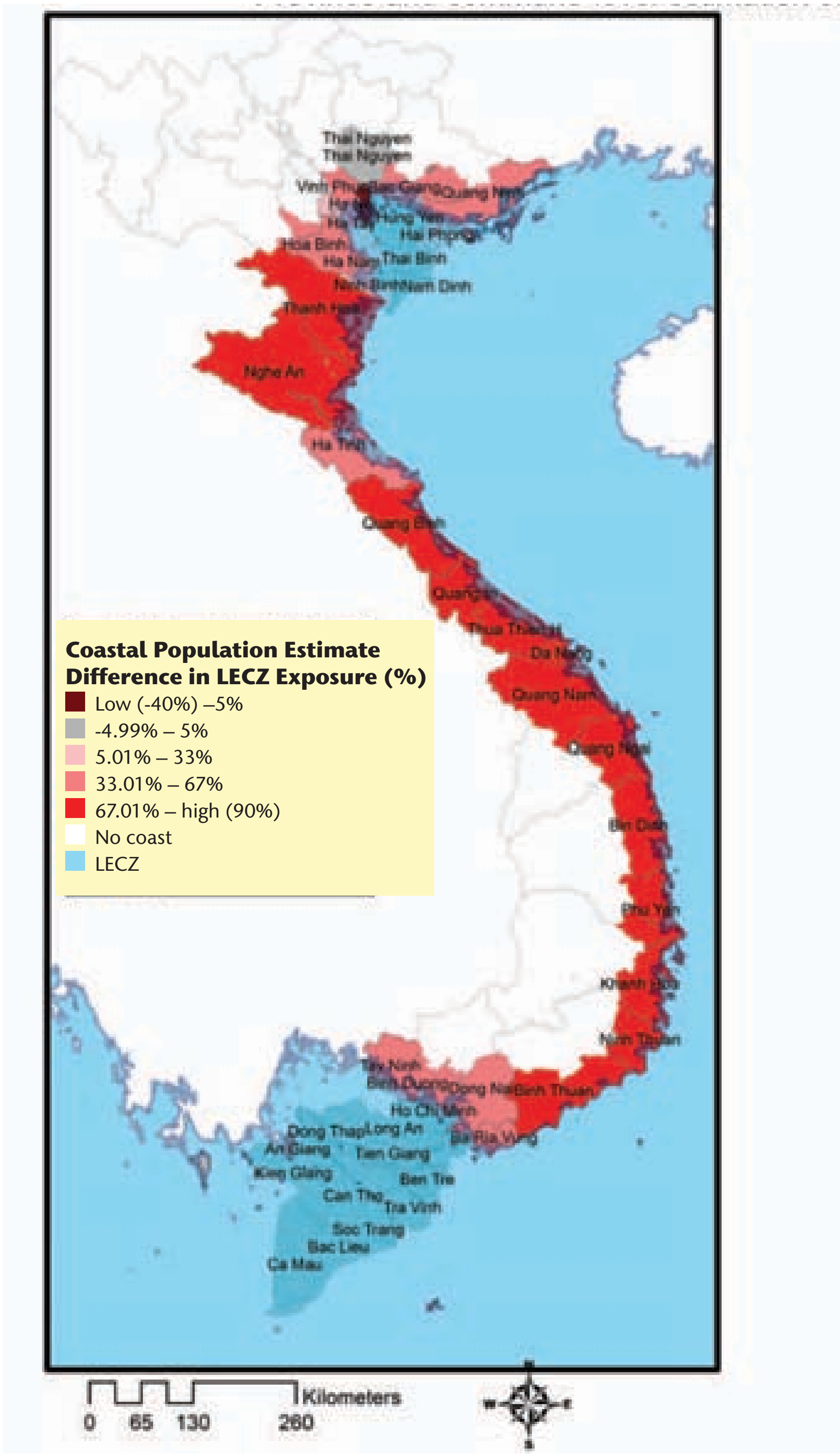
Province	Estimated population in LECZ (1000s)	Amount of misestimation (1000s)
Da Nang	153	-396
Dong Nai	168	-180
Quang Nam	112	-500
Quang NGA	130	-400
Quang tri	95	-207
Thua Thien H	252	-522
population or all of province population		

(typically population counts, perhaps by age and sex) to be reported, whereas for larger units data are often made available on household incomes or basic needs, race, educational and housing characteristics as well. There is wide variation in censuses across the globe in what variables are made available (Chamie, 2005) and even more variation in the information that is available for the smallest administrative units. One way for NSOs to deliver more detailed data at the small-area level is to deliver indicators directly, rather than just the raw data to produce the indicators. Chapter 4 describes relevant indicators.

In many industrialized countries and increasingly in newly industrializing countries, there is a good deal of census information available below the first administrative level (typically states or provinces). Data released for counties and even sub-county units—such as census tracts, block groups and blocks (or their equivalents)—contain more information than simple population counts (Peters and MacDonald, 2004; CPHSC, 2009), but the same general principle holds: The smallest units, blocks, contain only three variables: population counts by age and sex, grouped by race. Viet Nam is one country that, in recent years, has not only increased the spatial resolution of its census substantially, but has also collected much information below the first-order administrative units. Much of that information is also relevant to climate change, as highlighted below.

As noted previously, Figure 5.1 shows province-level and Figure 5.2 shows province- and commune-level boundaries for Viet Nam overlaid with the LECZ boundary, as a

Figure 5.3: Per Cent Difference in Estimates of Population Exposure to the LECZ: Province and Commune-level Estimation Compared



close-up of one region of Viet Nam. Figure 5.3 shows the province-level boundaries for the entire country, where the colour hues indicate the differences in the estimation of the population living in the LECZ when province-level population data are used as the basis of the calculation as against sub-province-level (i.e., commune-level) population data. At the province level, the map implies that the population is uniformly distributed throughout the province. Because more detailed data are available below the province level, it is known that this assumption of uniformity does not hold for population counts; it is not known, however, whether it fails to hold for other characteristics (e.g., migration rates). At least for population counts, one can determine the degree of mis-estimation of the population at risk that comes from a naive application of the assumption of a uniformly distributed population at the province level.

The magnitude of the mis-estimation is shown in Table 5.1. In southern Viet Nam, where some entire provinces fall fully within the LECZ, disaggregated data do not improve the estimation. But for coastal provinces, where communes tend to be much more densely populated than in interior communes, disaggregated data substantially affect the estimation, as indicated by the very large percentage of differences noted in red. For almost all coastal provinces, using province-level data far underestimates the population at risk of coastal hazards. Four provinces are underestimated by more than 500,000 persons each. Only in one province, Hanoi, was the mis-estimation in the opposite direction. The province-level data resulted in an overestimation of the population at risk. Why? The city of Hanoi, which is densely populated, is situated at a higher elevation than the surrounding areas and is above the 10 metres of the LECZ. The assumption of uniform population distribution is again false, and in this location produces an over count. Both under and over counts are problematic, particularly for agencies that might need such estimates to guide their planning. In sum, when spatially disaggregated data are available, they should be used. When they are not available, coarser-level data may be used in this type of geographical analysis, but only with caution and a clear articulation of any underlying assumptions used in the estimation.

The geographic size of administrative units is sometimes referred to as the intrinsic spatial resolution of census data. Unlike the resolution of grid cells, the resolution of census units is irregular. Even these smallest units are irregularly shaped and of varying sizes. Transforming data to a grid creates compatibility with other geographic layers that are also gridded—typically physical surfaces and data that have been collected through Earth-observing satellites. It is important to know the resolution of the underlying data, since it will influence the accuracy of the data transformed into grids, as well as any additional estimates based on these grids. In particular, higher resolution of underlying data means that each grid—which can only contain a single value—will better reflect the characteristics of the area it covers.

In general, and particularly when flexibility of data usage is important, finer spatial resolution of administrative units or satellite data is considered superior to coarse-resolution data. However, higher resolution data may be more costly to process, may require greater scrutiny, and, particularly when overlaying spatial data layers, the magnitude and number of mismatches between high resolution data sets are likely to be greater. In addition, for the purpose of governance and policymaking, it is often necessary, as well as practical, to report by coarse administrative units. It is far preferable, however,

Table 5.1: Province-level Summary of Mis-estimation of the population living within a Low Elevation Coastal Zone: A comparison of scale-dependent Estimates

Province	Estimated Population LECZ (1000s) calculated with level data (fine estimation)	Amount of Mis-estimation (1000s) from calculation using province-level data (coarse-scale estimation)
Ba Ria Vung	174	-149
Bac Giang	257	-329
Bin Dinh	112	-375
Binh Duong	57	-106
Binh Thuan	29	-241
Da Nang	153	-396
Dong Nai	168	180
Ha Nam	688	-73
Ha Noi 5	1,475	435
Ha Tay	1.375	-175
Ha Tinh	295	-482
Hai Phong	1,445	-160
Hoa Binh	3	-2
Khanh Hoa	108	-359
Nghe An	186	-979
Ninh Binh	550	-221
Ninh Thuan	29	-194
Phu Yen	75	-285
Quang Binh	78	-311
Quang Nam	112	-500
Quang Ngai	130	-400
Quang Ninh	164	-167
Quang tri	95	-207
Tay Ninh	267	-140
Thanh Hoa	572	-1,269
Thua Thien H	252	-522
Vinh Phuc	8	-5

N.B.: Red font denotes provinces where the amount of mis-estimation is greater than 500,000 persons

to have the ability to re-aggregate as needed, in particular since some problems may cross administrative boundaries. Imagine if policymakers wanted to tally demographic characteristics for the coastal and non-coastal areas of particular provinces; fine resolution data would facilitate this, though some re-aggregation would be necessary.

Lichter and colleagues (2010) recently compared three global-scale coastal zones and two population data sets to determine if there was one best data set, or combination of data sets, whose spatial resolution would produce the best estimates of coastal land and population. They emphasize that the data sets—and their interpretability—are very much reliant on the underlying spatial resolution and the clarity of the assumptions used to produce these data sets. They find that there is no one best data set or combination of data sets and that data sets need to be evaluated in part by their appropriateness for their intended use. They conclude with a familiar plea for transparency: "The provision of unambiguous definitions of the extent of the coastal zone, as well as of thorough and detailed descriptions of the methods and data employed and assumptions made for estimating area and coastal population, will enable the comparative evaluation of the results of different applications" (p.767).

At a local scale, sometimes much more can be said, and higher-resolution inputs of all types may be available. The recent study by Byravan et al. (2010) on infrastructure at risk of sea level rise in Tamil Nadu, India, is one such example demonstrating the extent of what can be done with local data and with fewer comparability concerns (though the article is only relevant in terms of LECZ, not population). But these examples, in more- and less-developed countries alike, are few and far between.

Scale of population data

Demographic data are increasingly available for small census units. Yet, to date, in general only population counts are easily obtainable for fine-scale cross-disciplinary work; Japan is the only country that appears to make its census data available in gridded formats.[4] Many limitations arise from not having finely resolved demographic data. This is a particular concern for data that describe aspects of population composition. However, other variables of interest that describe the vulnerability of the population or of homes (such as education, housing, race, linguistic isolation) are not typically available at the finest scale. Statistical methods may be used with variables available at different spatial resolutions to infer attributes to a finer resolution than that which is currently available, though these methods are relatively new and computationally and human-resource demanding (see, for example, Balk et al., 2009; Elbers et al., 2003). With the use of statistical techniques, data producers and users must become more aware of the underlying methodology and assumptions used to generate estimates. For example, it is essential to understand which data are combined and at what resolution so that data can be used in applications in ways that do not violate the underlying assumptions of their construction. (Violating assumptions may produce results that are biased or mis-estimated.)

While no study to date has treated a coastal region as an entity for estimating future population, with the increasing seaward hazards associated with climate change in the coming decades, this is a reasonable goal to be pursued by both the demographic and environmental science (or coastal science) communities. NSOs can play a critical role in this objective because they have exclusive access to the underlying census microdata to make such estimation and forecasting possible. That is, census microdata are not publicly released to protect the confidentiality of the population. Even samples of microdata, when they are made available, tend to be anonymized and can only be summarized by fairly coarse spatial units. However, census microdata can be summarized by any geographic entity, including ones that are not administrative in nature, and treated like any other geographic entity. By acquiring new spatial skills, the full power of census microdata can be used within NSOs, perhaps in collaboration with counterparts from agencies with geographic specialists.

Temporal scale

The spatial units corresponding to census report units change over time. Country boundaries change infrequently, but sub-province boundaries change regularly. Change is expected in some areas more than in others. For example, in fast-growing cities, the boundaries and intra-urban subdivisions change because the city is expanding both in population and spatial dimensions. Creating equivalencies between units over time requires knowledge and documentation of the change, as well as a set of rules on how to create such equivalencies. Some analysts may wish to apply everything to the current set of boundaries; others may choose the older set of boundaries; and even others will want to create a gridded transformation and then let the assumptions of the gridding process adjudicate the changes. Dealing with creating equivalencies over time between changing spatial variables is not entirely different from working with attributes that change, as commonly happens between decennial censuses. Because changes over time are intrinsic to censuses, it behooves census takers to make sure spatial data for each point in time is maintained and documented. This will give agency users and downstream analysts the ability to decide on how to create equivalencies between units which have changed over time. Gridding sometimes offers an approach that allows for attributes belonging to different administrative units in time t and time t+10 to be compared. Guidelines for managing these spatial changes are well articulated in the United Nations *Handbook on Geospatial Infrastructure in Support of Census Activities* (2009).

Data sets on populations and data sets on climate patterns can be used together to help understand the interactions between population and climate change. Integration between two data sets that share identifying units can be straightforward, but data inconsistency within and between places may be non-trivial (Balk et al., 2009). Many examples are given here with respect to a low elevation coastal zone, but there are many others that could be considered. For example, temperature and rainfall models (or surfaces created from observational data), aridity zones, drought scenarios, malaria endemicity zones and flood plains are other possible climate-specific data for which one might want to construct estimates of populations at risk. The spatial data delineating each of these zones would need to be co-registered with population data, so that mismatches do not occur. That is, each data set will need to be vetted with respect to the population data (as no standard set of coast lines exists, for example), whether rendered via vector or gridded format. The same would apply for each additional layer, including those representing infrastructure, housing or the built environment. It cannot be assumed that different data layers, even those produced by a single NSO, will have the same set of boundaries for coast lines, water-ways and other features that may impact the estimates derived from overlays.

There are always agreement issues related to the precision and accuracy of data layers when more than one spatial data layer is used to generate an estimate of populations at risk. There is no consensus on how to deal with multiple data layers. However, the first principle to apply is one that does no harm to the estimates. A second principle is to apply spatial uncertainty to allow for a range of populations at risk. Since demographic forecasts are produced by multiple scenarios, the idea of applying spatial uncertainty should be something that is conceptually (if not technically) palatable.

Critical Steps

Summarizing the points presented above, a series of steps are necessary to join the right census-derived data with the right climate-relevant layers while accounting for different data types and inconsistencies between data sources:

1. Identify the smallest spatial unit available from the census—i.e., the smallest for which data are available and for which digitized maps exist.
2. Identify the key indicators of interest, and the variables and crosstabs that compose them, for aggregation from microdata to small-area polygon data.
3. Identify other relevant geographies and data: low elevation coastal zones, flood plains, temperature data, precipitation data, drylands and other types of ecosystems.
4. Based on the criteria suggested above, decide whether the analysis will use gridded population data in concert with raster environment/climate data or will use polygons or zonal statistics derived from raster environment/climate data in conjunction with the existing small-area geography. Conduct the relevant transformations.
5. Identify and attempt to correct sources of error in the use of data from multiple sources. These can include geographic variations such as different coast lines, as discussed above. They can also include small-area polygons from the census that deviate from social boundaries. Overlaying small-area boundaries on aerial photography or satellite images can help in this exercise, and spatial software provides the tools to adjust census geography to better match what is found on the ground.

Skill Sets and Needed Capacities

To make fuller use of demographic data in spatial frameworks, and in applications that are non-demographic, greater engagement between demographers and other users of demographic data are needed. Towards that end, it would help if non-demographers gained an appreciation of the types and limitations of demographic data. And, similarly, of course, it would help if demographers acquired a better understanding of the other disciplines in which they aim to work. Therefore, demographers, statisticians and planners who work in NSOs need to become equipped with the skills required to overcome the challenges that arise when combining population data, whether from censuses or surveys, with environmental data useful for describing or predicting climate change hazards, whether derived from satellites or other spatial analysis.

While some of the skills necessary to integrate population data with environmental and climate change-related data are new, others are not. Even the new skills needed are increasingly becoming available to non-specialists. These skills and some resources on publicly available data and tools are identified below.

National Skills and Capacity to do Necessary Analyses

Those producing and analysing demographic data in NSOs must gain geographic information skills to work with spatial data. The easiest entry into GIS is to gain competency in working with vector data, though climate data may be raster data, and some statistical analysis will be enhanced by converting all data layers to raster format.

There are some demands on infrastructure mostly in the form of computational capacity, but these are relatively minor and increasingly getting smaller as computers advance, compared to the human resources needed. Nevertheless, a national data infrastructure that has spatial data as its backbone needs to have servers and networked computers to share both data and software applications. GIS software ranges from costly to open-source. Which data products are best depends on the needs of a particular agency. Adding GIS skills to an already well-trained work force is not a major commitment; however, if the NSO staff is already under-trained, adding these new skills may be a considerable strain.

Furthermore, the skills needed to link spatial data differ from those needed to create thematic maps, and these, in turn, differ from those needed to generate zonal statistics. All of these skills are necessary. The first set of skills (joining data, and perhaps some geoprocessing) is a prerequisite for linking two data sets, or even for linking non-spatial data tables with a set of codes or names that can be matched. The second (symbolizing data) is necessary to visual the data, make informative maps and shade those maps with relevant thematic overlays. The third (spatial analysis, zonal statistics) is necessary to generate population at risk estimates by various geographically specified zones.

The implementation of new skills is influenced by local and national data cultures. For one, spatial data need to be shared within and among agencies or parts of agencies. Yet spatial data, much more so than census tables, are often considered proprietary and tend to be severely restricted, even within a given country. This practice places severe limitations on analysis, informed policymaking and participatory decision-making within different branches of government or civil society. However, some countries overcome data restrictions by making data—even within agencies of NSOs—available through data enclaves where census microdata and any combination of their spatial information may be used.

Sharing is not just limited by data restrictions. Lack of interaction between government agencies can prevent joint work, both by formal limits on cooperation and a lack of understanding of the substantive analyses that need to be conducted. Doing the right analysis with the right outputs is critical in making the data work for policy. Particularly for NSOs, understanding what the Ministry of Environment or other ministries need is critical. Having the flexibility to deliver results using various geographic units is a very important skill in this regard. Setting up an institutional setting—such as a data lab—in which exchanges can occur is one possible option for greater integration: Data analysis can be conducted across government ministries, and specific requests can be made of the NSO.

Data Delivery Tools

Building sophisticated capacity for creating, managing and analysing spatial data may be more than many NSOs need or can accommodate. Fortunately, some NSOs create their own data delivery and analysis tools. For instance, Statistics South Africa has developed a mapping platform (http://mapserver2.statssa.gov.za/geographywebsite/) that integrates their census data with a wide variety of other data sets.

Software for population data processing and data dissemination

REDATAM

To estimate populations at risk, disaggregated data at lower geographical levels such as districts, counties or even enumeration areas are necessary. On the one hand, population and housing censuses seem to be the right data source to statistically and spatially analyse vulnerable populations, specifically for population structure, migration patterns, education level, indigenous people, household conditions, unmet basic needs, fuel for cooking and garbage disposal, among other characteristics. On the other hand, these data have always been sensitive in nature, and NSOs worldwide cannot provide microdata to third parties because of legal limitations. ***Redatam+SP*** (***RE****trieval of* ***DAT****a for small* ***A****reas by* ***M****icrocomputer* ***Redatam+SP***), a free software developed by the Centro Latinoamericano y Caribeño de Demografía (CELADE)-Population Division of the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) (www.cepal.org/redatam), can process and tabulate census microdata without providing the identities of individuals or households, thus maintaining statistical confidentiality at all times.

Redatam+SP capabilities are built around a standard computing kernel known as the *Redatam+SP* statistical engine. This highly efficient engine is comprised of a set of programming routines. It creates or imports databases into a proprietary format to produce the required outputs and to generate new variables to be aggregated permanently into the database. The conversion to proprietary format is important because this process compresses, encrypts and inverts the original data source in order to ensure that individual and household records remain confidential and to maximize efficiency of processing. Therefore, the *Redatam+SP* package permits in-depth population and demographic analysis based on census databases or other data sources.

Redatam+SP is particularly efficient in processing information for small areas as required by local-level planners and analysts in the public and private sectors. In addition to protecting the confidentiality of data, its most outstanding characteristics include its user-friendly simplicity and speed (Through the Internet, it can process one million records per second for a frequency of almost 500,000 records per second for a tabulation.); its ability to create indicators and add them permanently to the database within the programme; and its database structure which allows for explicit processing of different data levels—e.g., housing units, household- and individual-level characteristics—so that they can easily be combined to derive indicators at the most disaggregated geographical levels, counties, blocks or enumeration areas and exported to a GIS. Furthermore, the *Redatam+SP* Web Server provides the general public with an interactive system that allows for on-line processing of any census microdata database over the Internet (www.redatam.org). Thus, CELADE aims to provide global technical support to national institutions wanting to re-engineer their information dissemination programmes through the Internet.

The *Redatam+SP* software is not a sophisticated statistical package or a GIS, and while it is a highly customizable tool for countries and can produce statistical output tables and draw simple maps at lower geographical levels, at present it is not a fully flexible tool for use with climate or other geographic data. It does not allow users to upload data to the system and overlay the geographic layers of interest. Its better use is as a producer of population indicators that feeds a full fledged GIS or statistical package.

DEVINFO

DevInfo (www.devinfo.org) and its related *CensusInfo* tool are other means of mapping survey and census data. These tools show subnational details of pre-set characteristics from the underlying microdata (for surveys) or aggregated indicators (for censuses). Time series views are shown as well for a limited number of variables from the census data. However, user-supplied geographic data cannot be accommodated.

Both *Redatam+SP* and *DevInfo* offer much promise, but to be fully useful in the context of climate change these tools will need to preload climate zones. Some additional programming would be required to create summaries, if not zonal statistics, of populations at risk. Since *Redatam+SP* data sets have microdata as their base inputs, the creation of these summaries may be a fairly straightforward proposition for programmers. Simplifying the arduous requirements of data integration and estimation of zonal statistics will not produce the necessary outputs that every local or international user would want, but it would reduce the substantial burdens on municipal and local agencies and help place demographic data in the hands of many agencies for the purpose of climate adaptation in the short run.

Skill- and Institution-building Steps

This chapter has suggested that capacity for bringing census data to climate analysis is essential but often lacking. The following steps should be considered in developing a capacity-building strategy to address this gap:

1. Develop a national data infrastructure with integrated geographic information systems. While this may sound daunting, the hardware necessary to build these kinds of facilities is not substantially different from standard hardware, and software is readily available.
2. Ensure adequate human resources through a needs assessment of existing skills and training programmes to supplement staff capabilities. Liaising with local and regional educational institutions would contribute to this.
3. Consider developing a data lab that cuts across government ministries and departments for multi-sectoral analyses.
4. Focus on the ability to generate analytical results for different geographic units, including census units, administrative boundaries, catchment areas and climate exposed geographies, among others.
5. Explore the interests and needs of a range of potential users of the results, not only within government agencies, but also among academics, NGOs, local leaders and organizations representing key populations at risk, such as smallholder farmers and urban slum dwellers.

Conclusion

The rise of accessible geographic information systems, particularly as it coincides with the development of infrastructure for the 2010 round of censuses, has created an enormous opportunity to change the way governments, researchers and policymakers think about and address climate vulnerability. As argued in Chapter 1, the integration of population and socioeconomic data into climate response has the potential to shift perspectives of climate impact to include far more on the social environment.

Yet, as this chapter suggests, many steps are needed to make this transition happen, particularly by changing the ways that governments process and deliver population data. The presence of geo-referenced census data is not enough. These data must be processed from individual and household records to geographic building blocks, cleaned and then built into relevant larger geographies, whether in gridded form, by administrative boundaries or by the contours of climate geography. Such steps require resources, capacity, partnerships within and outside government and a clear understanding of the results that can be delivered. Is it worth it?

Climate impacts are already here and growing. Adaptation is without question essential to maintaining and improving livelihoods for those at risk, and, further, it is liable to be very expensive, though its costs will pay off in the long term by decreasing climate impacts on people, livelihoods and economic output (Parry et al., 2009). Census data are already collected and spatially referenced and include a wide range of relevant data that can be delivered in various ways to significantly improve understanding of the adaptive capacity that is linked to the geography of exposure. Further, more census data are on the way, every ten years for many countries—a time scale that seems long in social terms, but in climatic terms provides important and updated information at a pace not dissimilar from that of changes in the climate. Delivering census data in the way suggested in this chapter, and using it for vulnerability analysis as suggested in Chapter 4 and demonstrated in Section 3 of this book is a cost-effective approach for integrating relevant information, an approach that also happens to be irreplaceable. No other data set can provide this information, and many other methods of understanding and addressing climate vulnerability will benefit from it.

Notes

1. In addition, the global nature of climate change, and the way that it cuts across both national and subnational administrative boundaries, suggests that sharing information about vulnerability and adaptation should be done regionally and globally.

2. Over the past 50 years, the United Nations has contributed in significant ways to the successful implementation of national censuses. UNFPA has provided significant support to countries in undertaking censuses, mainly in the area of technical assistance. Today, most developing countries conducting a census receive some support from UNFPA. The United Nations Statistical Division has coordinated the development of principles and standards. These are important and fundamental standards to ensure the quality and consistency of data across time and place. Among the key documents produced, the most relevant for this chapter are the *Principles and Recommendations for Population and Housing Census: Revision 2* (United Nations, 2008), *the Handbook on Population and Housing Census Editing: Revision 1* (United Nations, 2010) and the *Handbook on Geospatial Infrastructure in Support of Census Activities* (United Nations, 2009).

3. The examples for Viet Nam were created with Veronique Marx of the UNFPA Viet Nam Field Office.

4. "The unit of area subdivided by grid mesh of about 1 km square is called standard grid-mesh and shows various statistical data. The Japanese Statistics Bureau, Ministry of Internal Affairs and Communications has been organizing the data of the Population Census and the Establishment and Enterprise Census into further subdivided 1/2 grid-square meshes measuring approx. 500m x 500m." Tokyo: Ministry of Internal Affairs and Communications. Website: www.stat.go.jp/english/data/mesh/index.htm, last accessed 31 October 2012.

References

Agrawal, A. 2010. "Local Institutions and Adaptation to Climate Change." Ch. 7 in: *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, edited by R. Mearns and A. Norton. 2010. Washington, D. C.: The World Bank.

Balk, D., et al. 2009. "Understanding the Impacts of Climate Change: Linking Satellite and Other Spatial Data with Population Data." Ch. 13 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and International Institute for Environment and Development (IIED).

Balk, D., et al. 2004. "A Spatial Analysis of Childhood Mortality in West Africa." Population, Space and Place 10: 175-216. Available at: http://onlinelibrary.wiley.com/doi/10.1002/psp.328/pdf.

Balk, D., and G. Yetman. 2004. "The Global Distribution of Population: Evaluating the Gains in Resolution Refinement." New York: Center for International Earth Science Information Network (CIESIN), Columbia University.

Balk, D., J. M. Guzmán, and D. Schensul. Forthcoming. "Using Census Data for Environment and Climate Change Analysis: An Introductory Guide." UNFPA Census Manual. New York: UNFPA.

Byravan, S., S. C. Rajan, and R. Rangarajan. 2010. *Sea Level Rise: Impact on major infrastructure, ecosystems and land along the Tamil Nadu Coast*. Madras, India: IMFR Research, Centre for Development Finance, Indian Institute of Technology, Madras.

Center for International Earth Science Information Network (CIESIN), Columbia University; International Food Policy Research Institute (IPFRI), the World Bank; and Centro Internacional de Agricultura Tropical (CIAT), 2004. Global Rural-Urban Mapping Project (GRUMP): Gridded Population of the World, version 3, with Urban Reallocation (GPW-UR). Palisades, NY: CIESIN, Columbia University. Available at: http://sedac.ciesin.columbia.edu/gpw.

Central Population and Housing Steering Committee (CPHSC). 2009. "The 2009 Viet Nam Population and Housing Census of 00.00 Hours 1st April 2009: Implementation and Preliminary Results." Ha Noi.

Chamie, M. 2005. "Country Reporting and Access: The Role of the United Nations Statistics Division: Paper presented at Censuses in the 21st Century: Improving Data Utilization and Dissemination." Paper presented at a Side Meeting of IUSSP XXV International Population Conference, Tours, France, 18-23 July 2005. Website: www.iussp.org/France2005/SideMeetingPapers/chamie.pdf, last accessed 16 November 2012.

Champion, A. G., and G. Hugo. 2004. *New Forms of Urbanization: Beyond the Urban-Rural Dichotomy*. Farnham, United Kingdom: Ashgate Publishing Ltd.

Crowell, M., et al. 2007. "How many people live in coastal areas?" Journal of Coastal Research 23(5): 3-6.

Elbers, C., J. O. Lanjouw, and P. Lanjouw. 2003. "Micro–level Estimation of Poverty and Inequality." Econometrica 71(1): 355-364.

Few, R. 2003. "Flooding, Vulnerability and Coping Strategies: Local Responses to a Global Threat." *Progress in Development Studies* 3(1): 43-58.

Guzmán, J. M., et al. (eds.) 2009. *Population Dynamics and Climate Change*. New York and London: UNFPA and IIED.

Lichter, M., et al. 2010. "Exploring Data-related Uncertainties in Analyses of Land Area and Population in the 'Low-Elevation Coastal Zone' (LECZ)." *Journal of Coastal Research* 27(4): 757-768.

McGranahan, G., D. Balk, and 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): 17-37.

Parry, M., et al. 2009. *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates*. London: Imperial College London, Grantham Institute for Climate Change and IIED.

Peters, A., and H. MacDonald. 2004. *Unlocking the Census with GIS*. Redlands: ESRI Press.

Small, C., and J. E. Cohen. 2004. "Continental Physiography, Climate and the Global Distribution of Human Population." *Current Anthropology* 45(2): 269-277.

United Nations. 2010. *The Handbook on Population and Housing Census Editing: Revision 1* (ST/ESA/STAT/SER.F/82/Rev.1). New York: Statistics Division, Department of Economic and Social Affairs, United Nations.

________. 2009. *Handbook on Geospatial Infrastructure in Support of Census Activities.* Studies in Methods. Series F, No. 103. New York: Statistics Division, Department of Economic and Social Affairs, United Nations.

________. 2008. *Principles and Recommendations for Population and Housing Censuses: Revision 2* (ST/ESA/STAT/SER.M/67/Rev.2). New York: Statistics Division, Department of Economic and Social Affairs, United Nations.

CHAPTER 6

Using Households Surveys in Climate Vulnerability and Adaptation Analysis

Landy Sanchez Peña and Regina Fuchs

Introduction

Although household surveys are a fundamental tool in contemporary demographic research, their use in research on population and climate change is still limited, particularly in the analysis of vulnerability and adaptation. Two main factors contribute to this: First, ready-made sociodemographic household surveys (versus custom-made surveys) often lack environmental variables or are difficult to link to other sources that provide environmental information. Second, household survey samples rarely provide the spatial resolution required by adaptation studies.

While these issues need to be addressed in future survey design, it is possible to increase the use of existing instruments in climate research. Because of their regularity and richness, household surveys can be used to characterize population vulnerability traits, as well as to examine behaviours relevant for environmental outcomes. Many countries have consistently collected living condition surveys for a long time, and instruments like the Demographic and Health Survey cover more than 80 countries across the developing world. Such temporal and geographical coverage can be used to better understand the dynamics underlying vulnerability to climate change, as well as variations in a population's adaptive capacity.

Focusing on Income and Expenditure Household Surveys (IEHS), this chapter shows that surveys provide useful potential indicators of vulnerability and adaptive capacity, even when information on exposure to and impacts of climate events is unavailable. The chapter first reviews potential contributions of household surveys within the vulnerability and adaption framework, relying on examples from IEHS conducted in Brazil, India, Indonesia and Mexico, to show their potential and limitations in accounting for different dimensions of vulnerability. In the second section, some methodological options to extend the geographical reach of surveys and how to incorporate hazard and impact information are discussed. Finally, the use of household surveys within Integrated Assessment Models (instruments used to build scenarios of predicted climate change) is considered, concluding that household surveys can contribute to mitigation and vulnerability efforts. This point is illustrated through the Population-Environment Technology (PET) model, an integrated assessment model that makes intensive use of household survey data.

Vulnerability and Household Surveys

Sociodemographic household data have historically been used in environmental research, but many studies often design their own surveys—for example, the Nang Rong, Thailand study (Rindfuss et al., 2003) and the longitudinal research in the Ecuadorian Amazon (Pan et al., 2007). Such surveys are largely designed because ready-made household surveys collected by National Statistics Offices (NSOs) do not usually provide enough information for environmental research. Large-scale data collections, such as National Demographic Surveys and Health or Living Standards Surveys, are not commonly used for climate change research. Although these sources often provide detailed demographic information, they do not contain directly collected data on emissions sources or on practices that could have a direct environmental impact. In addition, large surveys include only limited information on household exposure to climate events or on the consequences of climate change events on household welfare and behaviour.

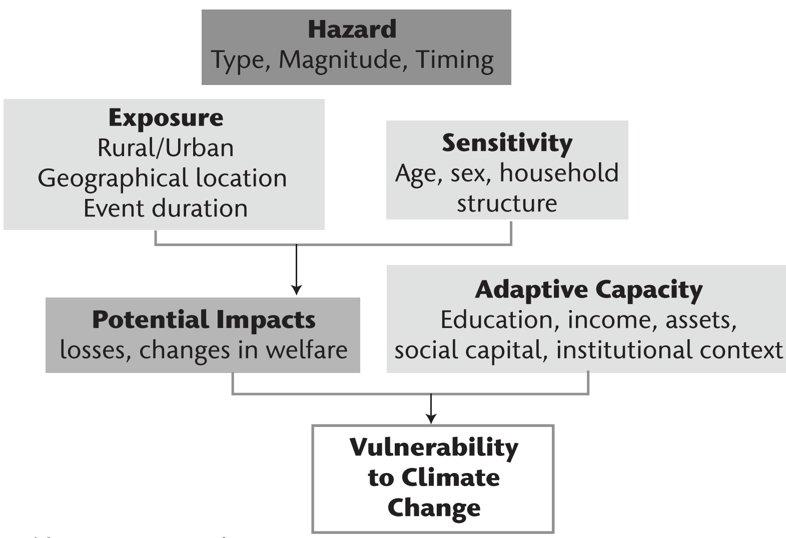
However, as current research shows, common national surveys do provide useful information that can be used to estimate individual and household behaviours that have an impact on emissions. For instance, national surveys can provide expenditure data to measure energy demand across household types (O'Neill and Chen, 2002; Dalton et al., 2008; Irongmonger et al., 2004; Lenzen et al., 2006; Pachauri, 2004). Some studies employ time-use and mobility data to model energy consumption patterns (Ewert and Prskawetz, 2002; Carlsson and Linden, 1999; Liddle, 2004; Pucher et al., 1998), and others use employment information to examine labour supply and its impacts on emissions (Pitcher, 2009). Such studies make a strong case for the household as a unit of analysis, rather than using only aggregated national statistics (Curran and de Sherbinin, 2004). They show that household size, family structure, place of residence, lifecycle stage and cohort membership can help explain consumption and mobility patterns, aside from providing data on well-known variables, such as income and social status. In addition, these studies point out the importance of using households as unit of analysis; they show that national or regional aggregates only provide a partial look to environmental trends, while analysing households informs about population behaviours, perceptions and decisions.

Ready-made household surveys are also used, although less frequently, to assess the vulnerability and adaptive capacities of subpopulations to climate change, but these efforts are limited in accounting for climate hazards and geographic variability and are restricted by a relatively coarse sample resolution. However, demographic surveys can be useful in accounting for certain components of population vulnerability. First, vulnerability to climate change differs largely across subpopulations with the direct impacts of climate change varying across locations. For instance, some regions will experience increased rainfall while others face prolonged droughts, and sea level rise will not be uniform along coastlines (see Adger, 2006; Fussel, 2007; O'Brien et al., 2007; Ionescu et al., 2009, Romero-Lankao and Qin, 2011). Household surveys can also be useful because climate change events can have different impacts depending on population characteristics. Heat waves, for example, impact the elderly more than the young, while dwelling conditions—depending on the socioeconomic status of the household, rather than on core demographic characteristics—determine the severity of impacts from natural hazards. Household surveys provide a rich description of population attributes, but their data need to be linked to climate hazards in order to determine whether and how such characteristics matter for vulnerability and adaptation.

Furthermore, household surveys provide information about subpopulations and their capacity to prepare for (and respond to) climate change impacts. Some households invest in new irrigation systems when faced with lower rainfall levels, while others may lack the financial resources or expertise to do so. Surveys provide information on household human capital and labour market experience, as well as other resources such as assets, ownership status and social capital. More important, several household surveys provide information on the institutional and economic context in which households are embedded; such contexts shape their vulnerability, including their adaptive capacity (O'Brien et al., 2007; Eakin, 2005). For example, researchers found that rural farmers' responses to climate variability are shaped not only by economic and social capital, but also by government programmes and community organization. When facing a negative climate event, some households may face "a double exposure" if they lack state or community support (Eakin, 2005).

Drawing on the work of Ionescou et al. (2009), Figure 6.1 outlines the strengths and limitations of household survey data by showing the types of variables demographic surveys often include. The indicators in each box are meant to be suggestive, but not comprehensive, of vulnerability components. The dark gray boxes represent areas where household surveys have the greatest limitations, while the light gray boxes depict areas of strength.

Figure 6.1: Household Surveys and Vulnerability Analysis



Source: Adapted from Ionescou et al., 2009.

The figure shows that household surveys contain limited or no information on climate stressors, but this is a limitation that can be overcome without excessive cost. Household surveys do not usually provide information on exposure to hazards, but geographical indicators—such as place of residence or population density—can be indirect approximations of exposure, even though they lack information on the duration or location (indoors versus outdoors) of exposure. Household surveys also provide indirect measures of household vulnerability through collection of data on age, sex and household structure. Living-standard surveys also include a full set of household welfare variables that can potentially be used as hazard impact indicators. Moreover, since these surveys provide information on the overall economic and social conditions of households, it is possible to determine whether environmental causes are the main drivers of household welfare. Finally, household surveys often provide information on education, income, assets and social capital, common indicators of knowledge and risk awareness, and adaptive capacity (Girard and Peacock, 1997).

Confidentiality and geographical constraints

As mentioned, two central limitations of household surveys are: a) inadequate information on hazards and impacts and b) their geographical reach. Instruments are needed that are specifically designed to measure vulnerability to address these issues fully; however, it is also possible to improve existing surveys by including a battery of additional questions and increasing sample size. An option to overcome the first limitation is to include a set of questions asking about the occurrence of climate events and their impacts in a given period. For example, a question could be formulated to ascertain whether the household suffered from a natural disaster in the last year, its month of occurrence and the economic or personal consequences for the household, such as economic hardship and infant deaths, among others. Interviewers could also ask for a comparison of this season's rainfall to that of previous years. Regarding detailed information on hazards, questions can only collect information on short-term weather perception. It is well-documented that recollection issues emerge as the period of reference becomes longer; therefore, surveys need to decide upon time intervals carefully, preferably not going back farther than five years (Bandyopadhyay et al., 2011). In addition, studies have documented the fact that respondents tend to recollect extreme weather more vividly and often overstate their relevance on changes over time (Maddison, 2007). This finding highlights the need for confirming self-reported weather data with other sources. On the other hand, information on household members' perceptions is by itself informative; for example, anticipating a drought based on their perception of previous years, people may decide to migrate, regardless of actual rainfall levels.

In fact, one complementary option for obtaining hazard information is to match household surveys to weather and/or biophysical data from external sources such as weather stations, remote sensing images or small-area climate projections. Studies that used household surveys coupled to biophysical information show the potential gains in understanding how populations are vulnerable to health risks (Hunter et al., 2010; Stevens et al., 2008), extreme-weather shocks (Pörtner, 2010; Frankenberg et al., 2009) or long-term processes like desertification (Baschieri, 2009) and agricultural changes (Nassolo, 2010), as well as how households are adapting to those emerging conditions (Baschieri, 2009). For this type of application, issues of confidentiality have to be resolved, since it would require identifying household locations at a finer scale–i.e., often point location. For this task, the work of national statistics offices could be crucial: They could either match a number of environmental variables to the surveys or generate a geographical identification code at a small scale, allowing researchers to apply for access to restricted data.

The second serious limitation of household surveys is that of small sample sizes which do not allow estimates at the local level. Climate change will have unevenly distributed effects across the globe, and it is necessary to address such geographical variation. Survey samples are usually small and not statistically representative at disaggregated levels, which limit their potential for vulnerability and adaptation analyses, especially when estimates for subpopulations and small areas are required. For example, the Income and Expenditure surveys conducted in Latin America between 2000 and 2008 showed that, of the 22 samples, almost all were representative of rural and urban populations; however, only 13 surveys provided estimates at a lower geographical level (state, metropolitan areas or regional levels). It is interesting to note, however, that many of these national surveys have increased their representativeness over the last decade, addressing public policy needs (Organisation for Economic Co-operation and Development [OECD], 2008). In addition, local states can request oversampling to produce accurate estimations of their regions. Even so, state or regional levels can still be at too high of an aggregation level for some vulnerability studies, while for others they may be sufficient. For example, while vulnerability to sea level rise requires small-scale studies, estimates about households that could be affected by changes in crop production, which can be useful for planning local government budgets, do not require such small-scale studies.

In recent years, there have been new developments in statistical methods for small-area estimations using survey data. These methods require merging household-level data with census and/or remote sensing data which enhance the reliability of small samples and improve their employability in climate change research (Setiadi et al., 2010; Lanjouw, 2004; Elbers et al., 2002; Ghosh and Rao, 1994). One of these developments is the "poverty map" which is well-known by governments and academia alike. This map matches basic dwelling and household demographic information from census data to living-standards information from household surveys in order to produce poverty estimations at a scale that would not be available otherwise. More specifically, the method models consumption or expenditures using a set of predictors common to both sources through regression estimates at the lowest geographical level at which a sample survey is representative. Then, the coefficients from these regressions are used to estimate the expenditures or consumption of every household in the census (Lanjouw, 2004; Elbers et al., 2002; Ghosh and Rao, 1994). The assumption is that the relationship identified in the sample from household surveys holds for the entire population (Davis, 2003). Although there are some concerns regarding the reliability of the estimates thus obtained,[1] this method is still useful when the main goal is to increase the precision of estimating populations at risk, rather than simply evaluating the underlying causes of a given phenomenon (Davis, 2003; Elbers et al., 2002). As such, this method could be useful in improving estimates of vulnerable populations, changes in livelihoods, health risks, etc.

Building upon a similar logic, Setiadi et al. (2010) suggest joining household information with census and remote sensing data to produce estimates of populations vulnerable to extreme weather events. The authors matched sociodemographic and daily activity records from a household survey to census data and then established a correlation with the physical environment inhabited by households in Panag, Indonesia. They were then able to extrapolate the sociodemographic characteristics of those residents to other areas and established degrees of vulnerability based on population traits, infrastructure and residential buildings (see also: Taubenböck et al., 2007; Khomarudin et al., 2008). A similar strategy can be implemented to increase the geographical resolution of household data and incorporate biophysical information. Methods are thus available to improve household survey data in terms of providing better estimates of vulnerable population groups, as well as for understanding their spatial and temporal variations.

Potential Uses of Household Surveys for Vulnerability and Adaptation Analysis

Income and Expenditure Household Surveys (IEHS) are a valuable tool for assessing household welfare and consumption patterns, as well as for understanding the impact of social and economic policies on households. While studies on energy consumption or household livelihoods regularly employ these surveys, climate research does not make use of the data available. This section illustrates how IEHS data can be used to assess vulnerability across population subgroups. Studies show that socioeconomic status and household demographics mediate risks, vulnerability and adaptation to climate change (Girard and Peacock, 1997). Income and Expenditure Surveys provide information about household sociodemographics, resources and several dimensions of exposure. To demonstrate their potential, an analysis of household surveys from Brazil, India, Indonesia and Mexico is employed.[2] All surveys provide a detailed characterization of household structure, living arrangements and age composition, as well as housing, education and income—variables shown to be relevant in environmental research (de Sherbinin et al., 2007; O'Neill and Chen, 2002, Jiang and Hardee, 2009). For example, the elderly and young children are particularly at risk during extreme-weather events, while educational and earnings levels mediate households' responses to climate variability (Peacock and Girard, 1997).

The impact of demography on income patterns

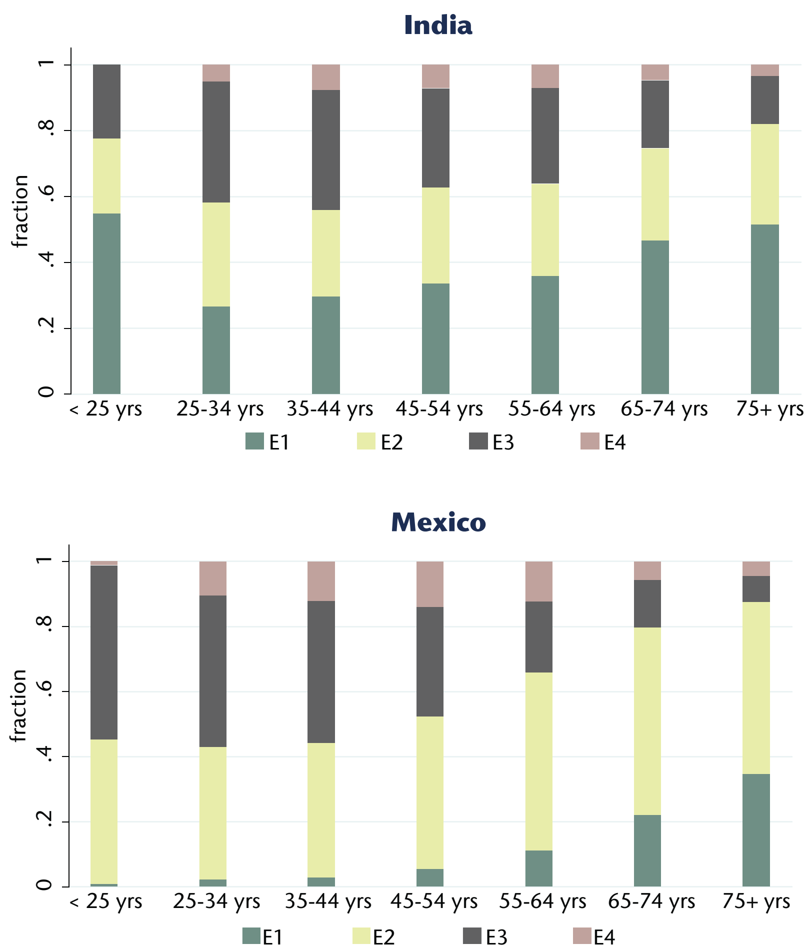
Diverse studies highlight the fact that vulnerability increases when households income sources are exposed to hazards and that income-source diversification is a common strategy to minimize risk, particularly in rural settings (Eakin, 2005). IEHS are particularly well equipped to describe income dependencies and, therefore, vulnerabilities, since they collect extensive information on income sources and the amounts each member contributes to total household income. Based on this data, it can be shown that the type of income dependency varies considerably over the life cycle. While this is a less explored topic, it is equally relevant for identifying populations at risk. Thus, when assessing vulnerability particular attention should be devoted to the elderly. It is not only necessary to consider their share of the population, but also their status and income structure in order to understand the degree of vulnerability.

In addition to a straightforward assessment of income structures, IEHS allow further disaggregation of populations by characteristics influencing labour income, such as education. Populations in all four countries studied experienced a substantial change in their educational attainment within the last decades (Lutz et al., 2007), thereby influencing employment and income. Today's older population shows a different pattern of education than the future aged population will have. Figure 6.2 compares the educational levels of populations in India and Mexico. E1 denotes no education, E2 some primary to some lower secondary education, E3 completed lower secondary to some tertiary education and E4 labels a completed tertiary degree.

Both countries experienced a substantial increase in educational attainment in all ages, and it is especially noticeable for younger cohorts in Mexico that there are almost no household heads without formal education. Assuming that education exerts an impact on earnings potential, and thus on income structure, this information, together with data on consumption expenditures, could be used to identify populations that are particularly vulnerable to extreme events.

Figure 6.3 shows the results from combining educational attainment with disaggregated information on labour and asset income. A steep increase of labour income by education can be observed in both India and Mexico, confirming a positive association between education and earnings potential. Asset income is low for younger cohorts, but increases with education. A noteworthy finding is that dependence on labour income,

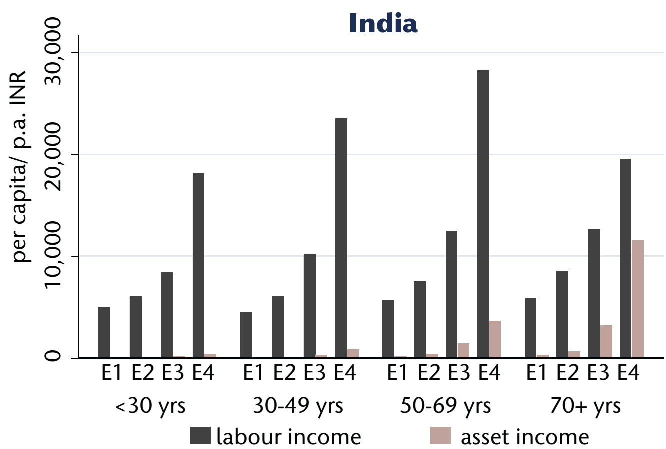
Figure 6.2: Education Distribution by Age in India and Mexico

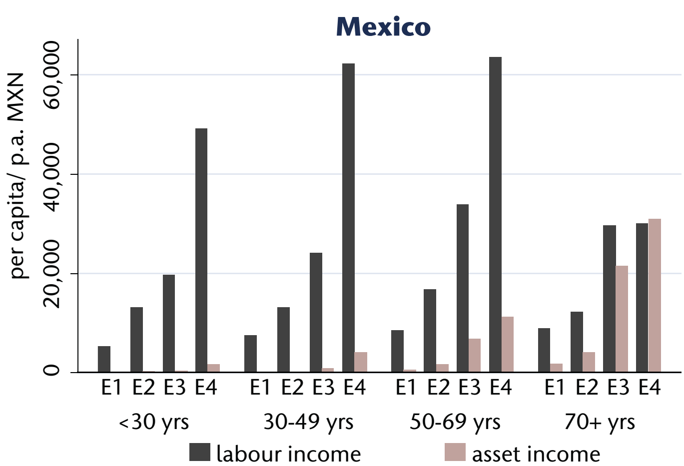


relative to asset income, is higher for the oldest age group in India than in Mexico. The combined effect of a larger educated population and a lower dependency on labour income in old age in Mexico may reduce the risk of being affected by climate-induced events because of increasing human capital and assets in older ages.

Surveys show that household characteristics markedly influence livelihoods and consumption behaviour. Changing educational composition or lifestyles can have an impact on cohort behaviours. Coherent conclusions as to the preferences of future populations can only be made from a longitudinal perspective focused on underlying population dynamics. Several countries perform longitudinal living standard surveys that can be used in vulnerability analysis, and it is also possible to reconstruct time series based on repeated cross-sectional data. For example, over the past decades, Mexico and Indonesia, and, to some extent, India and Brazil, collected several waves of data from expenditure and consumption surveys. Such series have vast potential for assessing vulnerability dynamics and making credible assumptions about future populations at risk.

Figure 6.3: Labour and Asset Income by Age and Education in India and Mexico





Living standards and livelihoods

Household surveys also provide detailed information on living standards and livelihoods that would be expensive to collect otherwise. Table 6.1 shows questions frequently asked in income and expenditure surveys and their relationship to vulnerability components. Housing conditions are indicative of family wealth, but dwelling age or construction materials could also be used as indicators of sensitivity to climate events, and housing structural conditions (e.g., wet foundations) could measure greater risk. IEHS often include information on surrounding infrastructure, a key variable of labour- market accessibility, and also an indicator of access to emergency relief systems and to mass media. This basic example shows the complex interaction between a variety of vulnerability dimensions. While the four surveys include general information on housing conditions, only the Brazilian survey considers access to roads. All but the Indian survey provide information on home ownership, but no survey gives detailed information on insurance. This is of interest in determining vulnerability to extreme events, and surveys could incorporate questions that provide richer information in this respect.

Sanitation, energy and water supply are broadly covered in household surveys, but detailed information on land that is owned and cultivated by a household—central to a better picture of livelihoods in rural areas—is only available in the Indian survey. Still, assessments on livelihoods could be obtained by analysing income and expenditure data. Detailed information on income is available for different sources (labour, assets, non-monetary, business, agricultural or self-employed income and private and government transfers, etc.). Such data allow vulnerable subpopulations to be identified through an analysis of their expenditures (e.g., spending on food) or dependencies on certain income sources (e.g., agricultural income or public transfers). Information on agricultural income helps identify populations vulnerable to changes in the quality of land or rainfall, while public transfer dependency reveals populations affected by poverty. Moreover, some of these surveys provide information on non-monetary income, a relevant source in rural settings since it takes into account self-production. Unfortunately, not all household surveys include the same detail on income sources: Government transfer data are limited in the Indian and Indonesian surveys, and a complete set of non-monetary incomes and transfers is available only in the Mexican and Brazilian surveys (Zigová et al., 2009). All the surveys offer limited information on savings, which could also help buffer losses of income after extreme events.

By connecting information on wealth and earnings potential from household surveys with remote sensing data or other sources examining the built environment, it would be possible to better understand the resources upon which households ordinarily depend, both at home and in the community. For example, it is possible to obtain information on irrigation systems, accessibility to health services or food markets. In addition, stratifying this information by demographic characteristics would allow the identification of subpopulations that are particularly vulnerable to certain types of shocks or changing climate conditions. Remotely sensed imagery, assessed at different points in time, coupled with longitudinal household information can provide valuable insights into changing living conditions. However, the potentials of linking individual-level data with remotely sensed geophysical data, land coverage and administrative records is still in the early stage of development and should be fostered to improve the usability of household survey records.

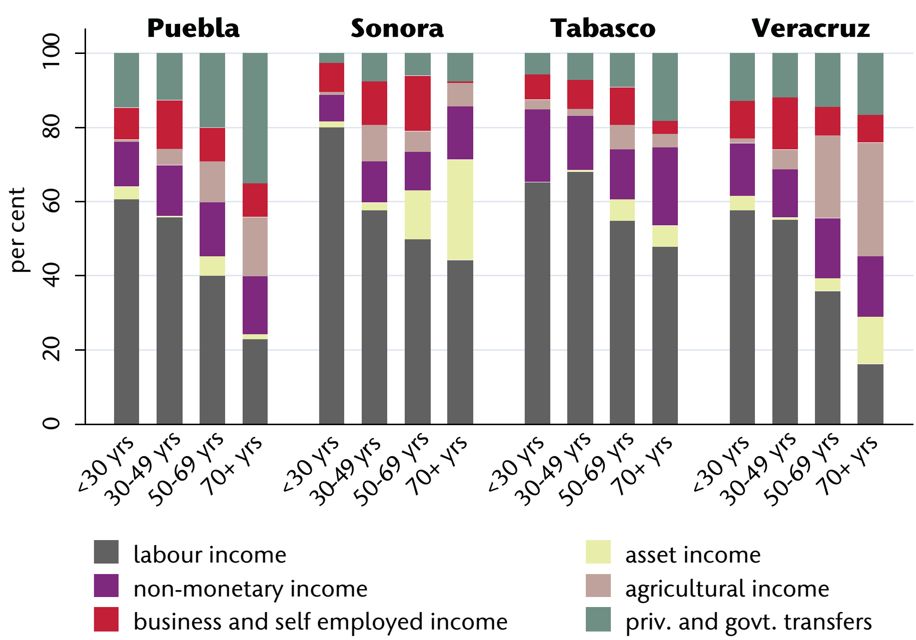
Table 6.1: Common Variables in IEHS and Their Relationship to Vulnerability

	Vulnerability Dimensions			
Variables	Wealth/Assets	Livelihoods	Health	Infrastructure
Housing				
Materials	X		X	X
Age	X		X	X
Type of house	X			
Road connectivity		X		X
Water accessibility				
Type of access (private, shared)	X	X	X	X
Type of supply (lake, ditch, direct connection)	X		X	X
Quality of supply (quantity, frequency)		X		
Electricity access				
Type of supply (public, private, self generated)	X	X	X	X
Quality of supply (quantity, frequency)	X	X	X	
Sanitation				
Type of facility (public, private)			X	X
Sewage connection (pond, river, open air)			X	X
Home Ownership				
Type of ownership	X			
Insurance coverage	X			
Access to Mass Media & Communication				
TV/Radio	X			X
Communication (mobile phone, internet)	X			X
Accessibility (network coverage, antenna)				X
Income & Employment				
Income sources	X	X		
Type of employment		X		
Employment industry		X		
Crops and livestock shares		X		

Surveys can also provide information on livelihood changes following extreme events. For example, the Mexican data allow for the modeling of earnings sources in rural areas, as well as investments in agricultural production. Assessing crop shares allows for the identification of groups of households that may be facing greater challenges due to climate change, both in terms of their agricultural production as well as income reliability. Expenditure surveys and time series can be used to project household income and consumption vulnerabilities for small scales. The same can be done with diet composition and food security, since surveys provide estimates of detailed food expenditures, as well as self-production (for a review of food security and vulnerability, see: Hunter, et al., 2008).

Household surveys can help identify populations that are particularly vulnerable to any changes in agricultural land structure that will affect their dependency on self-production and agricultural income. Figure 6.4 shows the income structure of Mexican households in four different states in rural areas.[3] Households are disaggregated into four different age groups and six income categories. Unlike many other surveys, Mexico's collects detailed information on non-monetary income and expenditures, which make up a sizeable share of total consumption in less developed regions (see purple area). The figure displays a wide variation in terms of dependency on agriculture as well as the magnitude of transfers and the share of labour and asset income within and across regions. Sonora, a rather developed state, shows a substantially higher dependency on asset income for older ages than other states. Labour income decreases in proportion to age in all regions, although it varies across regions. Unfortunately, not all surveys provide such regionally representative samples; Figure 6.4 suggests that even if increasing the sample size is expensive, it is worthwhile to do so as it increases survey usefulness.

Figure 6.4: Income Structure in Mexican Rural Households by State



Employing Household Survey Data within the Integrated Assessment Modeling Framework

While the previous section shows the potentialities and limitations of household surveys for climate change research, this section demonstrates the usefulness of household surveys in understanding the link between mitigation and vulnerability within the framework of integrated assessment models (IAMs), in particular the PET (Population-Environment-Technology) model. Integrated assessment models try to capture interactions between human system variables—population, technology, economic growth and land use—and the environmental processes that impact climate change. They are typically used to describe emissions scenarios, estimate the potential impact of different socioeconomic paths, including public policies, on those emissions and evaluate the costs of different mitigation alternatives (Moss et al., 2010; O'Neill and Nakicenovic, 2008).

Although IAMs are more commonly used in mitigation than in vulnerability efforts, recent developments are expanding their application to the latter. In the research community, there is an ongoing effort to develop a new framework for the creation and use of scenarios in climate change assessment. One key piece is the identification of shared socioeconomic pathways (SSPs) that can be useful for mitigation, vulnerability and adaptation endeavours (O'Neill et al., 2011). These pathways qualitatively describe assumptions about future development trajectories and provide quantitative information on their drivers – elements such as population dynamics, economic development, technology, lifestyles, human development, policy and institutions. SSPs try to identify the socioeconomic factors that make mitigation targets harder to achieve and the elements that pose challenges to adaptation (Arnell and Kram, 2011).

SSP components are broadly defined, but they need to be narrowed to provide enough information to allow integrated assessment models that produce meaningful scenarios associated with each component (O'Neill et al., 2010, p. 6). While the proposed SSPs promise to better describe the uncertainties surrounding climate change, they suggest that more detailed information would be needed to fit the integrated assessment models. The demographic and social variables included in household surveys allows IAMs to capture the socioeconomic population traits that point to greater emissions levels, as well as factors that lead to increasing exposure and those elements that challenge adaptation. Certainly, household surveys would be only one among other sources needed, but improving their longitudinal and spatial coverage could increase their applicability in this field in regard to population characterization. The PET model illustrates this potential and is a further development in IAMs.

Strengths of the PET model

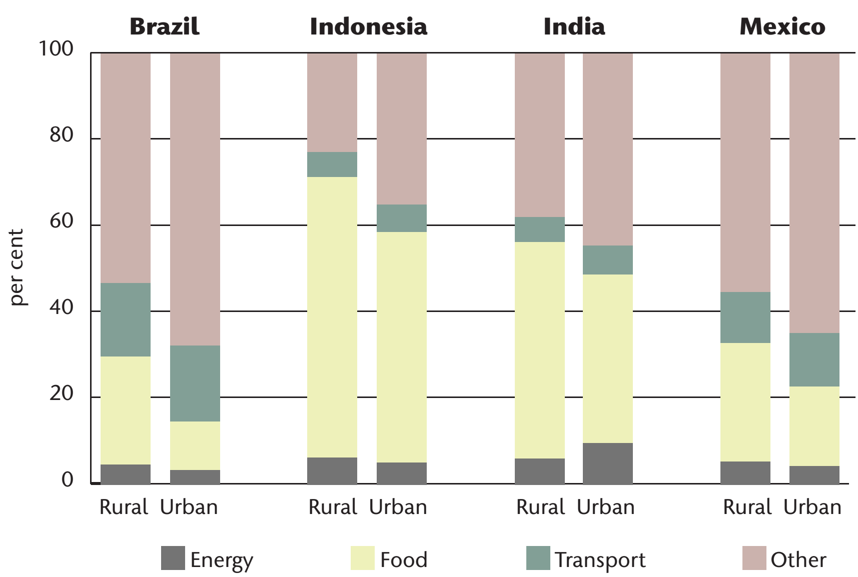
The PET model is an inter-temporal economic growth model. One of its strength is in capturing the direct and indirect effects of population dynamics through the production and consumption of energy goods (O'Neill et al., 2010; Dalton et al., 2008).[4] Most IAMs incorporate only population growth in accounting for demographic dynamics, although studies suggest that population processes and their implications on human livelihoods may also have an impact on energy demand, economic growth and land use (see: de

Sherbinin, 2006; O'Neill et al., 2010). In contrast to other IAMs, the PET model considers the impacts of a broader set of demographics, namely, household size, age structure and urbanization.

The PET model accounts for population changes based on household projections. These projections derive the baseline population structure from household surveys to generate headship[5] rates for the geographical region and category of interest (Jiang and O'Neill, 2009). As a forward-looking model, household projections are central to representing how expected changes in demographic characteristics will alter the levels of emissions. In addition, IEHS also improve scenarios by providing per capita consumption and labour income for each household type, which are then applied to the projected population composition by household type over the next 100 years. That is, in the PET model household surveys provide not only the information to model population structure, but also data to estimate the parameters that link subpopulations to consumption and production and, in turn, emissions (Zigová et al., 2009, p. 3). In this model, households are the primary unit of analysis: They provide labour and capital to producers and demand consumption and investment goods (Zigová et al., 2009; Dalton et al., 2008).[6]

Previous paragraphs suggest that estimates of household preferences and budgetary constraints from survey data can provide a convenient representation of regional and compositional effects. In fact, differences in consumption and demographic structures across and within countries are large. Figure 6.5 gives an example of households' varying consumption patterns across regions and rural/urban residence. Rural households have consumption patterns distinct from their urban counterparts. Less developed regions in Asia spend a higher share of total income on food than Latin American households. The PET

Figure 6.5: Variation in Budget Shares across Regions and Rural/Urban Residence



model accounts for such differences, since consumption and expenditure are disaggregated into 16 age groups, 3 household sizes and urban/rural residence—differences that shape consumption and labour supply (through income) and, ultimately, the level of emissions. Household survey data can provide information on indicators that shape the vulnerability (e.g., socioeconomic status, place of residence, human capital) of the projected population in order to develop alternative scenarios and answer questions such as how different development pathways would alter future vulnerability—i.e., who is likely to be more affected by climate events, and how adaptive capacity could unfold depending on whether mitigation targets are achieved. For instance, would poor urban households be disproportionately impacted by food-price increases in a world with no mitigation policy? Would vulnerability of the elderly increase with rapid urbanization? Could crop diversification increase rural household adaptation capacity in the face of slow technological change?

The current developments in IAMs offer additional areas of opportunity for household surveys. Time series of household surveys could be used to improve inter-temporal substitution parameters. It seems unrealistic to assume that income, consumption or even production levels will remain stable over time. Changes might be triggered by economic development, price changes, period effects (technological innovation or shocks) or changing preferences along cohort lines. By explicitly considering these issues, assessing longitudinal information from household surveys holds vast potential for climate change research.

A common criticism of IAM models is their global scale, particularly problematic for vulnerability and adaptation research (Moss et al., 2010; van Vuuren, 2010). Most models provide a dozen regional scenarios and look to capture variations in the driving forces of emissions. Data limitations and computational and estimation problems prevent simple increases in the number of units in these models (e.g., country, subnational zones, small areas) (for examples see: Asadoorian, 2005; van Vuuren et al., 2010). Moreover, vulnerability and adaptation analysis often requires an even smaller resolution. A spatial downscaling procedure can be applied to respond to this need: "[A] process where information at a large spatial scale is translated to smaller scales while maintaining consistency with the original dataset" (van Vuueren et al., 2010, p. 393). There are several methodologies, depending on the information, scale and resolution desired, as well as on the purpose of the downscaling, but all of them face the challenge of producing consistent estimates for smaller scales, as well as plausible assessments of changes over time (Grübler et al., 2007). Therefore, downscaling requires not a set of arithmetic rules, but a model that makes consistent estimations of global results on a fine scale. For this application, it is often necessary to apply supplementary data that permit linking both levels based on demographic or economic characteristics (see: Pitcher 2009)—a task in which household data can play, again, an important role.

Conclusion

Ready-made household surveys are relevant for addressing a broad set of questions that seek to understand the drivers and implications of climate change. Their geographical and temporal coverage make them a valuable instrument for examining issues related to mitigation, as well as vulnerability and adaption efforts. The strength of household surveys resides in their capacity to provide a better account of the population dynamics that underlie both emissions and vulnerability to climate change. The examples from Income and Expenditure Household Surveys presented above indicate that demographic variables could be used along with data on income sources, housing, human capital and consumption in order to grasp who may be more vulnerable, the resources they have to adapt and how different dimensions of vulnerability interconnect. Data availability, however, differs markedly across countries and years, limiting household survey use for climate research. A careful look at questionnaires is needed to understand their usefulness in each country and for comparative analysis.

In addition, there is a need to intensify efforts to expand climate information in household surveys. National statistical offices can play a central role in achieving this. On the one hand, a new set of questions can be added to surveys regarding climate variables and impacts on household welfare. On the other, household surveys could be linked to other environmental data sources, such as remote sensing imagery and weather stations. Together with the research community and government agencies, national statistical offices could define the questions to be included in the surveys, as well as coordinate efforts in order to solve the confidentiality and comparability challenges the task poses. Similarly, new statistical methods can expand the contribution of household surveys for small area estimation, especially if they are combined with other sources such as census data.

Within the context of Integrated Assessment Modeling, especially the PET model, household survey data help to refine the model's parameters by taking household composition, expenditure preferences and labour supply into account. Data from the household surveys and results from the PET model suggest that population processes such as ageing, urbanization and fertility declines will most likely have an impact on emission levels as well as on population vulnerability and the capacity to adapt to climatic events. There is still a lot of potential for integrating household survey inputs into IAMs, particularly considering the proposed new socioeconomic pathways useful for both mitigation and vulnerability efforts. Identifying the demographic dynamics common to both sides of climate change analyses, mitigation and adaptation, appears to be a significant need, and household surveys can provide sufficient indicators across multiple countries and dimensions.

Notes

1. The literature suggests that estimate reliability depends on sample size, common variables between both sources and the scale at which the estimation is made.
2. Brazil: Pesquisa de orçamentos familiares (POF) 2002-2003. Indonesia: Survei Sosial Ekonomi Nasional (SUSENAS), 2002. India: The Indian Human Development Survey (IDHS), 2005. Mexico: Encuesta de Ingresos y Gastos de los Hogares (ENIGH), 2005.
3. Each round of the Mexican income and expenditure survey (ENIGH) oversamples a set of regions to provide regionally representative estimates on the information collected.
4. Assumptions and calibration procedures of the model are quite complex. The focus here is on how household survey data are used in the PET model. For a full description, see: Dalton et al., 2008; Fuchs et al., 2009; Zigová et al., 2009; and O'Neill et al., 2010.
5. Headship rates are defined as the proportion of household heads, as share of the total population within the respective population sub-group. Further details can be found in Jiang and O'Neill (2009).

6. Given a budget constraint, households maximize their inter-temporal utility, which is obtained from the sum of labour and capital income. Household surveys allow for the calculation of a household's preferences using current consumption shares across goods, and are employed to parameterize the labour supply that is estimated from total household labour income (Zigová et al., 2009; Dalton et al., 2008).

References

Adger, W. N. 2006. "Vulnerability." *Global Environmental Change* 16(3): 268–281.

Asadoorian, M. O. 2005. "Simulating the Spatial Distribution of Population and Emissions to 2100." Joint Program on the Science and Policy of Global Change. Report No. 23. Cambridge, MA: Massachusetts Institute of Technology.

Arnell, N., and T. Kram (coordinating lead authors). 2011. "A Framework for a New Generation of Socioeconomic Scenarios for Climate Change Impact, Adaptation, Vulnerability, and Mitigation Research." Paper presented at the workshop on the Nature and Use of New Socioeconomic Pathways for Climate Change Research, Boulder, Colorado, 2-4 November 2011, Integrated Science Program, National Center for Atmospheric Research (NCAR), Mesa Laboratory. Website: www.isp.ucar.edu/socio-economic-pathways, accessed 7August 7 2012.

Bandyopadhyay, S., L. Wang, and M. Wijnen. 2011. *Improving Household Survey Instruments for Understanding Agricultural Household Adaptation to Climate Change: Water Stress and Variability*. Living Standards Measurement Study: Integrated Surveys on Agriculture. Washington, D. C.: The World Bank.

Barber, J. 2003. "Production, Consumption and the World Summit on Sustainable Development." *Environment, Development and Sustainability* 5(1-2): 63-93.

Baschieri, A. 2009. "Poverty And Vulnerability: A Static vs Dynamic Assessment of a Population Subjected to Climate Change Shock in Sub-Saharan Africa." Paper presented at the 26th IUSSP Population Conference, Marrakech, Morrocco, 27 September-2 October 2009.

Blaikie, P., et al. 1994. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. London: Routledge.

Bosello, F., and J. Zhang. 2005. "Assessing Climate Change Impacts: Agriculture." FEEM Working Paper. No. 94.05. CMCC Research Paper. No. 02. Rochester, NY: Social Science Research Network. Website: http://ssrn.com/abstract=771245, accessed 4 October 2012.

Carlsson-Kanyama, A., and A. Linden. 1999. "Travel Patterns and Environmental Effects Now and in the Future: Implications of Differences in Energy Consumption among Socioeconomic Groups." *Ecological Economics* 30(3): 405-417.

Chan, N. W. 1995. "Choice and Constraints in Floodplain Occupation: The Influence of Structural Factors on Residential Location in Peninsular Malaysia." *Disaster* 19(4): 287–307.

Cramer, J. 1998. "Population Growth and Air Quality in California." *Demography* 35(1): 45-56.

Curran, S., and A, de Sherbinin. 2004. "Completing the Picture: The Challenges of Bringing 'Consumption' into the Population-Environment Equation." *Population and Environment* 26(2): 107-131.

Dalton, M., B. O. O'Neill, and K. Zigová. 2008. "Effects of Household Age and Size on the Elasticity of Energy Consumption." Paper presented at the 31st International Association for Energy Economics Conference, Istanbul, Turkey, 18-20 June 2008. Laxenburg, Austria: International Institute for Applied Systems Analysis (IIASA).

Davis, B. 2003. *Choosing a Method for Poverty Mapping*. Rome: Food and Agriculture Organization of the United Nations.

de Sherbinin, A. 2006. "Rural Household Micro-Demographics, Livelihoods and the Environment." Population-Environment Research Network Cyberseminar, 10-24 April 2006. Website: www.populationenvironmentresearch.org/hh-pop-livelihoods-env2.pdf, accessed 4 October 2012.

de Sherbinin, A., et al. 2007. "Population and Environment." *Annual Review of Environment and Resources* 32: 345-347.

Eakin, H. 2005. "Institutional Change, Climate Risk, and Rural Vulnerability: Cases from Central Mexico." *World Development* 33(11): 1923-1938.

Elbers, C., J. O. Lanjouw, and P. Lanjouw. 2002. "Micro-Level Estimation of Welfare." Research Working Paper. No. 2911. Washington, D. C.: Development Research Group, The World Bank.

Entwisle, B., et al. 1998. "Land Use/Land-Cover and Population Dynamics, Nang Rong, Thailand." Pp. 121-144 in: *People and Pixels: Linking Remote Sensing and Social Science*, edited by D. Liverman, et al. 1998. Washington, D. C: National Academy Press.

Ewert, U. C., and A. Prskawetz . 2002. "Can Regional Variations in Demographic Structure Explain Regional Differences in Car Use: A Case Study in Austria." *Population and Environment* 23(3): 315-345.

Ezra, M., and G.-E. Kiros. 2001. "Rural Out-migration in the Drought Prone Areas of Ethiopia: A Multilevel Analysis." *International Migration Review* 35(3): 749–771.

Fischer, G., et al .2005. "Socio-economic and Climate Change Impacts on Agriculture: An Integrated Assessment, 1990-2080." *Philosophical Transactions of the Royal Society B* 360(1453): 2067-2083.

Frankenberg, E., et al. 2009. "Economic Consequences of the 2004 Tsunami for Households and Individuals in Indonesia." Paper presented at the 2009 Annual Meeting of the Population Association of America, Detroit, Michigan, 30 April-2 May 2009.

Fuchs, R., S. Pachauri, and B. O'Neill. 2009. *Production Data for the Population-Environment-Technology (PET) Model.* IIASA Interim Report. No. IR-09-025. Laxenburg, Austria: IIASA.

Fussel, H. M. 2007. "Adaptation Planning For Climate Change: Concepts, Assessment Approaches, and Key Lessons." *Sustainability Sciences* 2(2): 265–275.

Gaffin, S. R., et al. 2004. "Downscaling and Geo-spatial Gridding of Socio-economic Projections from the IPCC Special Report on Emissions Scenarios (SRES)." *Global Environmental Change* 14(2): 105–123.

Ghosh, M., and J. N. K. Rao. 1994. "Small Area Estimation: An Appraisal." *Statistical Science* 9(1): 55-93.

Gilland, B. 1995. "World Population, Economic Growth, and Energy Demand, 1990-2100: A Review of Projections." *Population and Development Review* 21(3): 507-539.

Girard, C., and W. G. Peacock. 1997. "Ethnicity and Segregation: Post-hurricane Relocation." Ch. 10 in: *Hurricane Andrew: Ethnicity, Gender and the Sociology of Disasters*, edited by W. G. Peacock, B. H. Morrow, and H. Gladwin. 1997. New York: Routledge.

Gram-Hanssen, K. 2004. "Domestic Electricity Consumption: Consumers and Appliances." Ch. 7 in: *The Ecological Economics of Consumption*, first edition, edited by L. Reisch and I. Ropke. 2004. Northampton, MA: Edward Elgar Publisher.

Greening, L., and T. Jeng. 1994. "Lifecycle Analysis of Gasoline Expenditure Patterns." *Energy Economics* 16(3): 217-228.

Grübler A., et al. 2007. "Regional, National, and Spatially Explicit Scenarios of Demographic and Economic Change Based on SRES." *Technological Forecasting and Social Change* 74(7): 980–1029.

Guertin, C., S. K. Kumbhakar, and A. Duraiappah. 2003. *Determining Demand for Energy Services: Investigating Income-driven Behaviours*. Winnipeg, Canada: International Institute for Sustainable Development.

Hentschel, J., et al. 2000. "Combining Census and Survey Data to Study Spatial Dimensions of Poverty and Inequality: A Case Study of Ecuador." *The World Bank Economic Review* 14(1): 147-165.

Hunter, L., R. De Souza, and W. Twine. 2008. "The Environmental Dimensions of the HIV/AIDS Pandemic: A Call for Scholarship and Evidence-Based Interventions." Guest Editor Introduction to Special Issue on "HIV/AIDS and the Environment." *Population and Environment* 29(3-5): 103-107.

Hunter, L., J. Reid-Hresko, and T. Dickinson. 2010. "Environmental Change, Risky Sexual Behavior, and the HIV/AIDS Pandemic: Exploring Linkages through Livelihoods in Rural Haiti." Paper presented at the 2010 Annual Meeting of the Population Association of America, Dallas, Texas, 15-17 April 2010.

Ionescu, C., et al. 2009. "Towards a Formal Framework of Vulnerability to Climate Change." *Environmental Modeling and Assessment* 14(1): 1–16.

Irongmonger, D. S., C. K. Aitken, and B. Erbas. 1995. "Economies of Scale in Energy Use in Adult-only Households." *Energy Economics* 17(4): 301-310.

Jensen, J. O. 2008. "Measuring Consumption in Households: Interpretations and Strategies." *Ecological Economics* 68(1-2): 353-361.

Jiang, L., and P. Hardee. 2009. "How Do Recent Population Trends Matter to Climate Change?" *Population Research and Policy Review* 30(2): 287-312.

Jiang, L., and B. C. O›Neill. 2009. *Household Projections for Rural and Urban Areas of Major Regions of the World*. IIASA Interim Report. No. IR-09-026. Laxenburg, Austria: IIASA.

Jiang, L., and B. O'Neill. 2004. "The Energy Transition in Rural China." *International Journal of Global Energy Issues* 21(1-2): 2-26.

Khomarudin, M. R., et al. 2008. "Spatial Improvement of Information on Population Distribution using GIS Approaches: An Input for Tsunami People Exposure Assessment." In: *Proceedings of Conference Towards Tsunami Safer Communities*. International Conference on Tsunami Warning (ICTW), 12-14 November 2008, Bali, Indonesia.

Lanjouw, P. 2004. "The Geography of Poverty in Morocco: Micro-Level Estimates of Poverty and Inequality from Combined Census and Household Survey Data." Washington, D. C.: The World Bank.

________. 2003. "Estimating Geographically Disaggregated Welfare Levels and Changes." Ch. 4 in: *The Impact of Economic Policies on Poverty and Income Distribution: Evaluation Techniques and Tools*, edited by L. A. Pereira da Silva and F. Bourguignon. New York: The World Bank and Oxford University Press

Lenzen, M., et al. 2006. "A Comparative Multivariate Analysis of Household Energy Requirements in Australia, Brazil, Denmark, India and Japan." *Energy* 31(2-3): 181-207.

Liddle, B. 2004. "Demographic Dynamics and Per Capita Environmental Impact: Using Panel Regressions and Household Decompositions to Examine Population and Transport." *Population and Environment* 26(1): 23-39.

Liu, J., R. Wang, and J. Yang. 2009. "Environment Consumption Patterns of Chinese Urban Households and Their Policy Implications." *International Journal of Sustainable Development and World Ecology* 16(1): 9-14.

Lutz, W., et al. 2007. *Reconstruction of Populations by Age, Sex and Level of Educational Attainment for 120 Countries for 1970-2000*. IIASA Interim Report. No. IR-07-002. Laxenburg, Austria: IIASA.

Lutzenhiser, L., and B. Hackett. 1993. "Social Stratification and Environmental Degradation: Understanding Household CO_2 Production." *Social Problems* 40(1): 50-73.

MacKeller, F., et al. 1995. "Population, Households and CO_2 Emissions." *Population and Development Review* 21(4): 849-865.

Maddison, D. 2007. "The Perception of and Adaptation to Climate Change in Africa." Policy Research Working Paper. No. 4308. Washington, D. C.: The World Bank.

Martine, G. 2009. "Population Dynamics and Policies in the Context of Global Climate Change." Pp. 9-30 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and the International Institute for Environment and Development.

Morrow-Jones, H. A., and C. R. Morrow-Jones. 1991. "Mobility Due to Natural Disaster: Theoretical Considerations and Preliminary Analyses." *Disasters* 15(2): 126–132.

Moss, J., et al. 2010. "The Next Generation of Scenarios for Climate Change Research and Assessment." *Nature* 463(7287): 747-756.

Nassolo, S. L. 2010. "Linking the Environment, Growth in the Economy and the Population: Forestry Sector Growth, Deforestation and Population Growth." Paper presented at the 2010 Annual Meeting of the Population Association of America, Dallas, Texas, 15-17 April 2010.

O'Brien, K., et al. 2007. "Why Different Interpretations of Vulnerability Matter in Climate Change Discourses." *Climate Policy* 7(1): 73-88.

O'Neill, B. C., et al.2011. *Meeting Report of the Workshop on the Nature and Use of New Socioeconomic Pathways for Climate Change Research*, 2-4 November 2011, Boulder, Colorado. Integrated Science Program, National Center for Atmospheric Research (NCAR), Mesa Laboratory. Website: http://www.isp.ucar.edu/socio-economic-pathways, last accessed 5 October 2012.

O'Neill, B., et al. 2010. "Global Demographic Trends and Future Carbon Emissions." *Proceedings of the National Academy of Science* 107(41): 1752-1756.

O'Neill, B., and B. Chen. 2008. "Demographic Determinants of Household Energy Use in the United States." *Population and Development Review* 28(Suppl.): 53-88.

O'Neill, B., and N. Nakicenovic. 2008. "Learning from Global Emissions Scenarios." *Environmental Research Letters* 3(4): 045014 (9 pp.).

O'Neill, B., F. MacKeller, and W. Lutz. 2005. *Population and Climate Change*. New York: Cambridge University Press.

OECD. 2008. *Household Behaviour and the Environment: Reviewing the Evidence*. Paris: OECD.

________. 2002. *Towards Sustainable Household Consumption: Trends and Policies in OECD Countries*. Paris: OECD.

Pachauri, S. 2004. "An Analysis of Coss-sectional Variation in Total Household Energy Requirements in India using Micro Survey Data." *Energy Policy* 32(15): 1732-1735.

Pan, W. K.-Y., et al. 2007. "Forest Clearing in the Ecuadorian Amazon: A Study of Patterns Over Space and Time." *Population Research and Policy Review* 26(5-6): 635-659.

Peacock, W. G., and C. Girard. 1997. "Ethnic and Racial Inequalities in Hurricane Damage and Insurance Settlements." Ch. 9 in: *Hurricane Andrew: Ethnicity, Gender and the Sociology of Disasters*, edited by W. G. Peacock, B. H. Morrow, and H. Gladwin. 1997. New York: Routledge.

Pitcher, H. 2009. "The Future of Scenarios: Issues in Developing New Climate Change Scenarios." *Environmental Research Letters* 4 (April-June): 025002 (7 pp.).

Pörtner, C. 2010. "Natural Hazards and Child Health." Paper presented at the 2010 Annual Meeting of the Population Association of America, Dallas, Texas, 15-17 April 2010.

Prskawetz, A., J. Leiwen, and B. O'Neill. 2002. *Demographic Composition and Projections of Car Use in Austria*. MPIDR Working Paper. No. 2002-034. Rostock, Germany: Max Planck Institute for Demographic Research.

Pucher, J., T. Evans, and J. Wenger. 1998. "Socioeconomics of Urban Travel: Evidence from the 1995 NPTS." *Transportation Quarterly* 52(3): 15-33.

Rindfuss, R. R., et al. 2003 "Household-parcel Linkages in Nang Rong, Thailand: Challenges of Large Samples." Pp. 131-172 in: *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*, edited by J. Fox, et al. 2003. Boston, MA: Kluwer Academic Publishers.

Romero-Lankao, P., and H. Qin. 2011. "Conceptualizing Urban Vulnerability to Global Climate and Environmental Change." *Current Opinion in Environmental Sustainability* 3(3): 142–149.

Romero-Lankao, P., H. Qin, and H. Dickinson. 2012. "Urban Vulnerability to Temperature-related Hazards: A Meta-analysis and Meta-knowledge Approach." *Global Environmental Change* 22(3): 670–683.

Setiadi, N., et al. 2010. "Integrating Socio-Economic Data in Spatial Analysis: An Exposure Analysis Method for Planning Urban Risk Mitigation." Pp. 367-374 in: *REAL CORP 2010 Proceedings/Tagungsband: Cities for Everyone, Vienna, 18-20 May 2010*, edited by M. Schrenck, V. V. Popovich, and P. Zeile. Unknown location: Competence Center of Urban and Regional Planning. Website: www.corp.at/archive/CORP2010_80.pdf, last accessed 5 October 2012.

Stevens, G., R. Dias, and M. Ezzati. 2008. "The Effects of 3 Environmental Risks on Mortality Disparities across Mexican Communities." *Proceedings of National Academy of Sciences* 105(44): 16860-16865.

Taubenböck, H., A. Roth, and S. Dech. 2007. "Linking Structural Urban Characteristics Derived from High Resolution Satellite Data to Population Distribution." Pp. 35-45 in: *Urban and Regional Data Management*, UDMS 2007 Annual, edited by M. Rumor, et al. 2007. London: Taylor and Francis.

van der Vink, G., et al. 1998. "Why the United States is Becoming More Vulnerable to Natural Disasters." *EOS: Transactions: American Geophysical Union* 79(44): 533–537.

van Vuuren, D. P., S. J. Smith, and K. Riahi. 2010. "Downscaling Socioeconomic and Emisssions Scenarios for Global Environmental Change Research." *Climate Change* 1(3): 393-404.

Zigová, K., et al. 2009. *Household Survey Data Used in Calibrating the Population-Environment-Technology Model*. IIASA Interim Report. No. IR-09-046. Laxenburg, Austria: IIASA.

CHAPTER 7

Adapting Urban Settlements to Climate Change: Local Vulnerability and Adaptive Capacity in the Urban Areas of Malawi

Daniel Schensul, David Mkwambisi, Sainan Zhang, David Dodman, Thomas Munthali and Dunstan Matekenya

Introduction

The emergence of climate change as an increasingly important challenge for countries, communities and households has come with the recognition that the tools to face current and coming changes are insufficient. In particular, the social and demographic dimensions of climate vulnerability and adaptation are not well understood, and this lack of understanding risks undermining both broad-based and local adaptation efforts (see Chapter 1). Causes of this gap include a lack of understanding of adaptation mechanisms; reduced attention to the study of climate change, particularly among social scientists; failure to marshal existing data in a way that is linked to climate change impact modeling; and failure to integrate the results of vulnerability analyses into existing climate change responses. Generating and using reliable sources of relevant data can address these barriers and thereby help to strengthen adaptive capacity and reduce vulnerability.

These issues are of particular relevance in low-income countries, where the impacts of human-induced climate change are likely to be felt first and most severely. The United Nations Framework Convention on Climate Change (UNFCCC) recognizes Small Island Developing States (SIDS), Africa and the Least Developed Countries (LDCs) as being particularly vulnerable, and together these form a group of about 100 nations identified by Huq and Ayers (2007) as being the "Most Vulnerable Countries". Malawi is designated an LDC based on its combination of low income, low indicators of health, nutrition and education and economic vulnerability. It is also located in a region expected to experience significant climate impacts. It is thus an important case for understanding the context, strategies and capacities in the response to climate change, particularly with regard to adaptation. Moreover, from a policy standpoint, Malawi is highly engaged in the issue, both in government and non-governmental organizations (NGOs), and with representatives of the international community. It also has the benefit of having a relatively recent population census—2008 (Government of Malawi [GOM], 2008)—as well as a recently completed demographic and health survey (NSO and ICF Macro, 2011). Therefore, with the right approaches, capacities and partnerships, Malawi could be well situated to develop a strong and innovative climate response programme that other countries could emulate.

This case study combines spatial analysis of the Malawi 2008 census with detailed national and local qualitative data analysis. It is focused on the stakeholders and policies relevant to Malawi's climate change response that can help to generate a better understanding of climate change vulnerability and to influence the direction of adaptation policy and implementation. An emerging body of work (e.g., Guzmán, 2009; Balk et al., 2009 and Chapters 4 and 5 in this book) is demonstrating that many of the social and demographic factors shaping vulnerability can be illuminated through analysis of census data. A wide range of data on spatial location, demographic characteristics, housing, services, energy use, education and other critical determinants of vulnerability are reported in the census (see Chapter 4 and Guzmán, 2009). Furthermore, in many countries, the 2010 round of censuses made a great leap forward in the use of geographic information systems (GIS), allowing highly localized analysis that can be linked to the geography of climate exposure (Chapter 5).

A National Climate Change Programme (NCCP: 2013-2016) is currently being developed in Malawi to coordinate work on climate change to achieve resilient and sustainable development. The focus of the NCCP will be on capacity-building, policy formulation, national climate change investment plans and financing and the national response framework. Key partners in the programme include 19 government ministries and departments, a number of multilateral agencies led by the United Nations Development Programme (UNDP) as well as academics, technical specialists and NGOs, with support from several donor countries. However, UNDP reported in discussion with the authors that data on climate change is perhaps the weakest aspect in generating the NCCP. Because of this, UNDP and its partners have started to work on vulnerability analyses and hazard mapping, and, in late 2011, were working on a capacity assessment of hazard mapping with the Department of Disaster Management Affairs (DoDMA).

There is also a growing body of literature and case studies examining specific elements of climate change impacts, vulnerability and adaptation in Malawi.[1] The research presented here is intended to support existing vulnerability assessment efforts through the inclusion of new data and new analysis. An expanded version of this work that includes a wider array of maps and spatial data, of which only a sample can be included here due to space limitations, will be used in Malawi to support data-driven climate response.

Urbanization and climate vulnerability

The increasing proportion of the population living in urban areas has significant and under-appreciated consequences for the nature of poverty and vulnerability. As this chapter shows, urban vulnerability and adaptation has been a major gap in Malawi's climate change response, despite rapid population growth rates and serious deficiencies in service provision in both large cities and emerging urban areas. The concentration of people and economic activities in urban areas can mean that larger numbers of people are exposed to particular hazards, as Schensul and Dodman (Chapter 1) explain. At the same time, if planned and managed effectively, such concentration can result in more cost-effective protective infrastructure and improved adaptive capacity for individuals and households. Although much attention to date has been given to rural vulnerability, at least partially as a result of the clear impacts of climate change on agriculture, the pace and scope of urbanization in many countries means that the terrain of adaptation will be increasingly urban.

The convergence of rapid urbanization with increasing climate impacts is something many countries will experience over the coming decades, with significant implications for the societal impacts of each (see: Chapter 2). The high concentration of people and economic activities in towns and cities; their reliance on a wide range of resources from outside their geographical boundaries; the inadequate provision of water, sanitation and drainage; inadequate funding from central government; lack of coordinated efforts by stakeholders; and pre-existing environmental challenges related to solid waste management, air pollution and water pollution mean that urban centres and their inhabitants in low- and middle-income countries are highly vulnerable to the effects of climate change (see: Romero-Lankao and Dodman, 2011). Given the range of the potential outcomes that depend on how urban growth and planning occur—whether slums emerge and expand, how services and infrastructure expand with growing population and economies, and how land and housing are distributed relative to exposure—urbanization and climate vulnerability are the specific focus of this case study.

Methodology

There are two main components to the methodology of this case study, which can be adapted and applied in other contexts[2]:

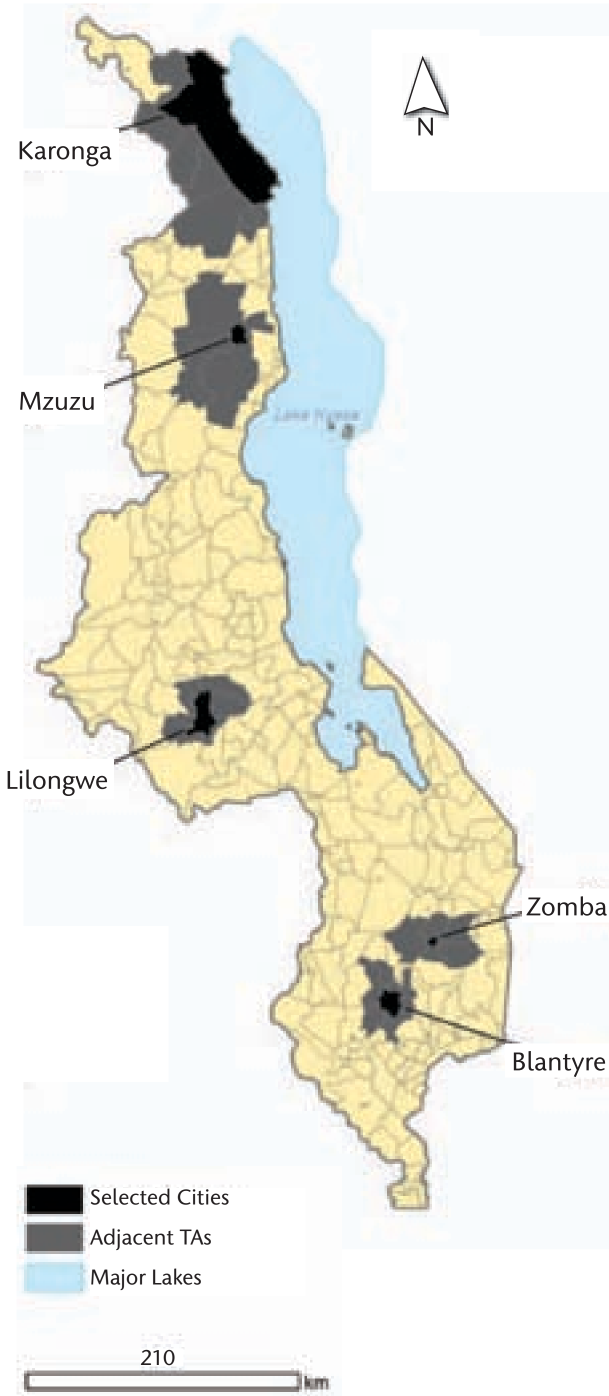
1. Spatial analysis of the 2008 Malawi census, focusing on vulnerability stemming from location, population density and composition, the built environment and human, social and economic capital;
2. Analysis of the key stakeholders and policies that shape and inform climate change responses at national and local levels.

Spatial analysis was conducted through a working partnership between UNFPA headquarters, UNFPA Malawi, the International Institute for Environment and Development (IIED) and the Malawi National Statistical Office. At its core was the merging of census data with a digitized map of the country, a process more technically challenging than in many other instances because this was the first time a significant spatial analysis of the Malawi 2008 census had been conducted. The base unit of the analysis was the Traditional Authority, or TA, an aggregate of the enumerator areas that represented the smallest unit of census data collection. In ideal circumstances, the analysis would have been based on the enumerator areas themselves. However, problems with the digitization of maps resulted in large numbers of enumerator areas (as many as 20 per cent, particularly concentrated in urban areas) not being captured. TAs were a much more robust analytical unit in this case, with nearly a complete match between the census data and digitized maps.

The spatial analysis focused on five urban extents (see Figure 7.1), each containing an urban area plus any adjoining TAs in order to capture people living beyond the formal urban boundaries, but still in close proximity. These were the four official cities of Lilongwe, Blantyre, Mzuzu and Zomba, as well as the secondary urban centre of Karonga. The statistical analysis techniques used were primarily descriptive, as much can be learned about climate vulnerability from the spatial distribution of census-based variables through simple proportions and indexes. Furthermore, when results are based on descriptive analyses, they are more accessible to policymakers and communities, meaning they are more likely to be used. And finally, the results presented in this chapter can be replicated in Malawi and elsewhere without advanced capacities in statistics. The stakeholder and policy analyses were undertaken through qualitative interviews with a range of partners from governmental and non-governmental organizations in September and October of 2011, as well as through review of relevant documents.[3]

This chapter continues with a presentation of key population indicators from Malawi based on outputs from the 2008 census. This is followed by a review of climatic variability and change in the country and an assessment of vulnerability to climate change at the city level. The final section explores the policy implications of this analysis and examines the role of local authorities and non-governmental organizations in responding to climate change.

Figure 7.1: Study Sites in Malawi



Population Dynamics in Malawi

Malawi's total population grew from about four million in 1966 to over 13 million in 2008 and is expected to reach 16.3 million by 2015 and 26 million by 2030 (GOM, 2010c). The country is divided into three administrative regions—North, Central and South—with a total of 28 districts. Only 15.3 per cent of the population lives in urban areas, though that proportion is growing rapidly and is projected to reach 33 per cent in 2050. Over 77 per cent of the urban population in Malawi live in the four cities: Lilongwe (669,532); Blantyre (648,852); Zomba (81,501); and Mzuzu (127,539). Each of the four, plus Karonga, is highlighted in this case study. Taken as a whole, the analysis covered a population of 3.42 million people, 1.79 million of whom live within urban boundaries.

According to the Malawi National Statistics Office's (NSO) Thematic Report on Spatial Distribution and Urbanisation (2010a, p. 38), "the recent increase in the level of urbanization in Malawi has been due to the development of new relatively small towns that are growing at fairly rapid rates." The country has witnessed significant economic deterioration in both rural and urban areas. Malawi's economy is predominantly agrarian with agriculture accounting for 33 to 37 per cent of GDP and 85 per cent of export earnings. However, agricultural markets, especially tobacco, have deteriorated over time such that large estates and other commercial farmers have withdrawn from the sector. Notably, urban centres have generally poor living conditions, with the Malawi "State of Environment" report (2010e, pp. 27-28) highlighting that "in 2001 it was estimated that over 90 percent of Malawi's urban population lived in slums characterised by, among other things, overcrowding, lack of potable water and poor sanitation facilities".

Although Malawi, like many African countries, has a relatively small proportion of its population living in cities, the annual urban growth rate between 2010 and 2015 is projected to be 4.2 per cent (UNPD, 2012), corresponding to a doubling of the urban population in only 17 years. This makes Malawi one of the fastest urbanizing nations in the world. The official census growth rates for the major cities of Mzuzu, Lilongwe, Zomba and Blantyre are 4.4 per cent, 4.4 per cent, 3.0 per cent and 2.8 per cent per year respectively (GOM, 2010a), with Mzuzu city having the highest inter-censal growth rate of 54 per cent.

Attempts to reduce the rate of urbanization include the creation of quasi-urban growth centres in rural areas that can provide similarly attractive environments. In these centres,

Table 7.1: Population Projection for Main Urban Centres in Malawi

Name of City	Mid-year population					
	2000	2005	2010	2015	2020	2023
Mzuzu	99,095	134,399	156,791	223,740	306,265	363,244
Lilongwe	498,185	669,114	768,012	1,037,294	1,365,724	1,589,975
Zomba	74,915	101,423	101,083	138,583	184,724	216,532
Blantyre	554,578	711,233	721,063	884,497	1,072,684	1,197,692

Source: GOM, 2010c.

roads, shells to house businesses, schools, clinics and markets have been the priority, together with catalysing small- and medium-enterprise emergence. Power generation and ensuring adequate water supplies have been significant barriers to this strategy. Malawi recently embarked on a process of political and economic decentralization, but this has already stalled. The CEO of Blantyre stated that "the slow implementation of the decentralization process has contributed to the stagnation [of urban programmes]. Urban areas are being pulled between the center and the local level because the process of decentralization is incomplete."

There are also distinct regional patterns in the distribution of the population in Malawi. The proportion residing in the southern region has declined from 47 per cent in 1998 to 45 per cent in 2008, while the central and northern regions have each seen an increase of 1 per cent over the same period. Given that fertility rates in urban areas are still high, it is likely that a significant portion of urban population growth is associated with natural increase, or births over deaths.

The median age of Malawi's population is 17 years, with 67 per cent of the population under age 25 and 54 per cent aged under 18 (GOM, 2009). This has significant implications both for the dependency ratio (which is high) and for the trajectory of future population growth, given the large number of women entering childbearing years (which heightens population growth even under circumstances of decreasing fertility, a phenomenon known as population momentum). Census data show that the proportion of female-headed households is lower in the focal urban areas than in rural areas—about 18 per cent compared to 29 per cent—which could be an indication of male labour migration to the cities. Multiple types of internal migration flows exist in Malawi, according to the Thematic Report on Migration (GOM, 2010b): rural-urban migration, as well as significant urban-urban and urban-rural migration (Table 7.2). District-to-city movements (e.g., Lilongwe District to Lilongwe City) or from other nearby districts to cities (e.g., Mzimba to Mzuzu) are common, suggesting that proximity matters for internal migration decision-making. All cities had significant net gains through migration between 1998 and 2008: 41 per cent in Lilongwe City and Mzuzu City; 30 per cent in Blantyre City and 16 per cent in Zomba City.

Table 7.2: Resident Total Population and Migration

Area	Population	In-Migrants	Out-Migrants	Net Migrants
Northern Region	1,679,491	261,417	278,933	-17,516
Central Region	5,497,252	897,760	758,089	139,671
Southern Region	5,852,755	952,004	1,074,159	-122,155
Blantyre District	339,406	61,878	65,216	-3,338
Blantyre City	648,852	323,075	129,324	193,751
Lilongwe District	1,232,972	71,600	159,398	-87,798
Lilongwe City	669,532	349,213	73,331	275,882
Mzuzu City	127,539	77,730	25,491	52,239
Zomba	81,501	48,079	34,667	13,412

Source: Extracted from GOM, 2010b (based on 2008 Census), Table 2.1.

Anecdotal reports during qualitative data collection suggest that urban-rural linkages remain strong, including links to peri-urban areas for small-scale agriculture. The prevalence of proximity-based migration as observed in the census provides some support to these reports. Furthermore, reinforcing a point made in Chapter 3 in this volume, these data suggest that in- and out-migration cannot be thought of separately.

Climate Change Impacts and Vulnerability in Malawi

While the production of downscaled climate projections or hazard geographies for the national and sub-national level remains a significant challenge, several government agencies and non-government organizations have identified the potential impacts of climate change in Malawi.

Box 7.1: Climate Change Impacts in Malawi

- **Agriculture** (rain-fed): reduced productivity due to droughts; crop losses; scarcity of raw materials; malnutrition/famine;
- **Water:** availability/scarcity; reduced quality; lower hydroelectric power generation; waterborne diseases;
- **Health:** temperature trends and water availability; spread of malaria, diarrhoeal diseases, malnutrition;
- **Gender:** droughts affect availability of resources; women walk longer distances (to collect water, food and firewood); women nurse the sick;
- **Energy:** affected by droughts; scarcity of firewood; lower hydro-electric generation potential;
- **Fisheries:** affected by droughts and floods; reduced reproduction; loss of biodiversity; destruction of ponds;
- **Wildlife:** droughts affect water and food availability; reduced reproduction; migration;
- **Forestry:** reduced productivity due to droughts; land degradation; forest fires; loss of biodiversity.

Source: Adapted from Figure 10.1, GOM, 2010e.

A lack of historical information prevents a meaningful assessment of climatic trends in Malawi. However, there is some evidence that the frequency of extreme weather events has been increasing in recent decades (GOM, 2010e). This evidence, however, needs to be interpreted carefully, as it is not based on a scientific review and relies only on the reporting of events as disasters.

According to discussions with DoDMA, the most common hazards Malawi faces include prolonged dry spells; droughts; flooding; water-borne diseases resulting from floods such as cholera; and strong rains and winds that damage many substandard dwellings. This is supported by various other sources including Stringer et al. (2006, p.148): "Almost three million hectares of the country are semi-arid or dry sub-humid, with drought both common and largely unpredictable. Approximately 90 percent of the country's 13.6 million inhabitants rely on rain-fed, subsistence agriculture to feed their families and sustain their livelihoods." Smallholder farmers are increasingly aware of the threat of climate change, according to representatives of the National Smallholder Farmers Association of Malawi, particularly in perceptions of increasing numbers of dry spells and floods. Given rapid urbanization and the emergence of changing weather patterns as a source of concern among Malawians, the convergence of these issues will only increase in importance over time (see Chapter 2).

As a whole, the focal areas for this case study exhibit significant diversity in vulnerability, with water, food security, housing, energy and livelihoods expected to be the hardest hit by climate change events, but with significant variations in the adaptive capacity of households and communities. Among the major concerns are housing and access to services across the country. Wide disparities exist between cities and rural areas and also within urban areas where variation is almost double that of rural areas. The adjusted Secure Tenure Index (STI)[5], a proxy for slums or substandard housing, is indicative of both the disparity between urban and rural and the variation within urban. One exception is water access, defined as water piped either into or near the home: Levels are consistently high—above 80 per cent—in neighbourhoods inside the urban boundaries of the study area. Literacy is high in both rural and urban areas, and without significant variation between the two. As a proxy of both income and connectedness, radio ownership levels are only somewhat higher in urban areas than in rural areas, but there is still significant internal variation and the numbers in both are not that high (Table 7.3).

Table 7.3: Selected Socioeconomic and Adaptive Capacity Indicators: Urban and Non-urban

	Areas within urban boundaries		Areas outside urban boundaries	
	Mean	Standard deviation	Mean	Standard deviation
Adjusted STI	36.97	19.81	5.39	2.32
Improved toilet	17.5%	21.2%	2.3%	1.4%
Literacy	84.3%	7.6%	67.5%	7.9%
Radio ownership	73.2%	8.9%	60.7%	7.9%

A recent study by Stringer et al. (2010) identifies intra-rural and rural-urban migration in Malawi as the "main adaptation strategy" (p. 153) being adopted to manage the impacts of low crop yields, frequent drying of rivers, flooding, destruction of ecosystem integrity and loss of biodiversity. However, the authors also note that climate change impacts are just one of a range of "push" factors encouraging migration from rural areas, along with land shortages, conflict, lack of employment opportunities and disease. At the same time, climate change may produce opportunities for rural livelihoods, for example, in winter crop production and fishing in areas, such as Chikhwawa and Nsanje, where there is more frequent flooding.

There are strong rural-urban linkages that shape both vulnerability to climate change and broader environmental impacts around issues of housing construction and energy provision. The use of burnt bricks for housing contributes to deforestation in areas around urban centres, where they are used extensively due to the high cost of other building materials (GOM, 2010e, p. 28). Urban elites are purchasing land in peri-urban areas, thereby reducing agricultural land, increasing rural vulnerability and contributing to rural-urban migration. Similarly, although of somewhat less relevance in urban centres, approximately two thirds of Malawi's houses are built of traditional materials from natural forests (including tree poles and grass) without replacement, which also contributes to deforestation (GOM, 2010e, Ch. 2). The fact that urban households consume more water than rural households also affects rural-urban dynamics, with the consequence of higher levels of demand and extraction in towns and cities. Although the national average domestic water demand is estimated at 125 litres per day per capita, the figure for rural areas is 27 litres, and in urban areas it is estimated at 200-360 litres (GOM, 2010e, p. xxix).

Nearly 85 per cent of urban households in the five study areas rely on biomass, wood and, primarily, charcoal, for cooking. The figure for rural areas is almost 98 per cent, essentially all wood. This dependence on biomass for fuel creates significant spatially concentrated environmental impacts on the areas surrounding the urban centres. The spatial distribution of forest stock is uneven in Malawi, with large surpluses in the north that are too costly to bring to the central and southern population centres, meaning that local degradation is significant (Kambewa and Chiwaula, 2010). Use of biomass as a fuel in urban areas has also increased in recent years due to the low capacity of the hydropower plants supplying electricity.

In brief, the flows of energy, building materials and water between rural and urban areas are shaped by population dynamics, with growing urban populations increasing the spatial concentration of demands on these natural products and growing urban income increasing demand. But their use also shapes patterns of urban vulnerability: As low-income residents are more heavily dependent on biomass for energy and natural materials for houses, they will suffer the most as the natural asset base is depleted. However, even the limited number of households that utilize electricity may be affected by climate change, as this is expected to have negative effects on hydroelectric power generation (GOM, 2010f, Section 4.2.3). Despite these multiple links, "current policy infrastructure neglects to recognize the horizontal links between rural and urban parts" (Stringer et al., 2010, p. 156).

Local analysis of vulnerability

This section examines the focal urban centres more closely, disaggregating vulnerability among and within each, including links to population and housing characteristics and the distribution of vulnerability across space.

Lilongwe

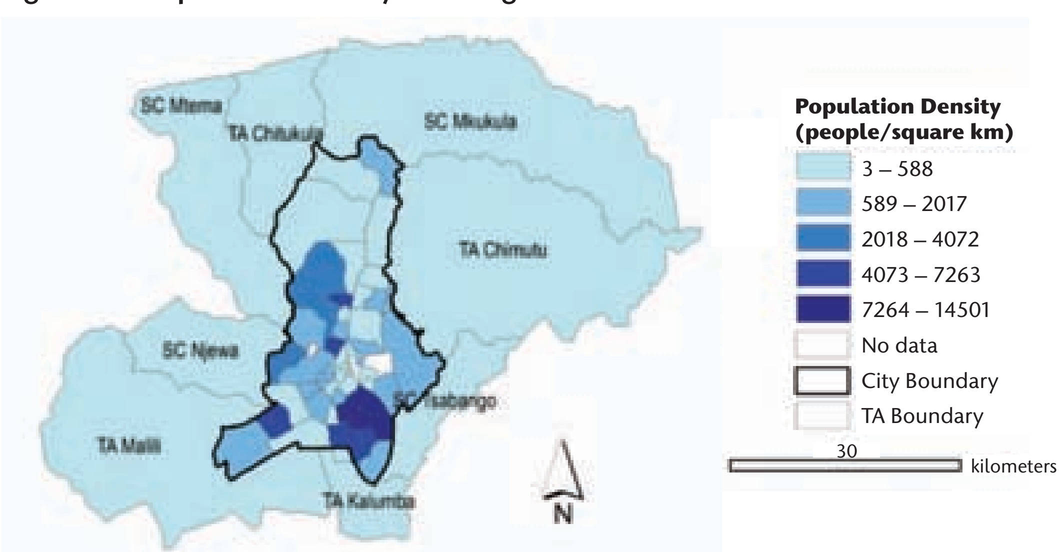
Lilongwe became the capital of Malawi in 1975. A city built with the support of South African planners, it was designed to be relatively dispersed, with residential areas on the margins. Stretching north to south more than east to west, plans called for large residential and agricultural areas to the north, between the city centre and the airport. Due to the lack of services and the distance from the city centre, however, the north has remained for the most part unsettled, while population has grown rapidly in both the centre and the south.

Discussions with the Lilongwe City Council suggested that while growth stagnated in the formal areas of the city during the intercensal period, some informal settlements doubled in population over the same time.[4] In addition, city authorities reported that people are moving just beyond the southern border of the city, where they can take advantage of proximity to the city without paying city rates. Population density (see Figure 7.2) is indeed extremely high in the south-east corner of the city, where informality is also high.

Access to agricultural land has historically been one of the key draws of Lilongwe for potential migrants, given its large land area and proximity to both urban and peri-urban agricultural areas. Lilongwe has enough of a farming base that the National Smallholder Farmers Association of Malawi has mobilized farmers to form the Lilongwe North and Lilongwe South Associations. However, census results show that Lilongwe (along with Blantyre) is one of the fastest growing cities in the world, with so much demand for residential land that the Lilongwe City Council Director of Planning said "open spaces are no longer open". Representatives of the Center for Community Organization and Development (CCODE) made a related but somewhat different point, suggesting that while land is available in some places, Lilongwe has "run out of land for low-income housing". CCODE's work on housing and upgrades has, therefore, focused mainly on the outskirts of the city.

Climate change is not the foremost priority for the city's policies and interventions. Lilongwe City Council Directors reported that the influx of people into urban areas is rendering existing services inadequate, and that the Council is "being pushed. . . . Instead of managing the city, the people are managing us". The Lilongwe City Council

Figure 7.2: Population Density in Lilongwe



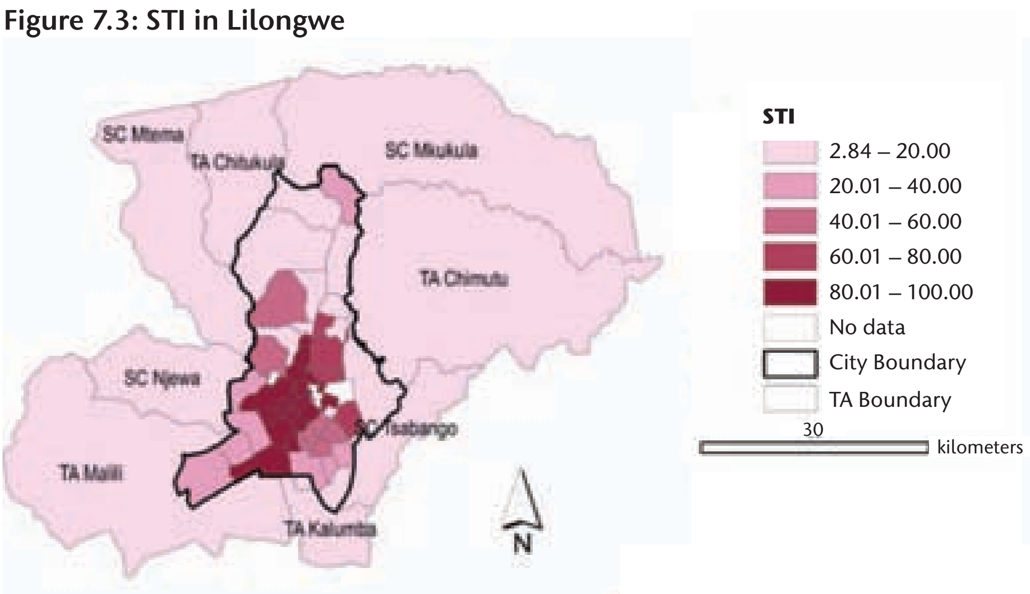
Director of Planning indicated that, in most cases, the city deals with issues on a "fire-fighting basis, [with the] issue of climate change [being] peripheral to what we do. Climate change is looked at as much more distant than the need to provide land and services. We need to deal with informal settlements and services before dealing with climate change." The data show not only the challenges in addressing land and services but also the links to climate vulnerability in the longer term.

The adjusted STI shows some of the starkest inequalities in Lilongwe, and indeed in Malawi, with the central swath of the city near the highest levels of the index, while the informal segments of the city to the southeast—particularly Areas 23, 24 and 36—show levels much closer to rural areas (see Figure 7.3). These results show that informality and lack of access to services are a critical priority in both urban and rural areas.

Lilongwe residents, along with many other urban residents in Malawi, still rely on agriculture (Mkwambisi et al., 2011), with the census indicating that about 14 per cent of the labour force within the city boundaries work primarily in that sector. Moreover, illustrating the extension of urban lifestyles beyond the formal boundaries, only 60 per cent of the workforce in surrounding TAs works in agriculture. Both within and outside the boundaries, many more use urban or peri-urban agriculture to supplement income or food stores. Furthermore, the Lilongwe City Council Director of Engineering reported that trading, especially of agricultural goods, is one of the main drivers of movement to Malawi's cities, both permanent and temporary.

The DoDMA disaster dataset describes a number of hailstorms that occurred late in 2007, 2008 and 2009 that hit the entire Lilongwe District, with significant damage to both houses and crops. Houses with grass roofs are more vulnerable to damage caused by hailstorms and other severe weather events. Analysis shows that most houses of this type are located outside the city boundaries, and most of DoDMA's reports of damage from the storms were from those areas.

Figure 7.3: STI in Lilongwe



Heavy rains and flooding have also sometimes been a problem, for example, in Chilinde and Ntandire, high density locations in 2011-2012, and could increase in a changing climate. Two variables associated with flash-flood vulnerability—impermanent materials in walls and floors and use of pit latrines—continue to highlight the south-east areas as the most vulnerable in the city.

About 80 percent of households in Lilongwe have access to water piped into their homes or to community standpipes. This stands in stark contrast to the surrounding rural areas, which rely entirely on wells and boreholes. Urban water infrastructure may increase resilience to heat waves, both in the need for drinking water in hot weather and to reduce transmission of water-borne and water-washed diseases in higher temperatures.

Commenting on the climate in urban areas, the Lilongwe City Council Deputy Director of Health and Social Welfare said:

> Over the last ten years we have witnessed an increase in dust and that wind velocity is always high. This is mostly due to tree cutting that has taken place within and outside the city. We have seen that all the wetlands (*dambos*) in urban areas no longer exist and people are now constructing houses in areas that were river beds. The city is also receiving little rain and Lilongwe River that used to flood every year is no longer causing any flood-related problems. Recently we have observed that Lilongwe City is warmer throughout the year due to deforestation and lack of evaporation.

While the rural areas around Lilongwe City rely almost exclusively on wood for cooking, census data show that the informal areas of the city have much higher proportions of charcoal use. The rates of use of improved cooking fuel—propane, electricity and the like—are low in informal areas, but substantially higher in the more formal parts of the city. Cash markets for charcoal in informal areas create a range of vulnerabilities linked to fluctuating prices, and the decreasing forest stock puts an extremely large number of households at risk of significant energy insecurity. In addition, the burning of both wood and charcoal creates hazardous fumes that tend to disproportionately impact the health of the women and girls tasked with cooking. The areas around Lilongwe are increasingly being deforested, due to a wide range of demands for wood, including as a key fuel for cooking. The Lilongwe City Director of Environment suggested that widespread tree cutting has destroyed the city's tree cover, reducing water absorption capacity in the ground and exacerbating the drying of streams.

The Lilongwe Director of Engineering stated in an interview that certain infrastructure projects have also increased climate vulnerability, for instance, through generating greater surface run-off than planned, which stresses drains and damages roads, and through greater pressure on the city's resources. Protection work on roads is a major priority in the city, using both city and national resources through the Roads Authority. More frequent de-sludging of waste water treatment plants is also critical, as is lobbying the central Government to maintain infrastructure more broadly.

Blantyre and Zomba

Blantyre is the country's primary city from an economic and demographic standpoint. It was a colonial city that started as an agricultural node, with a dense city center that expanded over time without significant planning. Recent effects of urban land expansion without planning have included settlement up steep slopes on the city's outskirts, which are vulnerable to landslides.

Box 7.2: The City of Blantyre

"Blantyre City is the oldest urban centre in Malawi, established by the Scottish missionaries in the 1870s and declared a planning area in 1897. It is the hub for communication, industrial, commercial activities and cooperation in Malawi. The influence of Blantyre declined when Lilongwe became the capital city in 1975. However, it has maintained its grip as the commercial capital of Malawi. The city offers a number of economic opportunities but lacks resources to meaningfully implement its strategies and provide the required basic social infrastructure and urban services required for economic development to take place. Over 65 per cent of the city's population lives in informal settlements which occupy about 23 per cent of the land in Blanytre. Poverty stands at 24 per cent while unemployment stands at 8 per cent."

Source: UN-HABITAT, 2011a, p. 8.

Blantyre's Chief Executive Officer is primarily focused on the issue of urbanization and population growth within the city. His understanding is that rural-urban migration is being driven by the perception that urban areas offer better opportunities, in part because the land that people depended on is not reliable anymore. The question now, according to the CEO, is not whether the Government should stop people from urbanizing (as some current policies attempt) but how to manage cities to accommodate more people.

Addressing population density and the resulting congestion in Blantyre, as well as in other cities, has been a priority. Special challenges that have, in some instances, been exacerbated by density have included service delivery, environmental impacts, health problems among the densely settled poor, strife caused by inequality between poor and rich and interference by the wealthy in Blantyre's development plans.

In the aggregate, indicators relevant to this study point to equal or lower vulnerability as compared to Lilongwe. Also apparent from the data is that variation in these indicators within Blantyre is substantially lower than in Lilongwe. This is not to say that inequality is low: The adjusted STI in Blantyre shows a similar pattern to that of Lilongwe, with a central swath in the highest quintile and large numbers of neighbourhoods in the third and fourth quintiles. A recent survey (Africa Food Security Urban Network [AFSUN], 2011) found high levels of food insecurity, particularly among female-headed and -

centred households, households with large family sizes and low-income households. Food transfers from rural areas and other towns were a critical contributor to food security, and almost one third (31 per cent) of sampled households used urban agriculture as an additional livelihood strategy.

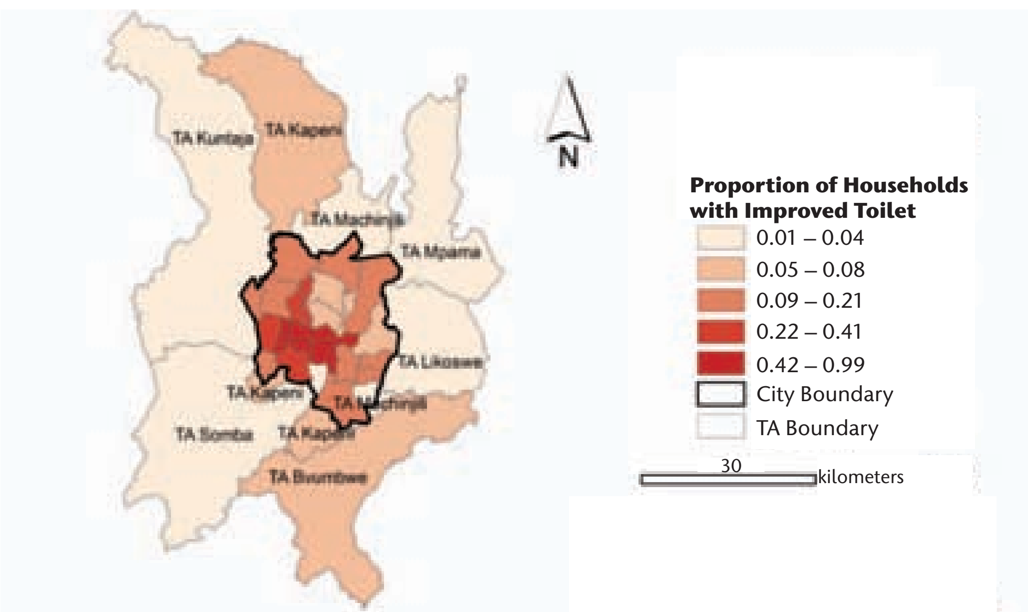
Within Blantyre, the key development challenges have had to do with the effects of increasing consumption: making sure garbage is taken away and re-used/recycled where appropriate, dealing with the surging number of vehicles in the last five years and with problems of air quality and inadequate sewer systems for removing human waste. Mapping household toilet facilities indicates large parts of the city without improved toilets (see Figure 7.4). According to Blantyre's CEO, health services in the city have declined due to funding constraints, with community clinics for children being particularly affected.

Zomba, to the north-west of Blantyre, while defined as a city, functions in many ways as a satellite urban area to Blantyre. According to UN-HABITAT's (2011b) Zomba profile, "the local economy of Zomba comprises of trade and distribution, community and social services, agriculture, and some light industries. Poverty stands at 29 percent and over 60 percent of the population lives in informal settlements (p.8)." Analysis of the adjusted STI shows that Zomba shares many of the urban challenges being experienced by Blantyre: It also has a relatively well-serviced central area, with rapidly declining physical infrastructure outside of the center.

Karonga

With relatively low population density compared to Lilongwe and Blantyre, Karonga is an emerging urban area on Lake Malawi in the northern region. Key informants reported that many residents in Karonga have been engaged in a range of informal income-

Figure 7.4: Proportion of Households with Improved Toilets, Blantyre



generating activities, especially in trading small items, due to cross-border commerce and the presence of mining, though the large majority (over 86 per cent within the urban boundary and about the same outside) rely on agriculture as their main source of income. Proximity to the lake and to several wetlands provides residents with access to fish and to productive land for growing rice, cassava and bananas.

In Karonga, a number of the settlement areas are between the North Rukuru River and a dyke. In 2010, the river overflowed and flooded the first settlement area and rice fields before breaking through the dyke to flood the whole town. Upper catchment areas have been deforested, enhancing the likelihood of water runoff and river flooding.

Karonga's housing infrastructure varies in its vulnerability to flooding, particularly in the case of toilet facilities. In most areas within the urban boundary, around half of the households have earth floors, and a very high proportion rely on pit latrines or other non-improved toilet facilities, which are especially vulnerable to flooding and are linked to cholera outbreaks in the aftermath of flooding. Only in the centre of town are vulnerability indicators substantially lower. The rest of Karonga falls far short of these benchmarks, with areas outside the urban boundary even worse off.

DoDMA data also show flooding in other rivers in the district, including the Songwe River. Despite the long history of floods, people continue to live in flood plains, some still in tents provided as relief during previous floods, and, to this point, there have been few interventions to help residents adapt to the flooding. One exception has been a programme to relocate key services in Karonga to higher ground, which is being implemented by the Ministry of Housing and Urban Planning, with support from UN-HABITAT.

A number of droughts have also affected Karonga: Data from DoDMA show that a drought in 1996-1997 impacted 36,000 households, and the response involved significant relief efforts from the national Government and domestic and international NGOs. On the positive side, the large majority of urban residents in Karonga have access to piped water, either in the home or from community standpipes (the latter being far more prevalent), providing some protection during droughts depending on the water supply.

Mzuzu

Mzuzu has a spatial structure common to Malawi's urban areas: a reasonably well serviced and formal centre that declines as it moves to the outskirts of the urban boundary and then to rural areas entirely outside the city. Within Mzuzu, three townships stand out as having very low vulnerability on housing and service access indicators: Kaning'ina, Masasa and Chasefu. These are not the most densely populated areas of the city, though.

Just to the south of these three townships are Viphya and Msongwe, with a combined population of almost 15,000 and near diametrically opposed vulnerability indicators, including STI in the fourth quintile and fewer than 10 per cent of households with improved toilets. Mzuzu and its surrounding areas have a relatively higher flood risk, and clearly there are massive disparities in vulnerability and resilience within the city.

Box 7.3: The City of Mzuzu

Mzuzu City, with a population of 133,968 and growing at 4.2 per cent per annum, is one of the fastest growing cities in Malawi and is the third largest urban centre after Lilongwe and Blantyre. It is the hub of government administration, business, industry, commerce and services for the northern region of Malawi, and it serves a hinterland with a population of 1,708,930. Declared a city in 1985, it originated from a Tung Oil Estate in 1947 and has grown from 23 km^2 to 143.8 km^2 in 2008. However, the city lacks adequate infrastructure and services. Over 60 per cent of the population lives in unplanned settlements. The city does not have adequate policies and regulations to support orderly and planned growth. Improvement and expansion of service delivery, proper urban planning and good financial management are crucial for the development of the city.

Source: UN-HABITAT, 2011c, p. 8.

Implications for Malawi Climate Change Policy: Integrating Urbanization and Population Dynamics

National policy development on climate change

Existing reports and policies on the environment and climate change in Malawi do not address many of the issues contributing to the vulnerabilities that are described above. The policy responses to climate change recommended by the State of Environment Report (2010e) have a stronger emphasis on reducing greenhouse gas emissions and addressing mitigation concerns (see pp. 225-226) than on reducing vulnerability. Similarly, the policy responses that have been recommended to address the impacts of climate change and climate variability show little or no recognition of urban issues or of issues related to population dynamics. The 2006 National Adaptation Programme of Action (NAPA) (GOM, 2006) addresses eight sectors (agriculture, human health, energy, fisheries, wildlife, water, forestry and gender) and identifies six main "vulnerable communities" (Karonga, Chongoni, Salima, Chikwawa, Nsanje and Zomba). Only two urban areas are included in this list (Karonga and Zomba), and the sectors that are identified are mainly rural, including sustainable rural livelihoods, forest restoration, agricultural production, preparedness for droughts and floods and the sustainable utilization of Lake Malawi and lakeshore areas.

Within Government, climate issues are coordinated at the national level by the Ministry of Development Planning and Cooperation (MoDPC). The Economic Planning Division within this Ministry coordinates three climate change-related programmes: the Poverty Environment Initiative (PEI), the Agricultural Development Programme (AAP) and the National Programme for Managing Climate Change. This fits well with national development goals as it also aligns with the implementation of the Malawi Growth and Development Strategy (MGDS). Furthermore, population and development issues are covered by the same Ministry's Population Unit, creating a suitable institutional entry point for issues related to urbanization and other population dynamics.

Several policy-related processes are in place at the national level, including a national policy road map to facilitate the formulation of a National Climate Change Policy, with the University of Malawi being engaged in mid-2012 to produce this. The issues paper informing this policy has identified several areas of focus, including agriculture, health, human population (which includes population dynamics) and capacity-building. The Government also has a climate change management structure in place. For example, the MoDPC chairs the Steering Committee, while the Technical Committee is chaired by the Department of Climate Change and Meteorological Services (DCCMS) with the Environmental Affairs Department (EAD) as the Secretariat. The structure also includes a Government-Development Partner Working Group chaired by the MoDPC.

Currently, 19 government ministries and departments are engaged in climate change mainstreaming processes, and it has been recommended that a national climate change body be established to coordinate all areas of climate change including research, capacity-building, adaptation and mitigation (GOM 2010f).

The Government has also committed to having the cabinet approve the revised National Population Policy before the end of 2012. This will cover, inter alia, the links between the environment, natural resources and population and provide multi-sectoral guidance in ensuring the integration of population dynamics and emerging issues such as climate change into national, sectoral and decentralized development plans and programmes. The Government of Malawi has also, for the first time, prioritized population and sustainable development into a stand-alone sub-theme under social development in its Malawi Growth and Development Strategy (MGDSII: 2011-2016). Environment, natural resources and climate change have also been prioritized as a stand-alone theme in the same MGDS II.

Additionally, a National Disaster Preparedness and Relief Committee process is aimed at the formulation of a National Disaster Risk Management Policy which is incorporating issues of climate change. The policy will facilitate the effective coordination of disaster risk management programmes in the country and ensure that disaster risk management is mainstreamed into the development planning and policies of all sectors in the country. Notably, Malawi is a signatory to the Hyogo Framework for Action.

DoDMA has managed to support communities affected by climate change-related hazards. However, the recommendations of the Malawi Vulnerability Assessment Committee (MVAC), coordinated by DoDMA at the district and national levels, have not been accepted in many cases. For example, in Karonga, the Director of Development and Planning (DPD) indicated that the MVAC findings are questionable and not owned by local institutions. DoDMA's support also rarely includes population issues or urbanization. Previous studies have shown that urban populations are not receiving the support they require because they do not have the traditionally accepted structures that are used for channeling aid.

In addition, there is a significant gap in the coverage of disaster reporting and support in urban areas. District commissioners' offices or city councils conduct assessments and submit them to DoDMA for relief assistance. However, disaster risk management committees are usually formed at the village and district levels, so district councils are actually better able to respond to disasters than city councils. DoDMA has, in fact, indicated that there is no consistent reporting of disaster impacts from cities, pointing to the unreliable and inconsistent reports on property damage and other impacts of the recent rains in Mzuzu as an example. City councils also tend not to consider disaster risk issues, particularly in zoning, housing construction and other development projects. DoDMA has advised that there is a need for planning authorities in urban areas to work closely with them, but to this point this has not happened.

Until now, consideration of environmental risks has been consistently omitted from planning. Discussions with the Environmental Affairs Department made clear that mitigation rather than adaptation continues to be a priority in the response to climate change and that deforestation in and around the cities is one of the central focuses. One of the problems in regard to land use is a lack of policy harmonization, for instance, between water and agriculture. Forests and catchment areas have not been preserved. Developers are supposed to get approval from EAD, including an Environmental Impact Assessment, but they often do not, or do so only after building has begun. There is political will within the EAD to change the nature of development, but the EAD does not have the political support within the government system to enforce this objective.

The role of local authorities

There is considerable recognition of the need to involve and support local authorities (including city assemblies) in reducing the risk from environmental hazards and climate change: For example, a strategic goal in Malawi's 2010 report on progress towards the Hyogo Framework for Action (GOM, 2010d) recognized the need for investment and proactive measures to support local development structures at district and city assembly levels. Indeed, the Local Government Act of 1998 mandates local authorities to do all planning, and, while the power of controlling development is held by the Minister responsible for planning, this task has been delegated to the local authorities in Blantyre, Lilongwe, Zomba and Mzuzu with specific town planning committees mandated to control development (GOM, 2010e, p. 31).This is explicitly linked with the broader issues facing human settlements in Malawi as a result of urbanization, including the provision of adequate safe housing for a growing urban population. The Hyogo Framework for Action report also identified the absence of a policy framework for human settlements and the need for disaster risk reduction to be incorporated in the design of these areas.

The Second National Communication on Climate Change, however, does not make explicit mention of the role of sub-national levels of government in reducing vulnerability and risk for urban residents. It does recognize the "limited institutional capacity [of] the city and town assemblies" (GOM, 2010f, p. lxxxi) as a barrier to mitigation, and recommends that "enhancing the capacity of City and Town Assemblies" become a key element for supporting mitigation (Section 5.4).

The literature generally acknowledges the importance of actions taken by local authorities to address climate change risk. For instance, Stringer et al. (2010, p. 157) conclude:

> The current trend towards urbanization in Malawi highlights the need to define a clear role for local governments in urban areas to better engage them in the adaptation process. In doing so, this could provide multiple benefits across a range of different sectors and enhance support for the local practices and adaptations that rely on existing rural-urban linkages.

Despite these important linkages, city councils are still not represented in the existing management structure. Indeed, overall budgetary allocations from the central government to city councils are very small, and national statistics indicate that progress towards most of the Millennium Development Goals is lagging in Malawi's urban centres (Munthali, 2011a). Given the findings about vulnerability and potential climate impacts within cities provided in this report, as well as the strong and constant links city policymakers have with climate-related projects, one clear recommendation is that the councils of the main cities be formally included in both the gathering of the necessary information to plan for risk reduction and in the implementation of specific activities. This will require substantial increases in the financial and technical resources available for this purpose.

NGOs and climate change response at national and local levels

Most of the non-governmental organizations working in Malawi have a rural development focus for both poverty reduction and climate change response. The Civil Society Network on Climate Change, coordinated by the Centre for Environmental Policy and Advocacy (CEPA), is the main inter-NGO platform for advocacy on climate change issues. The network has 22 members, including national and international NGOs. The national NGO members focus heavily on disaster risk reduction, particularly for floods and droughts. Most of these concentrate on small-scale agriculture and crop diversification. Key climate change issues for the network include mainstreaming such concerns into the planning process, influencing allocation of resources towards environment and climate change-related issues (including those of lower-level urban centres) and capacity-building of implementing institutions.

There are few urban activities undertaken by the members of the network, many of whom focus on community-based adaptation in rural or peri-urban areas. The Executive Director of the Centre for Environmental Policy and Advocacy explained that it was about targeting need and "the old thinking that the ones that need support are in the rural areas". Donors drive much of the prioritization of work at the national level, and there is a sense that donors are unlikely to be sympathetic towards work in urban areas on the assumption that the latter are already better off. Mkwambisi et al. (2012) also suggest that lack of official administrative structures in urban areas, such as the Area Development Committees and Village Development Committees in rural areas, has resulted in the urban poor being unable to access services from the Government.

Some activities are increasingly linked to rural trading centres, and urban areas rely heavily on rural areas to supply food and resources for energy and construction. Many of the specific resources identified by the NGO community as a means of enhancing the adaptive capacity of low-income communities are also explicitly rural in their focus:

For example, CARE's Community-Based Adaptation Toolkit[6] identifies agricultural skills, farmer-based organizations, irrigation infrastructure, seed and grain storage and micro-insurance as the key forms of community capital that need to be supported—most of which have only limited relevance in urban contexts.

There is increasing recognition of the potential for community-based responses to climate change in low- and middle-income nations, specifically around community-based adaptation (CBA), and several CBA projects have been implemented in rural Malawi. CBA is based on the premise that local communities have the skills, experience, local knowledge and networks to undertake locally appropriate activities that reduce vulnerability to a range of factors including climate change (Ayers and Forsyth, 2009). However, in practice, most CBA has been undertaken in rural communities, and to be effective in towns and cities it will have to accept a broader and more complex definition of "community" that is not based solely on restricted geographical location and engages in the more complex political economies characteristic of urban areas (Dodman and Mitlin, 2011). If this can be done through community organization and the development of collective solutions, then the CBA approach has the potential to link local environmental conditions to the broader institutional frameworks shaping urban development (Soltesova et al., forthcoming).

Although not explicitly addressing climate change, the type of activities undertaken by the Centre for Community Organization and Development (CCODE) can contribute significantly to building resilience for low-income urban residents. CCODE is a support NGO for the Malawi Homeless People's Federation, and its role is to strengthen the ability of communities to identify alternative ways of addressing everyday challenges. Its focus, determined by community members, is on resilience, savings, conducting enumerations and negotiating with the private sector and government. Programme areas are concentrated on land and housing, water and sanitation and health and livelihoods. Mzuzu, Blantyre and Lilongwe all contain project sites.

Conclusion: Bringing Spatial Data to Urban and Climate Adaptation Planning

Malawi has been able to initiate an impressive process to establish a climate response framework, albeit one with significant gaps—gaps that are shared by many other countries as well, some with far more resources than Malawi. This chapter has examined both climate vulnerability and adaptation responses in the context of population dynamics—particularly urbanization—and how spatial analysis and visualization of census data can be a defining data source in understanding vulnerability.

As described above, the analytical methods used in this chapter are not overly complex. The most challenging part involved processing the census data and census geography in order to link the two, a prerequisite for spatial analysis. This analysis represents the first effort to do this in Malawi, and as such it met with challenges that in other contexts may have already been addressed. Despite the hurdles, the results have shown how a range of demographic and socioeconomic factors, coupled with exposure to particular hazards, can contribute to the vulnerability of households and communities both around and within Malawi's urban areas.

In addition, despite the impressive efforts and technical capacity of many government departments, data about population dynamics have not been incorporated into climate change responses. This has resulted in a limited understanding of vulnerability and in the exclusion of urban areas from priority concerns. Integrating urbanization, spatial distribution and its links to exposure and census-based indicators of sensitivity and adaptive capacity into the climate response can help to ensure that Malawi's climate change planning is better targeted to meeting the needs of the most vulnerable groups. Furthermore, the mapping of these results can provide a powerful means of communicating differential vulnerability and adaptive capacity to key stakeholders, from government to NGOs, community leaders and the private sector.

Additional work remains. These data and results need to be jointly examined with stakeholders in Malawi to ensure their validity and to identify entry points for influencing policy. Hazard mapping is still limited in Malawi, meaning that climate-relevant geography is not well identified. Eventually, the building blocks of the census will allow data to be produced for specific geographies: flood plains, heat island effects, precipitation and the like. Malawi's National Statistical Office has human and hardware resources in GIS and could eventually be in a position to generate results for climate exposure geography. It is also critical that, in preparing for the next census, the NSO makes maximum use of its GIS capacity and infrastructure by enhancing the process of digitizing census maps. Enumerator areas remain the best building blocks for generating spatial results, and it would be ideal if the digitization process captured them more accurately in the next census.

Practical, intersectoral and participatory adaptation planning and programmes remain a work in progress all over the world, particularly in countries where resources are limited. There is still a lack of clarity in the emerging National Adaptation Plans (NAPs) as defined during the COP17 negotiations in Durban in 2011 and a lack of data on vulnerability is one of the key gaps. To the extent that census data can be effectively marshaled for adaptation planning, it will go a long way towards creating an evidence-based foundation for effective climate change responses.

Notes

1. This includes papers on urban agriculture (Mkwambisi, 2008 and 2010; Mkwambisi et al., 2011); waste management (Lilongwe City Council [LCC], 2010; Chipeta and Binauli, 2005; Matope, 2002; desertification (Stringer et al., 2010); spatial planning (Brown, 2011); vulnerability assessments (see DoDMA), and climate change and economic development in (Munthali, 2011b).

2. IIED and UNFPA are currently engaged in a similar programme of work in Indonesia.

3. Documents reviewed include the Second National Communication (GOM, 2010d), the State of Environment Report (GOM, 2010e) and the Malawi Growth and Development Strategy II (2011-2016). From government departments and ministries, interviews were conducted with the Ministry of Development Planning and Cooperation (MoDPC), Environmental Affairs Department (EAD), National Statistics Office (NSO), Department of Disaster Management (DoDMA) and the District or City Councils of Lilongwe, Blantyre and Karonga. Among United Nations organizations, information was collected from United Nations Development Programme (UNDP), UNFPA and the United Nations Human Settlement Programme (UN-HABITAT).

   Non-governmental organizations that were covered include the Centre for Community Organisation and Development (CCODE), National Smallholder Farmers Association of Malawi (NASFAM), Centre for Environmental Policy and Advocacy (CEPA), the Coordination Unit for the Rehabilitation of Environment (CURE), Environment Africa, Foundation for Community Support Services (FOCUS) and the Red Cross. From academia, data was gathered from Leadership in Environment and Development in Southern and Eastern Africa (LEAD-SEA), Bunda College of Agriculture and Malawi Polytechnic.

All quotations from officials from Government, NGOs and United Nations Organizations (unless otherwise attributed) are from interviews conducted by the authors in September and October of 2011.

4. Within-city analysis of intercensal change is beyond the scope of this chapter, which only examines 2008 census data at the small-area level.

5. The Secure Tenure Index is used in the estimation of slums prepared for MDG 7.10. The five components of this index are electricity connection, regulatory compliance of structure, permanency of structure, connection to the sewer system and water access within 200 metres (Herr and Karl, 2002). Four of these five—the exception being regulatory compliance—can be found in some form in the Malawi census (and many others). All STI references are, therefore, an adjusted version using just the four available inputs. A range of statistical comparisons with STI calculations in other contexts suggested that the adjusted version is sufficiently robust.

6. http://www.careclimatechange.org/tk/cba/en/Open_Toolkit.html

References

African Food Security Urban Network (AFSUN). 2011. *AFSUN Policy Brief: Blantyre*. Website: www.afsun.org, last accessed 12 October 2012.

Ayers, J., and T. Forsyth. 2009. "Community-based Adaptation to Climate Change: Strengthening Resilience through Development." *Environment* 51(4): 22-31.

Balk, D., et al. 2009. "Mapping Urban Settlements and the Risks of Climate Change in Africa, Asia and South America." Pp. 80-103 in: *Population Dynamics and Climate Change*, edited by J. M. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Brown, D. 2011. "Making the Linkages between Climate Change Adaptation and Spatial Planning in Malawi." *Environmental Science and Policy* 14(8): 940-949.

Chipeta, L., and L. Binauli. 2005. "Domestic Solid Waste Management Problems in Urban Malawi: The Case of Blantyre City." Pp. 82-93 in: *Physical Planning in Malawi*, edited by M. A. Zeleza-Manda. Lilongwe, Malawi: Alma Consultancy.

Dodman, D., and D. Mitlin. 2011. "Challenges for Community-Based Adaptation: Discovering the Potential for Transformation." *Journal of International Development*, DOI: 10.1002/jid.1772.

Government of Malawi (GOM). 2010a. "2008 Malawi Population and Housing Census Thematic Report on Spatial Distribution and Urbanisation." Zomba, Malawi: National Statistical Office, GOM.

_______. 2010b. "2008 Malawi Population and Housing Census Thematic Report on Migration." Zomba, Malawi: National Statistical Office, GOM.

_______. 2010c. "Malawi Population Projections." Lilongwe: Malawi: National Statistical Office, GOM.

_______. 2010d. "National Progress Report on the Implementation of the Hyogo Framework for Action (2009-2011)." Lilongwe: Commission for Poverty and Disaster Management Affairs, GOM.

_______. 2010e. *Malawi State of Environment and Outlook: Environment for Sustainable Economic Growth*. Lilongwe, Malawi: Ministry of Natural Resources, Energy and Environment.

_______. 2010f. "Second National Communication of the Republic of Malawi to the Conference of the Parties of the United Nations Framework Convention on Climate Change." Lilongwe, Malawi: Ministry of Natural Resources, Energy and Environment, GOM.

_______. 2009. "2008 Malawi Population and Housing Census Main Report." Zomba, Malawi: National Statistical Office, GOM.

_______. 2006. "Malawi's National Adaptation Programme of Action." Lilongwe, Malawi: Environmental Affairs Department, Ministry of Mines, Natural Resources and Environment, GOM.

Guzmán, J. 2009. "The Use of Population Census Data for Environmental and Climate Change Analysis." Pp. 192-205 in: *Population Dynamics and Climate Change*, edited by J. Guzmán, et al. 2009. New York and London: UNFPA and IIED.

Herr, H., and G. Karl. 2002. Estimating Global Slum Dwellers: Monitoring the Millennium Development Goals 7, Target 11." UN-HABITAT Working Paper. Nairobi: Monitoring Systems Branch, Global Urban Observatory, UN-HABITAT.

Huq, S., and J. Ayers. 2007. “Critical List: The 100 Nations Most Vulnerable to Climate Change.” *Sustainable Development Opinion*. London: IIED. Website: http://pubs.iied.org/pdfs/17022IIED.pdf?, last accessed 13 October 2012.

Kambewa, P., and L. Chiwaula. 2010. “Biomass Energy Use in Malawi.” Background paper prepared for the IIED for an international Ecosystems Services for Poverty Alleviation (ESPA) workshop on biomass energy, Parliament House Hotel, Edinburgh, 19-21 October 2010. Website: http://pubs.iied.org/pdfs/G03075.pdf, last accessed 13 October 2012.

Lilongwe City Council (LCC). 2010. “Lilongwe City Waste for Wealth Baseline Study Report on Waste Characteristics.” Lilongwe, Malawi: Lilongwe City Council.

Matope, J. J. 2002. “Blantyre City Environmental Profile: Final Report for UNDP and UN-HABITAT.” Blantyre, Malawi: Blantyre City Assembly.

Mkwambisi, D. D. 2010. “Urban Land Supply.” Ch. 6 in: *Malawi Urban Housing Sector Profile*, edited by A. G. Tipple. 2010. Nairobi, Kenya: UN-HABITAT.

_______. 2008. “Urban Agriculture and Food Security in Lilongwe and Blantyre, Malawi.” Ch. 5 in: *Agriculture in Urban Planning: Generating Livelihoods and Food Security*, edited by Mark Redwood. 2008. London: Earthscan Publishing and the International Development Research Centre (IDRC).

Mkwambisi, D. D., E. D. G. Fraser, and A. J. Dougill. 2012. “Urban Agriculture, Institutions and Development.” Pp. 73-76 in *A Planet for Life: Towards Agricultural Change*, edited by P. Jacquet, R. K. Pachauri, and and L. Tubiana. New Delhi: The Energy and Resource Institute.

_______. 2011. “Urban Agriculture and Poverty Reduction: Evaluating How Food Production in Cities Contributes to Food Security, Employment and Income in Malawi.” *Journal of International Development* 23(2): 181-203.

Montgomery, M. 2009. “Urban Poverty and Health in Developing Countries.” *Population Bulletin* 64(2).

Munthali, T. 2011a. “Millennium Development Goals and Sustainable Urbanisation in Malawi.” Paper presented at the Malawi 2nd Urban Forum, Crossroads Hotel, Lilongwe, Malawi, 27-28 October 2011. Lilongwe: UN-HABITAT and the Government of Malawi.

_______. 2011b. “Do Population Dynamics Matter for Climate Change and Sustainable Development: Lessons for Malawi from African Case Studies.” Paper prepared as part of the United Nations “CC:Learn” Climate Change Training Imitative Workshop and presented at the Environment and Climate Change Symposium, Crossroads Hotel, Lilongwe Malawi, 19-21 October 2011.

National Statistical Office (NSO) and ICF Macro. 2011. *Malawi Demographic and Health Survey 2010*. Zomba, Malawi, and Calverton, Maryland, USA: NSO and ICF Macro.

Romero-Lankao, P., and D. Dodman. 2011. “Cities in Transition: Transforming Urban Centers from Hotbeds of GHG Emissions and Vulnerability to Seedbeds of Sustainability and Resilience: Introduction and Editorial Overview.” *Current Opinion in Environmental Sustainability* 3(3): 113-120.

Satterthwaite, D. 2004. *The Under-estimation of Urban Poverty in Low- and Middle-income Nations.* Human Settlements Working Paper, Poverty Reduction in Urban Areas Series. No. 14. London: IIED.

Soltesova, K., et al. (Forthcoming [2013]). “Community Participation in Urban Adaptation to Climate Change: Potential and Limits for CBA Approaches.” In: *Community participation in urban adaptation to climate change: potential and limits for CBA approaches*, edited by J. Ayers, et al. London: Earthscan.

Stringer, L., et al. 2010. “Adaptation to Climate Change and Desertification: Perspectives from National Policy and Autonomous Practice in Malawi.” *Climate and Development* 2(2): 145-160.

United Nations. 2012. *World Urbanization Prospects: The 2011 Revision* (POP/DB/WUP/Rev.2007). New York: Population Division, Department of Economic and Social Affairs,United Nations.

UNFPA. 2007. *The State of World Population: Unleashing the Potential of Urban Growth*. New York: UNFPA.

UN-HABITAT. 2011a. “Malawi: Blantyre Urban Profile.” Nairobi: UN-HABITAT.

UN-HABITAT. 2011b. “Malawi: Zomba Urban Profile.” Nairobi: UN-HABITAT.

UN-HABITAT. 2011c. “Malawi: Mzuzu Urban Profile.” Nairobi: UN-HABITAT.

CHAPTER 8

The Challenges of Adaptation in an Early But Unassisted Urban Transition

George Martine and Ricardo Ojima

Introduction

The increasing concentration of population in towns and cities of the developing world presents the most pressing challenge, and the greatest opportunity, for future adaptation efforts globally. Urban areas are, on the whole, more resilient to climate variability because they favour economic productivity, the generation of employment and, on the aggregate, greater access to social benefits—all of which enhance the capacity of urbanites to adapt to climate change. Moreover, urban economic production and, thus, the generation of employment and income for urban populations are much less dependent on the climate. Rural livelihoods rely to a greater extent on favourable weather and are more likely to be adversely affected, for longer periods of time, by climate adversity and unexpected fluctuations.

On the other hand, urban areas are adding growing masses of population groups that are often the most vulnerable to climate change—the urban poor in exposed areas. The universal aggregated advantages of towns and cities, in terms of income and living standards, hide the fact that they also include a large and increasing proportion of the very poor and most vulnerable, both in the North and global South. The poor are more vulnerable because they are most exposed to the risk and almost always suffer the most from the consequences of disasters. In this context, it is critical to observe that the current urban population of developing regions is expected to more than double by mid-century, thereby exposing sizeable population contingents to hazardous and risky situations. The consequences of not preparing adequately for extreme climate events have already been highlighted in the calamity rates presented by several cities, even in the developed world – as illustrated by the case of New Orleans after Hurricane Katrina. Yet the lack of defenses in urban areas, and the extreme inequalities that underlie it, are not inevitable. More effective policies are required in order to take advantage of urban concentration for both mitigation and adaptation and to minimize climate-related risks for the growing masses of urban poor.

Understanding vulnerability as a multidimensional and multi-scale concept helps to move research and policies beyond a focus on the simple economic capacity to face environmental risks and dangers. The potential advantages of urban concentration for adaptation have to be nurtured and cannot be taken for granted. The vulnerability of individuals or groups is magnified or reduced relative to the types of social and institutional mechanisms they can activate (Ojima and Marandola, Jr., 2011; Hogan and Marandola, Jr., 2005; Marandola, Jr., and Hogan, 2007). Even when poverty conditions are similar, the relative efficacy of urban planning, differential access to systems of prevention and alert, and the relative capacity of different groups to activate diverse forms of support, all generate different outcomes in the event of natural disasters.

Dealing with urban vulnerabilities requires specific guidelines and policies that are consistent with their bundles of stresses and assets. But what are these guidelines and policies? What can be done to maximize the advantages of urban concentration in reducing vulnerability and to limit the damages of climate-related threats in urban areas?

There has been widespread agreement that adaptation efforts under the threat of global climate change need to be proactive. Post-hoc adaptation is nothing new: all societies have been obliged to adapt to change of one form or another (Adger et al., 2009; Giddens, 2010). Given the current context, however, it is critical to move towards anticipatory adaptation, particularly in rapidly-urbanizing regions. From that standpoint, the fact that most urban growth in Africa and Asia is still to come constitutes a favourable scenario—at least in principle. These regions have a valuable chance to prepare better for potential risks. To do so, however, they will need better strategies and policies than the ones adopted so far in order to promote positive and forward-looking approaches (Martine and McGranahan, 2010; Martine, 2011).

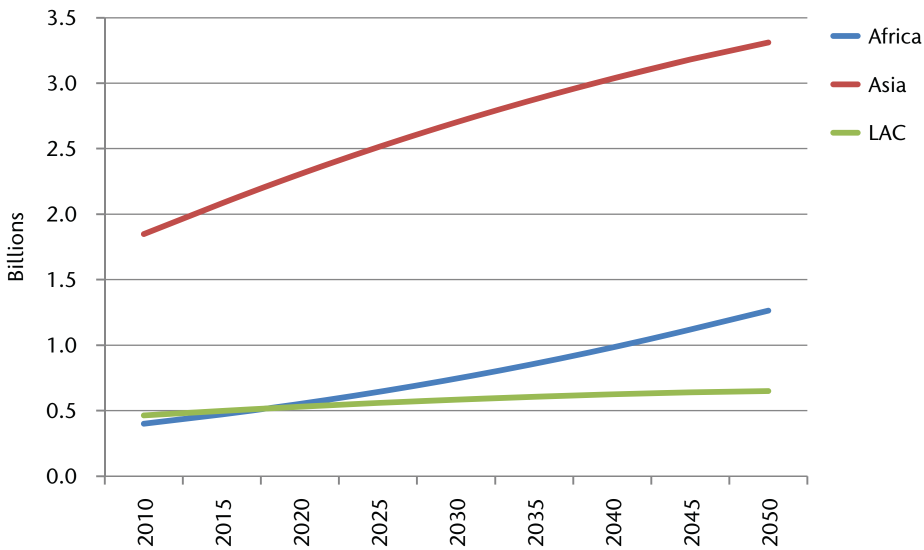
To help in this reflection and the resulting design of necessary strategies, this chapter presents a case study of Brazil, a developing country which has practically completed an early urban transition *without* the benefit of essential proactive policies, and whose urban population has already suffered severely on repeated occasions from natural disasters because of that oversight.

Two types of issues emerge from an examination of Brazil's experience. First, a review of urban growth processes in relation to current vulnerabilities suggests that the present exposure of the poorer segments of today's urban inhabitants to the risks of natural disasters has its roots in the negative attitudes and the resulting policy stances adopted by decision-makers over time with regard to the process of urbanization. This reflection is of enormous importance for other developing countries which are now in the early stages of their own urbanization process and which, for the most part, are facing this transition with the same types of unhelpful negative attitudes (See Chapter 2).

Second, the analysis of vulnerability and resulting adaptation needs in current-day Brazil enables us to reflect on how the impacts of urban growth on vulnerability and resilience are mediated by governance issues in basic areas such as land use, sanitation and transportation. Making the right decisions early, while developing countries are still in the incipient stages of their urban transition, is a particularly critical and urgent necessity. Many of the differences between an energy-saving compact city and a sprawling one, or between a resilient city and a vulnerable one, tend to be fixed early in a city's development and are hard to reverse. The decisions that are now being taken—or not being taken—in the rapidly burgeoning cities of other developing countries will have enormous impacts on future adaptation to extreme weather.

As shown in Figure 8.1, the absolute size of the urban population in developing regions has experienced enormous increases, and this growth is expected to continue. By mid-century, Africa, Asia and the Latin American and Caribbean (LAC) regions will have amassed a total of 5.2 billion urbanites, doubling their current urban population and dwarfing the 2.9 billion remaining in rural areas. This huge increase in urban population will have enormous significance for mitigation and adaptation, especially in Africa and Asia, which will add 2.3 billion new urbanites in the next four decades. Whatever the dimension of their urban problems now, they will be exacerbated by the urban growth that is still to come, despite declining rates of growth. The manner in which that growth evolves under globalized economic competition will determine the socio-economic future of humankind, and the way in which rapidly-growing urban areas prepare for and react to climate change will largely determine the outcome of global adaptation efforts.

Figure 8.1: Number of Urban Inhabitants, Africa, Asia and LAC, 2010-2050 (in billions)



Source: United Nations, 2012.

In contrast to most of the developing world outside of Latin America, Brazil has had an early and rapid urban transition, with some 85 per cent of its population already living in towns and cities, and more than a third of those in cities of one million or more inhabitants. Focusing on the determinants and characteristics of adaptation needs in a developing country that has essentially completed its urban transition can provide important lessons for other countries that are currently on the cusp of massive urban growth.

The following section briefly describes Brazil's urban transition and discusses its significance for the current status of vulnerability in urban areas. This is followed by a discussion of specific urban characteristics that are having particularly important consequences for adaptation in Brazil, namely land use, city location and growth patterns, sanitation and transportation.

Brazil's early urban transition[1]

Rural-urban migration began in earnest in Brazil during the 1930's due to a combination of factors. The economic crisis of the 1930s devastated the country's rural economy and forced it to adopt urban import-substituting industrialization at a time when declining mortality rates and a surge in international migration were producing accelerated rates of demographic growth. The Second World War greatly intensified the demand for industrial products and attracted large waves of migrants from sluggish agricultural areas, as well as immigrants from abroad. By 1950, some 36 per cent of Brazil's population was residing in urban areas, a figure comparable to the proportion only found fifty years later in Africa and Asia.

Import-substituting industrialization, supported by diverse federal Governments during the entire 1930-1980 period, continued to promote urbanization. Meanwhile, sustained decreases in mortality accelerated population growth, multiplying the stock of potential migrants in rural areas while also quickening natural increase in towns and cities. Policies by the military Government aimed at modernizing agricultural production in the 1960s and 1970s ended up promoting further land concentration and expelling all types of small farmers and rural workers at a rapid pace. As shown in Table 8.1, rural-urban migration increased from 3 million in the 1940s to 17 million in the 1970s. A total of 41 million migrants trekked to urban areas over the period from 1940 to 1980, equivalent to more than half of the country's total population growth during that cycle. The number of urban localities having 20,000 or more inhabitants increased from 29 to 330 during the same period, while the total number of people living in towns and cities increased by more than 69 million.

Table 8.1: Rural-urban Migration, Increase in the Number of Cities and in Urban Population, Brazil, 1940-1980

Population Movements	Period				
	1940-1950	1950-1960	1960-1970	1970-1980	1940-1980
Rural-Urban Migration (in millions)	3	7	14	17	41
Increase in the Number of Cities with 20,000 + inhabitants	29	65	92	144	330
Population Increase in urban areas (official definition), in millions	6.0	13.2	20.9	29.1	69.2

Source: Calculated from IBGE, Demographic Censuses, various years.

In short, over a very brief period, Brazil was, somewhat unintentionally, converted from a rural-agricultural country to an urban-industrial one. This transformation was neither planned nor chosen. The people leaving rural areas were, for the most part, forced to do so en masse by a combination of agricultural policies and rapid population growth. Meanwhile, urban decision-makers constantly tried to prevent, retard or complicate the arrival and settlement of new urban inhabitants, while also dealing ineffectively with rapid rates of natural increase (or births over deaths) within the cities.

No systematic efforts were made to plan for the accommodation and integration of this massive increment of new urban inhabitants. On the contrary, a variety of direct and indirect policies—some of which persist to this day—were implemented in a futile effort to reduce population growth in towns and cities (Feler and Henderson, 2008). This attitude can be cited as the main determinant of vulnerability in large segments of Brazil's urban population today.

Much to everybody's surprise, the frenetic rhythm of urban growth and concentration in Brazil subsided quickly from the 1980s onwards. Rural-urban migration decreased from 17 million in the 1970s to 6 million in the first decade of this century. Several reasons can be adduced to explain this quick turnaround. First, the 1980s were marked by the severest economic crisis since the 1929 world crash. Cities, particularly large and formerly dynamic cities, were the most affected. Drastic reductions in urban employment generated return migration and movement to smaller localities. This was aided by a process of industrial de-concentration from the nation's main economic hub which had already begun in the 1970s. Moreover, Brazil experienced an unusually rapid decline in fertility from the 1960s onwards. Total Fertility Rates fell from over six per woman in the 1960s to well below replacement levels today. This has resulted in decreased rates of growth in the already-depleted stock of potential migrants in rural areas, as well as in reduced rates of natural increase in urban areas. Nevertheless, as described later in this chapter, certain forms of urban concentration continued, with important consequences for vulnerability and adaptation.

Urban Poverty and Vulnerability

The highly stratified and un-ordained nature of Brazil's urban land market during its entire process of urban growth, coupled with the explicit lack of attention to the land and housing needs of the largest social contingent, obliged the urban poor to perennially settle as best they could on inadequate and inappropriate terrain. They inevitably ended up in the worse possible places, on land that nobody else wanted or that was unsuitable for human habitation: alongside steep slopes, on floodplains, toxic terrains, fragile ecosystems, tidal flats and so forth. Most of these squatter or informal settlements were considered illegal, giving urban authorities an excuse not to provide them with infrastructure and services. As the cities expanded, some of these occupied terrains became of interest to speculators and developers, resulting in the expulsion of the poor to even more distant and undesirable sites.[2]

Restriction of residence to such uninviting territories, often at a great distance from potential sources of employment and without services or infrastructure, unnecessarily accentuated human misery and became the starting point for a vicious cycle of poverty. It limited the possibilities of the poor to take advantage of what the city had to offer, impacting vulnerability both directly in terms of exposure and substandard infrastructure and indirectly through extending and deepening poverty.

Settlement patterns of the poor in the context of such unfavourable conditions have also had a broader impact on the cities themselves. Deforestation to clear space for housing – a practice that, it should be clarified, is not exclusive to poor people – has often been a direct cause of flooding. Since the poor often have little choice but to invade stigmatized or off-limit terrains, they have also occupied ecologically fragile areas and watersheds, thereby endangering the city's water supply and other ecosystem services. In the Metropolitan Region of São Paulo alone, some 2 million people are living in areas that were demarcated as environmental protection areas (Bonduki, 2011). Meanwhile, the occupation of natural buffer zones in urban floodplains and wetlands has not only endangered the lives and possessions of the poor, it has also increased the probability of flood damages in other parts of the city. For instance, the occupation of steep slopes and the removal of tree cover have increased the frequency of landslides that not only bury the residents themselves, but also spill over into roads, tunnels, streets and houses at lower levels.

The sprawling and haphazard patterns that typify the settlement of urban lands by poor people also make it much more difficult to put basic infrastructure into place, including roads and pathways that would facilitate the free circulation of residents. The sprinkling of such settlements throughout the city also creates hurdles for the design of effective mass transportation and increases the costs of implementing it. The destruction of precarious infrastructure during natural disasters, especially with regard to water supply and transportation, can become a serious impediment to emergency measures during times of crisis.

Historically, the main natural disasters experienced by Brazil were related to the severe recurrent droughts in the Northeastern region. However, in recent years, the more serious natural disasters have increasingly been linked to floods and landslides, especially in urban areas. Thus, between 2008 and 2011, more than 80 per cent of the people affected by "natural" disasters in Brazil, and 76 per cent of all deaths attributable to them, were victims of floods and landslides (Tominaga et al., 2009; EM-DAT: The OFDA/CRED International Disaster Database, 2012). In one famous recent case, an entire small community built on a landfill in the city of Niteroi was buried during heavy rains in April of 2010, leaving an estimated 100 people missing or dead.

The effects of deficiencies of urban planning affect more than the poor. The increased violence of weather-related events foreseen in climate change scenarios put entire towns and cities at risk. For example, a major tropical storm hit several smaller cities located in the mountainous region near Rio de Janeiro in 2011, killing 900 people and leaving another 13 thousand homeless (see Figure 8.2). A good proportion of these victims were from more affluent social classes. This episode helped waken authorities to the need for planning and monitoring in order to avoid disasters of this order of magnitude; however, practical responses are still embryonic.

In brief, the failure to foresee and prepare for massive urban growth, in which poor people made up the largest social category has left a legacy of preventable poverty and vulnerability in Brazilian towns and cities. What could have been done differently? It would have been totally unrealistic to provide housing for all who arrived in towns and cities. However, a viable strategy, once urban growth was accepted as inevitable, would have been to provide serviced land for the growing urban population, as suggested by UNFPA (2007, pp. 40-43). Although less ambitious than traditional housing schemes that futilely try to provide built-up and fully-serviced housing, this requires a radical

Figure 8.2: Flooding and Devastation in Cities near Rio de Janeiro, Brazil.

Photo 1.

©Marlene Bergamo/Folhapress

Photo 2.

©Marlene Bergamo/Folhapress

change in attitude towards urban growth and land planning. By contrast, the laissez-faire attitudes that have prevailed historically towards urban growth in Brazil have been responsible for much of the human tragedy and physical losses experienced during extreme climatic events.

Avoiding such negative policies and moving forward positively with urbanization can be identified as the main strategy that policymakers in the rapidly-urbanizing countries of Africa and Asia will have to adopt if they are to reduce the vulnerability of their growing urban population to future natural disasters. The importance of adopting a more proactive stance towards inevitable urban growth cannot be overestimated in adaptation efforts. The following pages will describe some of the areas in which inappropriate attitudes towards urban growth, especially in relation to the land and housing needs of the poor have increased vulnerability and made adaptation to climate change unnecessarily problematic in Brazil.

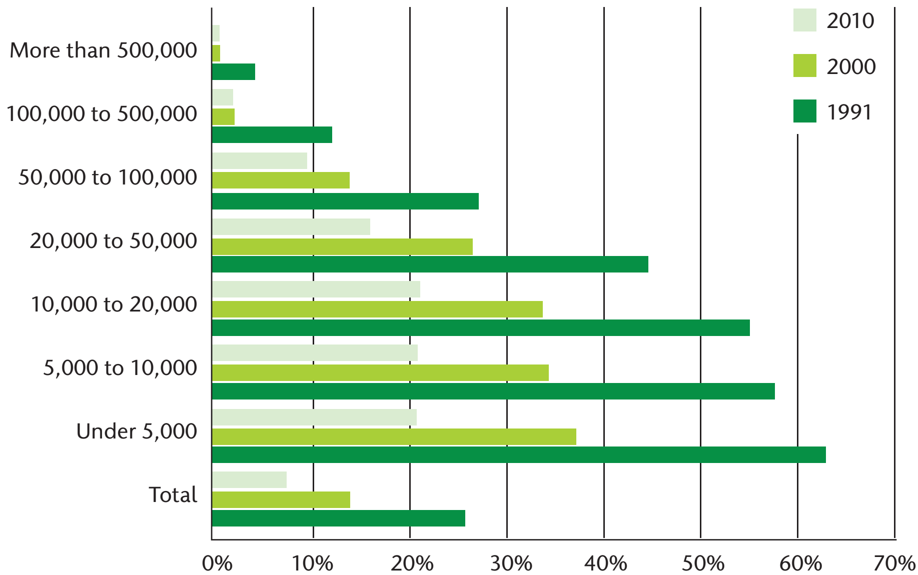
Sanitation

Neglecting the needs of the largest social category in urban growth is not limited to land use and housing. As elsewhere throughout the developing world, Brazil's informal settlements generally suffer from a lack of access to water, sewerage or solid waste management systems. Considering that the main forms of natural disasters that affect today's Brazilian population are floods and landslides, precarious sanitation inevitably multiplies the risks associated with these phenomena in the type of terrains most frequently occupied by the urban poor. This not only affects the health of these residents, but also pollutes rivers and ends up affecting the appearance, air quality, health, economic success and, therefore, the prosperity of the entire city (Martine, 2011). The efficacy of post-emergency adaptation responses are likely to be seriously compromised in such conditions.

The deficiencies of basic sanitation services in Brazil are attributable to governance issues rather than to population concentration. Rural-urban differences in access to clean water or sewage facilities are dramatic in favour of towns and cities. Moreover, at the aggregate level, larger urban areas are significantly better off in terms of sanitation. For instance, access to sewage facilities is directly correlated with the size of the municipality. Smaller municipalities and urban localities suffer from the same deficiencies in sanitation as informal settlements. More than 60 per cent of households in municipalities having less than 5,000 inhabitants have inadequate sanitation. Fortunately, these smaller municipalities contain only 2.3 per cent of Brazil's population and sanitation improves dramatically, at the aggregate level, with the size of the locality, as shown in Figure 8.3. In turn, however, larger localities have a greater concentration of shantytowns and poor people who are also underserved.[3]

Accumulated deficiencies in the sewage system in urban areas have a large effect on the aggravation of natural disasters. As a rule, sewage facilities are not provided in localities that lack other urban amenities, such as asphalted streets and effective drainage systems. Consequently, they are unlikely to be found in informal settlements. As of 2010, 53 per cent of the Brazilian urban population was still not connected to sewers and only 38 per cent of all sewage was being treated. Consequently, despite

Figure 8.3: Proportion of All Households Having Inadequate Sanitation by Size of Municipalities, Brazil, 1991-2010



Source: IBGE, 1991, 2000, and 2010.

the urban advantages in sewage connection, billions of litres of refuse end up being dumped *in natura* into rivers, lakes, aquifers and river basins, the margins of which tend to be densely populated, contributing to sickness and disease, particularly during the hot weather (Carlos, 2012). The indirect effects of natural disasters linked to climatic events, such as the incidence of leptospirosis or cholera in post-flooding periods multiply the socio-environmental vulnerability of cities. Even those groups not directly affected by floods or landslides can be subjected to diseases that reach their most contagious phase in post-disaster periods.

Rainwater drainage is another crucial component of preparedness for the tropical storms that are endemic to much of Brazil. Extensive paving of the urban surface with concrete and asphalt, together with the waterproofing and artificial re-channeling of natural water flows, are practices that directly contribute to an increasing number of flash floods and landslides. The inadequacy of urban drainage systems has its roots in flawed conceptions of water resource management, as well in the buildup of sediment and silt in drainage systems and in riverbeds due to erosion. All these serve to compound the problems caused by the lack of adequate sewage and garbage collection systems and, ultimately, to multiply the risks from extreme climatic events.

Such considerations suggest that most of the recent "natural" disasters in Brazilian urban areas associated with climatic events actually stem in large part from social, economic, demographic or political processes: That is, they are mainly of anthropogenic origin. Such a view is further confirmed in Table 8.2, which is based on a national survey of basic sanitation carried out by the Brazilian Census Bureau (PNSB 2008). This survey registered floods and overflows in 40.8 per cent of all municipalities at some time between 2003 and 2008 and investigated the "aggravating factors" in each of these events.

Table 8.2: Type and Frequency (%) of Aggravating Factors Encountered in Municipalities Affected by Floods and Overflows between 2003 and 2008 in Brazil

Major Regions	Inadequate Dimensions of Project	Obstruction of grills, manholes, etc.	Unsuitable construction	Intense and inappropriate land use	High water table	Physical interference in drainage system	Deforestation	Discharge of Solid Residues	Others
North	26.7	37.3	30.0	50.0	16.7	16.0	22.7	32.7	26.0
Northeast	22.4	34.5	31.4	45.8	17.4	18.0	17.9	30.3	22.4
Southeast	34.2	50.3	33.4	45.4	14.8	18.7	26.7	33.4	16.8
South	37.2	54.5	30.5	35.6	14.8	20.7	16.5	26.4	16.9
Center-West	28.9	35.5	28.9	35.5	17.4	14.9	20.7	29.8	23.1
Brazil	30.7	45.1	31.7	43.1	15.8	18.6	21.3	30.7	19.3

Source: IBGE, PNSB, 2008.

Although there seems to be some degree of overlap between a few of these response categories, the data undeniably reveal considerable "human error" underlying the exacerbation of natural events, chief of which is the irregular occupation of inadequate areas—in 43.1 per cent of the cases. Moreover, several other categories, such as "inadequate dimension of projects", "unsuitable construction" and "physical interference in the drainage system", point to ineffective planning and engineering. This information reflects both the impact of inadequate approaches to urban growth in Brazil, as well as the need to adopt better public policies, not only with respect to land use, but also in relation to construction, public works and urban expansion in general.

Overall, this survey would suggest that few of the municipalities that experienced floods or overflows had the disposition, interest and/or technical capacity to design and implement services in sanitation and storm-water management. The type of planning and engineering mistakes revealed in this survey reflect not only technical difficulties and lack of trained human resources, but also larger governance issues that are assuming increasing significance in the face of climate change and its probable impacts on the frequency, vehemence and consequences of extreme climatic events in the future. Shoddy construction practices, such as the irresponsible disposal of construction waste material, also reflect the tendency to cut corners and maximize profits.[4]

Although the data sources for Table 8.2 do not permit the correlation of the consequences of such practices for different social groups, it would seem inevitable that they most directly impact the informal settlements and the poorest residents of the municipalities affected.

Location and Growth Patterns: Significance for Adaptation

Adaptation needs and policies can be expected to vary in largely-unchartered ways according to a variety of a city's features. Location is probably the most significant determinant, but other characteristics such as city size, density, affluence and governance also influence needs and capability to adapt. City location does not follow a universal pattern; towns and cities of every size are found on every type of terrain and topography, from seaside to plains to mountain-tops and everywhere in between. Nevertheless, there are certain locations and patterns of growth that can be identified historically in most countries and that have significance for vulnerability and adaptation.

In the context of climate change, coastal cities have assumed heightened interest (see chapter 2). During the first centuries of its occupation by colonial powers, Brazil's urban areas were almost exclusively located on the coastline, in consonance with the outward-oriented economic interests of the Portuguese crown. Although inland occupation has progressed greatly in the last 100 years, the coastline still harbors a large proportion of Brazilian cities and population. As of 2010, some 28.6 million people resided on the coastline, equivalent to 17.8 per cent of the country's urban population. According to a study of populations at risk in Low Elevation Coastal Zones (defined as the area less than 10 meters above sea level and contiguous to the coast) by the Center for International Earth Science Information Network (CIESIN), the number of people at risk in the Brazil's LECZ increased from 9.7 in 1990 to 11.4 million in 2000: some 90 per cent of these inhabitants live in urban areas, according to these data (CIESIN, 2012).

Most of the population in coastal zones at risk to storms and flooding due to climate change are found in larger cities, as shown in Table 8.3. As of 2000, some 207 localities were at risk, the majority of these being smaller cities with less than 100,000 people. However, three-fifths of the population at risk resided in a city having at least one million people. Obviously, it will be necessary to devise adaptation strategies and proposals for all residential categories, including rural areas. Indeed, it is probable that smaller and sparsely settled localities will have fewer technical and financial resources to formulate effective plans. Nevertheless, this Table provides a first indication of the need to recognize the dimensions of potential calamities in larger cities and to focus greater attention on the needs of these centres.

Table 8.3: Number of Cities and Population Residing in Low Elevation Coastal Zones (LECZ), Brazil, 2000

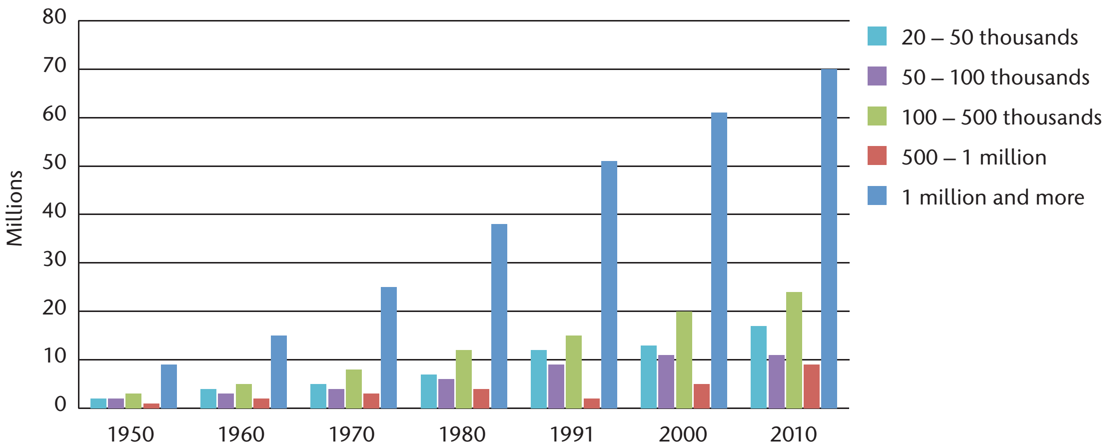
Size Class of Urban Localities	Number of Urban Localities from each size class in LECZ	Resident Population in each size class	% of Residents in LECZ, by Size Class
Under 100,000	176	1,598,391	15.83
100 – 500,000	16	1,378,853	13.66
500,000 – 1 million	4	1,075,323	10.65
1 – 5 million	10	4,070,652	40.33
5 million +	1	1,970,599	19.52
Total	207	10,093,318	100%

Source: CIESIN, 2012.

Patterns of Growth and Adaptation

The process of urbanization in Brazil over the last half century has been characterized by an increasing concentration of the urban population in large cities. The number of urban localities with 20 thousand or more inhabitants grew from 89 in 1950 to 870 in 2010, while the population living in such localities increased from 24 to 131 million. However, as shown in Figure 8.4, this growing urban population became increasingly concentrated in a few large cities over time. Thus, the number of urban agglomerations having a million or more inhabitants only increased from 5 to 16 during the period from 1950 to 2010, but the population of such localities swelled from 18 to 70 million in the interim.

Figure 8.4: Distribution of Urban Population by City-Size Class, Brazil 1950-2010 (in millions)



Source: For 1950 to 1980, CELADE, 2012; for 1991 to 2010, authors´ calculations based on IBGE, Demographic Censuses.

The 16 Metropolitan Regions (MRs) contained 53 per cent of the population of all urban localities having 20,000 or more inhabitants in 2010 and accounted for more than two-fifths of their population growth during the 2000-2010 period, as well as concentrating large clusters of the more vulnerable populations. In view of this, the significance of concentration into larger cities and, more specifically, the implications of these trends for the Brazilian capacity to adapt to climate change merits careful consideration.

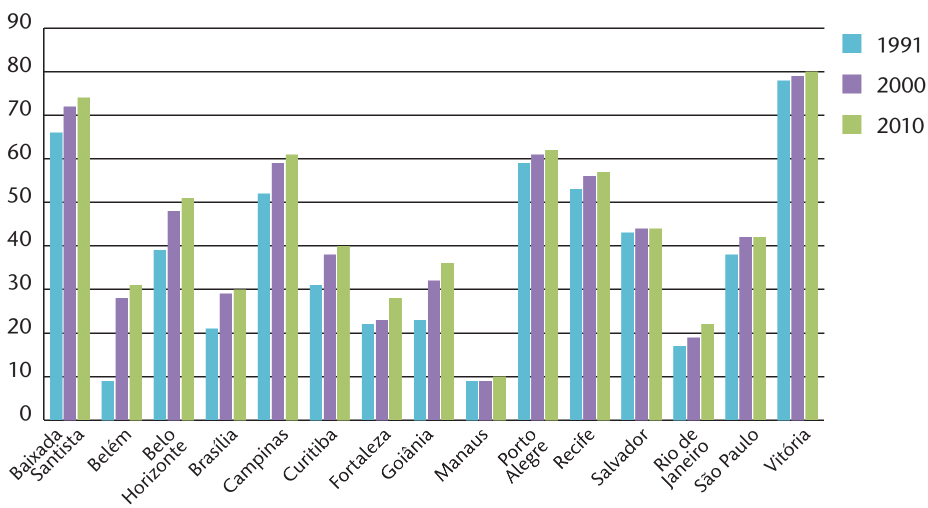
During recent decades, a major feature of growth in these larger cities has been their expansion into their respective peripheries, as shown in Figure 8.5. That is, as cities grow, they inevitably spread out into adjacent territories and administrative units. However, as a result of economic globalization, the spread of cultural patterns favouring suburbanization and improved travel facilities, outward territorial expansion has increased greatly in recent years (Ojima and Hogan, 2009a).

The first question that this observation raises is: What is the nature and effectiveness of existing political, administrative and technical entities to deal with the complex management issues that inevitably affect such large and heterogeneous agglomerations, particularly at times of climate crisis?

In general, as noted by a former Vice-Minister of the Ministry of Cities in Brazil, the situation is unpromising: "Despite its economic, political, social, demographic, cultural, territorial and environmental importance, there is a significant lack of Government in the Brazilian metropolises, evidenced by the incipient initiatives of inter-municipal and federative administrative cooperation. . . . The downturn verified in social policies during the years 1980 and 1990, notably in transport, housing and sanitation, besides the dismantling of the metropolitan agencies, has led our cities to the trivialization of urban tragedies. Despite its urgency, the metropolitan issue does not sensitize any political force or institution which assigns it a prominent place on the national agenda" (Maricato, 2011).

The fact is that as cities grow, the tendency is for them to become more fragmented, not only in spatial terms, but also in political and administrative ones. That is, responsibility for urban problems tends to be divided among a growing number of administrative entities and layers. However, some of the most critical problems of large urban areas extend over a much broader region and cannot be dealt with piecemeal. These key problems require a quasi-regional approach.

Figure 8.5: Proportion of the Metropolitan Population Residing in Peripheral Municipalities, 15 Brazilian Metropolitan Regions, 1991 to 2010



Source: IBGE, Demographic Censuses, 1991 to 2010.

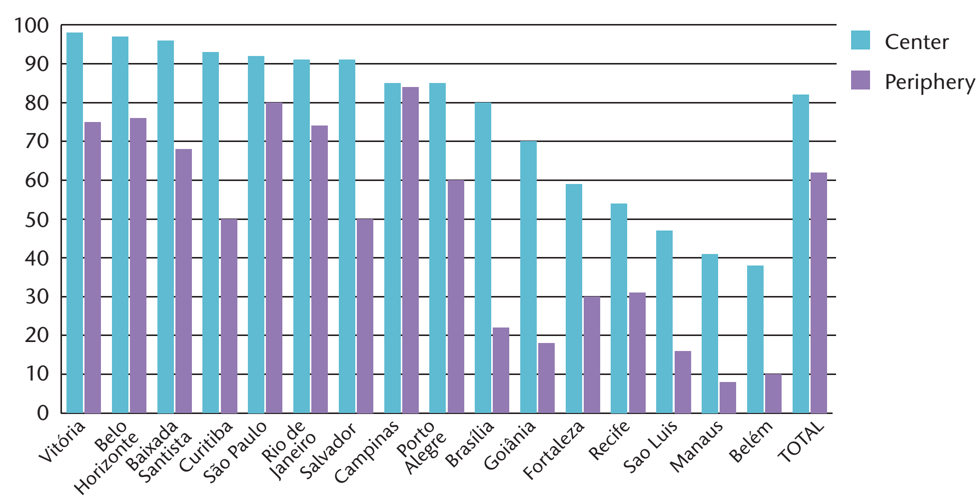
In the context of adaptation to climate change, the faster growth of urban peripheries in all 15 metropolitan regions highlights the need for urban management institutions that extend beyond the boundaries of particular municipalities. The metropolitan area of Belo Horizonte, for instance, has 49 municipalities, each with its own short-term elected administration, management system, technical capacity and responsibilities in key governance domains. Meanwhile, most of the critical metropolitan problems—whether in environmental issues, transportation, housing, water, sanitation or security—actually require both a longer term and larger-scale or regional approach. According to the 1988 Constitution, issues of land use regulation and zoning are governed by the municipalities. This further heightens conflicts of interests and thus leads to fragmentation or even contradictory policies within a metropolitan region (Ojima and Hogan, 2009b). Such a division of responsibilities stymies not only planning and effective management of key urban processes, but also impedes quick operational responses to natural disasters.

Fragmentation of responsibilities for the urban territory in Brazil's larger cities has led to administrative inefficiency and compounds social and environmental problems (Magalhães, 2010). However, some progress is being made: On June 16 of 2011, a new system of urban management was sanctioned by law for the 39 municipalities of the São Paulo Metropolitan Region in order to deal in a cooperative and integrated manner with the key issues that affect this critical region. The challenges in implementing and replicating this model are numerous.

Several indicators attest to the significant differences in income and living standards between central and peripheral areas. For instance, the income of the population living in the central municipality of the MRs was 56 per cent higher than that living in their peripheral municipalities (Torres, 2002). This, in itself, has an obvious impact on adaptation possibilities. According to the 2010 Census, Brazil had some 6,000 shantytowns, in which 11.4 million people, or 6 per cent of the population, resided. It is generally agreed that this figure substantially under-enumerates the number of poor urban dwellings and residents in the country, but the point to be made here is that 90 per cent of these shantytowns were identified as located in Metropolitan Regions, the majority in peripheral municipalities.

In comparison to the central part of the city, the outskirts are also underserved in terms of sewage facilities, by comparison to the central part of the city, as shown in Figure 8.6. It is clear that the coverage of the sewerage systems varies significantly between MRs but,

Figure 8.6: Percentage of Households Linked to Sewage Networks in Central and Peripheral Areas of Metropolitan Regions, Brazil 2010



Source: IBGE, Demographic Census, 201 in all cases, the central cities have a more developed system. Contributing to this disparity is the fact that, as a result of the country's rapid fertility decline and changes in family arrangements, the number of households is expanding at a faster rate than that of the population, especially on the periphery of the MRs. During the 2000-2010 period, the number of households grew at an annual rate of 2.6 per cent and that of population at 1.5 per cent.

Urban Expansion, Transportation and Response to Extreme Climatic Events

Peripheral urban growth has additional implications for adaptation. In this connection, a key issue is related to the fact that the more rapid expansion of population and households in peripheral areas of MRs in Brazil has not been accompanied by a concomitant increase in economic activity and employment, nor by improvements in mass transportation.

The concentration of economic activity and of most public services in the original and central municipality still prevails in most cities, obliging more and more people to use some form of transportation on a daily basis. However, the socio-economic dynamics of the outskirts of many MRs are changing, and daily commuting also occurs in the opposite direction. Census data reveal that, in Brazil as a whole, the number of people who reside in a community different from that of their workplace rose from 7.3 million in 2000 to 11 million in 2010. Approximately two thirds of these commuters reside in a Metropolitan Region. Some 62 per cent of them travel daily from the periphery to the central city, while the remainder move to work in the opposite direction.

Increased dispersion and commuting can be seen as a process that, in itself, increases vulnerability for poor people: It exposes them to the daily perils and inconveniences of spending many hours a day on inadequate transportation, and obliges them to travel ever greater distances to access services and amenities that their urban residence should theoretically provide (Ojima and Hogan, 2009a). According to a recent nation-wide household survey (IBGE, PNAD, 2011), some 10 per cent of the Brazilian population spends more than an hour a day in journey to work. Thus, increased commuting brings into play one of the major and still rapidly-growing problems of large urban areas in Brazil—transportation. The connection between centre-periphery in the MRs and the consequent commuting imbroglio impacts adaptation efforts in very direct and important ways when extreme climate events occur.

Although a few cities such as Curitiba have made some headway in improving mass transit and reducing the number of private cars on city streets, Brazil as a whole is firmly committed to the automobile. The world's sixth largest car manufacturer, Brazil had an 86 per cent increase in the number of cars on its streets during the first decade of this century alone. Supported by fiscal incentives, this industry, together with its forward and backward linkages, is a huge cog in the country's economy, and its products appeal to an increasing consumer base as both a practical solution and a status symbol. Given the chaotic situation of public transport in most cities, driving has, in fact, almost become a necessity for the increasing numbers who can afford to buy an automobile. Cheaper prices, installment plans and a growing middle class have made this dream possible for rapidly-increasing numbers of people. As of 2010, 42 per cent of all households on the periphery, and 46 per cent of those in central cities of Brazilian MRs, possessed a private automobile, with the proportion being higher in the largest cities. This does not change the fact that the majority of the population still does not have access to private transportation. Historically relegated to distant and or inaccessible areas, the poorer population depends on what is generally a chaotic mass transportation system, whose efficiency diminishes even further as the number of private cars on the road is multiplied, in a classic double bind.

The problem is that, although the rapid doubling of cars on the streets fails to attend the needs of the majority, it is already bringing cities to a standstill, literally. No matter how much public money is spent on roadways, overpasses, parking garages and high speed lanes, the growing physical mass of automobiles surpasses traffic capacity. The traffic problems that are monstrous on good days and in nice weather inevitably increase during periods of intense rain. Brazil's largest city, São Paulo, has experienced gridlock on more than one occasion during heavy weather. Traffic jams of close to 300 Kilometers have been registered. People who live in poorer settlements and/or who depend on public transport are particularly subject to extreme discomfort and disruption of their lives in such circumstances.

The collision course between massive traffic problems and increasingly violent climatic events as a result of global climate change presages a magnification of the progressively more severe man-made 'natural' disasters in large Brazilian cities. Already, flash floods periodically wash away cars and pedestrians caught on lower-level street areas, while also invading households and buildings in the area. Poorer residential areas, as noted earlier, are most exposed due to construction in hazardous areas, on steep and unstable hillsides or on former mangrove swamps or tidal flats. Such problems, related to poor quality and location of housing, are compounded by the obstruction of natural drainage channels and massive sealing of the land area with concrete and asphalt pavement. In addition, the difficulties of locomotion in sudden storms are particularly distressful for poorer people, who are well aware of the fragility of their homes, and yet are most penalized by the aggravation of transportation problems in trying to reach them.

Moreover, as these climatic events intensify in frequency and violence, such immediate consequences of intense storms may also disrupt post-hoc responses, due to the difficulties of locomotion and lack of communication that creates gridlock during storms. Time is of the essence in emergency relief work. The mobilization of the necessary emergency services, equipment and first responders in the disaster area require open roadways, since this urgent work cannot be accomplished by air or water alone, especially if weather conditions continue unstable. Yet, the search for victims and rescue efforts needs to begin immediately after a disaster. Quick support to victims is also essential since the vast majority of those affected by a disaster will die within 72 hours of impact (Walker, 1991). Emergency management requires a free flow of information as well as of personnel from relief services, including fire fighters, police, ambulance crews and aid workers. Prevention of the disaster-related risks of disease must begin within hours of the event.

In short, it can be predicted that the response to increasingly frequent and progressively more intense climatic events is going to be severely hampered in large Brazilian cities by growing traffic problems. These reflect a prevailing culture, as well as economic and political decisions made at a much higher level. People want cars and purchase them as soon as they can minimally afford them. On another level, the economic benefits of the automobile are highly prized even by recent Worker Party administrations at the federal level. However, it has long been recognized that a model which stimulates the utilization of private transportation is a serious deterrent to the provision of efficient public transport. It is socially unjust and, ultimately, impossible to sustain. Moreover, the imminent threat of increasingly violent climatic events shows that this model will ultimately magnify the impacts of such events in unanticipated ways.

Such observations corroborate the notion that adaptation and response depend not only on infrastructure and technical management, but also bring in broader issues of justice and governance. Although the poor will always be the primary victims of bad governance, the response problems linked to the transit issues looming on the horizon in large Brazilian cities will ultimately affect all social classes.

Although unpopular with the upper-income classes, the decision to switch immediately and decisively to the support of public transportation during early stages of the urban transition would have enormously positive social and environmental implications. Moreover, the medium and long-term economic effects of investing in public transportation are likely to be at least as beneficial as is the current support for the private automobile. As extreme climate events become more frequent, reliance on public transportation systems will also be critical in facilitating more rapid and effective responses to natural disasters. Unfortunately, reversing the reliance on inefficient private transport in order to promote effective public transit systems is unpopular in a country that has accepted the global cultural value of the automobile as a symbol of status and an instrument of independence. Moreover, it would involve a redefinition of the development model that makes private transportation a main cog of its economic strength and political support. Changing this perspective in Brazil will take time; hopefully, the inevitable increases in transport problems will help to enhance awareness-raising and better policy decisions. This is a key domain in which change is imperative, for both mitigation and adaptation purposes

Conclusion

Without question, the primary locus of both demographic and economic growth today is in towns and cities. These already harbor half of the world's total population and, at the aggregate level, will account for all demographic increases during the coming years. Moreover, they concentrate increasing proportions of the world's more vulnerable people. Hence, as urbanization inexorably proceeds, adaptation efforts will inevitably have to pay increasing attention to the needs of highly concentrated masses of poor people in towns and cities of different sizes.

Decisions made now in countries that are still at an early stage of their urban transition will condition the resilience and vulnerability of their cities and of their urban population in the future. Such countries can make key decisions that will affect not only the lives of the poor but also make a significant difference in terms of overall preparedness for climate change. The experience of Brazil, a developing country that has undergone an early urban transition suggests that key areas for policy include location, land use and housing, basic infrastructure, especially in the area of sanitation, and transportation.

The use of land, and within this, the provision of land and housing for the poor, is perhaps the most critical element. In rapidly urbanizing developing countries, the lack of attention to the land and housing needs of the poor affects the sustainability and viability of the cities. The way land is used and the manner in which the urban population occupies space is highly critical for environmental outcomes and for the adaptation of the urban masses to weather-related natural disasters. Such observations heighten the need for effective forward-looking policies to guide the rapid growth of urban areas in developing countries.

Under current conditions, a large proportion of poor urbanites, including migrants, end up living in slums that are devoid of minimal infrastructure and services. Anything that can be done for the population already living in such areas, in terms of improving their housing and living conditions, will undoubtedly constitute a critical element in bolstering the capacity of the poor to withstand the effects of severe climate events. In particular, investments in urban sanitation and water supply infrastructure, along with more pedestrian and recurrent travails in collecting solid wastes and unblocking canals and storm sewers will all prove critical when the city is faced with severe weather events.

However, the main point to be made here is that such efforts aimed at improving the resistance capacity of *existing* slum populations, no matter how effective, are insufficient when viewed in a longer-term perspective. The towns and cities of developing countries, especially in Asia and Africa, can be expected to experience enormous rapid growth for decades to come. Under current conditions, a majority of these people will find their way into old or new urban slums. Preparedness requires a proactive approach to their settlement in appropriate locations.

The ability of cities in developing countries to adapt to climate change and to reduce vulnerability among their large contingent of poor people would be greatly improved if national and local Governments took proactive steps to deal with the land and housing needs of the growing contingents of the urban poor. Providing minimally serviced accessible land and basic infrastructure requires a radical change in approaches but would generate enormous dividends, not only for adaptation but also for the future of the cities themselves.

Notes

1. This and the next section briefly summarize excerpts from the work by Martine and McGranahan (2010 and 2012).
2. For instance, Rio de Janeiro's "Cidade de Deus" (City of God), made famous by a movie of that name, was created when the residents of well-located favelas were removed to a new settlement on the outskirts of the city in order to permit the construction of high rise apartments for the wealthy in the original favela locations.
3. Strictly speaking, the data in Figure 8.3 refer to municipalities by size, rather than urban localities. However, given that 85 per cent of Brazil's population is urban, the correlation between size of locality and of the municipality is high.
4. A recent study estimates that construction wastes amount to 0.55 tonnes per person per year in Brazil. São Paulo alone generates some 17 thousand tonnes of construction wastes per day; 70 per cent of that is discarded irregularly in open air sites, much of it on the banks of springs and streams. Information from a recently published book by Álvaro Rodrigues dos Santos, *Ecodebate*: http://www.ecodebate.com.br/2012/10/02, accessed 2 October 2012.

References

Adger, W. N., I. LorenzonI, and K .L. O'Brien. 2009. "Adaptation Now." Pp. 1-22 in: Adapting to Climate Change: Thresholds, Values, Governance, edited by Adger, N., I. LorenzonI, and K. O'Brien. New York: Cambridge University Press.

Bonduki, N. 2011. "O modelo de desenvolvimento urbano de São Paulo precisa ser revertido." Estudos Avançados 25(71): 23–36.

Carlos, E. 17 July 2012. "Os sem saneamento" (The Sanitation-less). Ecodebate.

CELADE (Latin American and Caribbean Demographic Centre). 2012. Ad hoc calculations of internal migration and urban growth in Brazil by Jorge Rodriguez and Daniela Gonzalez. Santiago, Chile: CELADE, Economic Commission for Latin American and Caribbean (ECLAC).

CIESIN. 2012. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP). Alpha Version. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Website: http://sedac.ciesin.columbia.edu/gpw/lecz, (accessed 30 August, 2012).

EM-DAT: The OFDA/CRED International Disaster Database. 2012. Brussels: Center for Research on the Epidemiology of Disasters. Website: http://www.emdat.be/, last accessed 8 October 2012.

Feler, L., and J. V. Henderson. 2008. "Exclusionary Policies in Urban Development: How Under-servicing of Migrant Households Affects the Growth and Composition of Brazilian Cities." NBER Working Paper Series. No. 14136. Cambridge, M): National Bureau of Economic Research. Website: www.nber.org/papers/w14136.pdf , last accessed 8 October 2012.

Giddens, A. 2010. A política da mudança climática. Rio de Janeiro: Zahar.

Hogan, D. J. and E. Marandola, Jr. 2005. "Towards an Interdisciplinary Conceptualisation of Vulnerability." Population, Space and Place 11(6): 455-471.

Instituto Brasileiro de Geografia e Estatística (IBGE). 2010. "Censo Demográfico 2010 – Aglomerados Subnormais: Primeiros Resultados." Rio de Janeiro: IBGE.

______. 2000. "Censo Demográfico 2000." Rio de Janeiro: IBGE.

______. 1991. "Censo Demográfico 1991." Rio de Janeiro: IBGE.

______. 2008. "Pesquisa Nacional de Saneamento Básico: PNSB 2008." Rio de Janeiro: IBGE.

______. 2010. "Pesquisa Nacional por Amostra de Domicílios: PNAD 2010." Rio de Janeiro: IBGE.

______. 2010. "Pesquisa Nacional de Saneamento Básico: 2008." Rio de Janeiro: IBGE.

Magalhães, F. (ed.). 2010. Regiões Metropolitanas no Brasil : Um paradoxo de desafios e oportunidades. Washington, D. C.: Inter-American Development Bank.

Marandola, Jr., E., and D. J. Hogan. 2006. "Vulnerabilities and Risks in Population and Environment Studies. Population and Environment 28(2): 83-112.

Maricato, E. 2011. "Metrópoles desgovernadas." Estudos Avançados 25(71): 7-21. Website: http://www.scielo.br/scielo.php?pid=S0103-40142011000100002&script=sci_arttext, last accessed 8 October 2012.

Martine, G. 2011. "Preparing for Sustainable Urban Growth in Developing Areas." Ch. 1 in: Population Distribution, Urbanization, Internal Migration and Development (ESA/P/WP/223), by the United Nations. New York: Population Division, Department of Economic and Social Affairs, United Nations.

Martine, G., and G. McGranahan. 2012. "The Legacy of Inequality and Negligence in Brazil's Unfinished Urban Transition: Lessons for Other Developing Regions." *International Journal of Urban Sustainable Development.* Special Edition: DOI:10.1080/19463138.2012.735236.

______. 2010. "Brazil's Early Urban Transition: What Can It Teach Urbanizing Countries?" IIED/UNFPA Working Paper. No. 4. London: International Institute for Environment and Development (IIED) and UNFPA.

Ojima, R., and D. J. Hogan. 2009a. "Mobility, Urban Sprawl and Environmental Risks in Brazilian Urban Agglomerations: Challenges for the Urban Sustainability in a Developing Country." Pp. 281-316 in: Urban Population and Environment Dynamics in the Developing World: Case Studies and Lessons Learned, edited by A. de Sherbiniin, et al. 2009. Paris: International Cooperation in National Research in Demography (CICRED).

______. 2009b. "The Demographic Composition of Urban Sprawl: Local and Regional Challenges concerning Global Environmental Change in Brazilian Metropolitan Areas." Paper presented at the XXVI IUSSP International Population Conference, Marrakech, Morocco, 27 September-2 October 2009. Paris: International Union for the Scientific Study of Population (IUSSP).

Ojima, R., and E. Marandola, Jr. 2011. "Indicadores e políticas públicas de adaptação às mudanças climáticas: vulnerabilidade, população e urbanização." Revista Brasileira de Ciências Ambientais 18: 16-24.

Tominaga, L. K., and J. Santoro, and R. do Amaral. 2009. Desastres Naturais: conhecer para previnir. São Paulo: Instituto Geológico.

Torres, H. 2002. "Migration and the environment: a view from Brazilian metropolitan areas." Pp. 147-166 in: Population and Environment in Brazil: Rio + 10, edited by D. Hogan, E. Berquó, and H. Costa). Campinas: National Population and Development Commission of Brazil (CNPD), Brazilian Association of Population Studies (ABEP), and Population Studies Center (NEPO).

United Nations. 2012. *World Urbanization Prospects: The 2011 Revision*. New York: Population Division, Department of Economic and Social Affairs, United Nations.

UNFPA. 2007. *The State of World Report 2007: Unleashing the Potential of Urban Growth*. New York: UNFPA.

Walker, P. 1991. "International Search and Rescue Teams. A League Discussion Paper." Field Studies Paper. No. 1. Geneva: League of the Red Cross and Red Crescent Societies.

CHAPTER 9

Planning for Adaptation in a Megacity: a Case Study of the Mexico City Metropolitan Area[1]

Boris Graizbord[2]

Introduction

The United Nations (2012) identifies 23 megacities having 10 million or more inhabitants in the world in 2011 and projects that this number will increase to 37 by 2025. Mexico City is the third largest of these and is already experiencing the effects of multiple climatic events. An analysis of this megacity's experience should help other cities that are now at earlier stages of their growth to understand the factors that exacerbate the consequences of natural disasters in large cities and to formulate policies that will avoid repetition of the attitudes and approaches—particularly with respect to land use—that ultimately enhance vulnerability and thwart adaptation efforts.

The effects of multiple human activities on climate change are of considerable concern to the present Mexican federal administration.[3] The country's energy use and emissions of CO_2e per capita are the highest in Latin America, and Mexico relies on an inefficient carbon-based economy. While most attention is directed towards mitigation efforts, there is increasing recognition that adaptation issues are also fundamental to consider in a climate change strategy.

Both mitigation and adaptation are especially important in Mexico City, which has experienced significant population and land growth in the last five decades and where—at more than 6.2 tCO_2e per capita—emission levels are 20 per cent higher than the country's average. The previous and current administrations of the city Government[4] have thus promoted a strategy to incorporate climate change into the planning agenda. In accordance with the national Special Program on Climate Change, the city Government's present strategy stresses "the need to attend [to] vulnerable populations" (Poder Ejecutivo Federal, 2009, p. 49) as part of the Climate Action Program of Mexico City (Programa de Acción Climática de la Ciudad de México or PACCM). In the context of this programme's focus on adaptation, this chapter maps the areas at risk from hydro-meteorological hazards within the Mexico City Metropolitan Area (MCMA) and identifies vulnerable populations and housing based on socioeconomic indicators derived from the census.

The first two sections of this chapter describe recent growth trends in the MCMA and present some of the characteristics of urban expansion in megacities. Next, there is a brief description of the increasing risks that climate change poses to peripheral metropolitan areas in general and to the metropolitan municipalities of the MCMA in particular. The chapter then proposes an approach to analyse urban vulnerability with regard to population, housing and immediate surroundings and combines this approach with an assessment of spatial distribution in order to measure vulnerability in the MCMA. The chapter further demonstrates how the spatial distribution of vulnerability relates to risks from various natural hazards and hydro-meteorological events that affect the Valley of Mexico. The final section discusses particular aspects of the Mexico City Government's climate change programme in light of recent influential documents regarding megacities, climate change, poverty and adaptation.

Urbanization and Metropolitan Dynamics

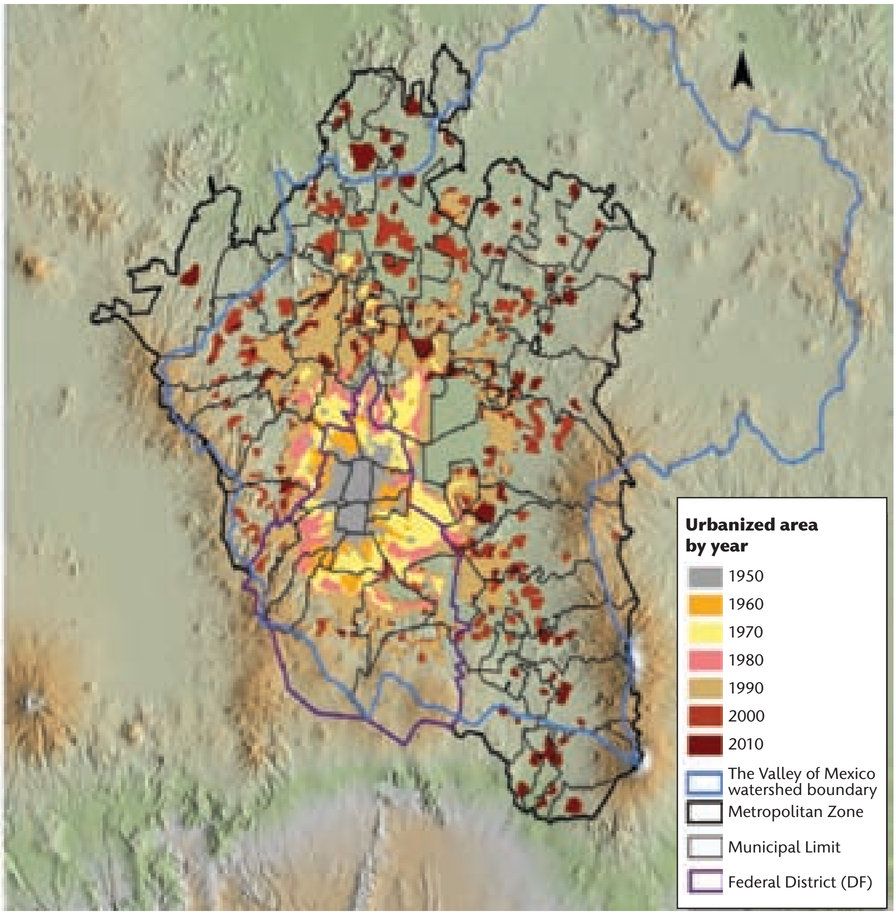
One in every five urban dwellers in Asia, Latin America and the Caribbean and Northern America lives in a large urban agglomeration. In 2011, 23 urban agglomerations had at least 10 million inhabitants and thus qualified as megacities (United Nations, 2012). Despite their visibility and dynamism, megacities still account for a small, though increasing, proportion of the world's urban population. In absolute numbers, however, their growth is remarkable; between 1970 and 2011, the number of people living in megacities has multiplied almost 10 times, from 39.5 million to 359.4 million, and this number is expected to reach 630 million by 2025. Today, approximately one person out of 10 living in an urban area resides in a megacity; by 2025, it is expected that this proportion will increase to about one person out of seven (United Nations, 2012, p. 5).

Mexico City was designated a metropolitan area in 1950 when it had 3 million inhabitants. By then, its contiguous urbanized area had already extended beyond the jurisdictional limits of the Federal District, spilling into various neighbouring municipalities in the State of Mexico.[5] By 1980, the MCMA reached 10 million inhabitants and, now, with 20.4 million inhabitants, Mexico City is the third largest of the 23 megacities in population size and is projected to be the fifth largest of 37 megacities by 2025 (United Nations, 2012, Table 3, p. 7).

Although the MCMA has continued to grow in terms of both population and area, these two forms of expansion have followed different patterns. While the demographic growth rate reached its peak in the 1960s at 3.6 per cent per year, this has declined steadily to 1 per cent per year from 2000 to 2010. Meanwhile, the physical expansion of the urban area continued rapidly until the 1990s, with population density decreasing over time but with settlements established at increasing distances from the historical downtown, the central business district. Since 1990, the spatial continuity of the urbanized area has been disrupted, and there are now areas of urban land use without any physical connection or contiguity to previously urbanized areas. This leapfrog pattern of expansion, depicted in Figure 9.1, coupled with previous rapid expansion of the land area, characterize Mexico City's urban sprawl.

Tables 9.1 and 9.2 show that, while the MCMA's population grew by a factor of six over 60 years, the population in the peripheral metropolitan municipalities increased 356 times, from 29,000 in 1950 to close to 10.8 million in 2010. Over the same period, the area

Figure 9.1: Urban Growth in the Valley of Mexico, 1950-2010



Source: Data for 1950 to 1980 was digitized from Ward (1980) and from INEGI (1990; 2000; 2010) for 1990 to 2010.

Table 9.1: MCMA: Population Growth, 1950-2010

Population							
Areal unit	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
MCMA	*2,952,199*	*5,125,437*	*8,623,157*	*13,878,912*	*14,944,341*	*17,556,227*	*19,573,867*
Federal District	2,923,194	4,816,617	6,840,471	8,831,079	8,235,744	8,605,239	8,810,393
Metropolitan Municipalities	29,005	308,820	1,782,686	5,047,833	6,708,597	8950,988	10,763,474

Growth rates						
Areal unit	**1950-1960**	**1960-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2010**
MCMA	*5.7*	*5.3*	*4.9*	*0.7*	*1.6*	*1.1*
Federal District	5.1	3.6	2.6	-0.7	0.4	0.2
Metropolitan Municipalities	26.7	19.2	11.0	2.9	2.9	1.9

Source: Based on: Ward, 1980; Consejo Nacional de Población (CONAPO), 1994; and Instituto Nacional de Estadística y Geografía (INEGI), 2010.

Table 9.2: MCMA: Urban Physical Expansion, 1950-2010

Urban area (Sq.Km)							
Areal unit	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
MCMA	*176.6*	*328.2*	*657.6*	*855.1*	*1702.5*	*1855.7*	*2261.7*
Federal District	171.2	296.5	481.8	589.6	773.52	798.38	806.16
Metropolitan Municipalities	5.4	31.7	175.9	265.5	928.98	1057.32	1455.51

Growth rates						
Areal unit	**1950-1960**	**1960-1970**	**1970-1980**	**1980-1990**	**1990-2000**	**2000-2010**
MCMA	*6.4*	*7.2*	*2.7*	*7.1*	*0.9*	*2.0*
Federal District	5.6	5.0	2.0	2.8	0.3	0.1
Metropolitan Municipalities	19.3	18.7	4.2	13.3	1.3	3.2

Source: Based on Ward, 1980; Consejo Nacional de Población (CONAPO), 1994; and Instituto Nacional de Estadística y Geografía (INEGI), 2010.

occupied by the metropolis increased 10 times, as the continuous urbanized area in the metropolitan municipalities of the State of Mexico grew from five to more than 1,400 square kilometers between 1950 and 2010. However, the rate of growth in both population and surface area fell from around 6 per cent per year in the fifties and sixties to 1 per cent during the decade from 2000 to 2010. The periphery continues to show relatively higher rates of growth than the core area (the Federal District), where average yearly growth rates in the last decade were only 0.3 per cent in population and nearly zero in the urbanized land area.[6]

Urban Sprawl and Socioeconomic Vulnerability

Economic growth and employment have not kept up with population growth and distribution across the MCMA over the last 60 years. Urban expansion has resulted in an increase in the number and proportion of poor residents in the metropolitan area, while an increased demand for public and private goods and services has resulted in growing environmental pressures on ecosystem resources, such as water, in the Valley of Mexico. This unsustainable expansion is being driven by four main factors:

1. Local authorities lack the capacity to manage growth since land use, in practice, is uncontrolled in Mexico;
2. Land and housing developers, responding to an aggressive national policy promoting "social interest" housing, take advantage of permissive (i.e., corrupt) local governments by not following the normative guidelines outlined in municipal urban plans;
3. "Ejidatarios",[7] operating under local, state and federal authorities that allow an uncontrolled process, sell their former *ejido* lands which have been deregulated since 1992 (Diario Oficial de la Federación, 1992);

4. Commercial banks, taking advantage of a long period of controlled low inflation, offer relatively inexpensive credit, largely used for housing in response to a federal policy directed at lower-income groups and urban workers.

Urban sprawl, in the context of weak public authority and unregulated land markets, increases the cost of urbanization exponentially. The provision of physical and social infrastructure ceases to be cost effective in outlying areas as the marginal costs of public-service delivery become higher than average costs for the city and, of course, higher than marginal benefits, such as improving health conditions of residents and avoiding the delivery of water tanks to these areas. As a result, infrastructure and public services are not fully provided in expanding peripheral areas, increasing the inequality gap between "core area" inhabitants and the population in the periphery.

Urbanization, Climate Change and Increasing Risks

For the first time, the United Nations' *2011 Revision* of the *World Urbanization Prospects* includes geographical coordinates for all cities with more than 750,000 inhabitants in 2011 (633 in total), allowing demographic trends in urban agglomerations to be linked with various spatial and environmental characteristics (e.g., coastal areas, earthquake faults or climate zones). The same document provides data for 456 cities with more than one million inhabitants, representing 1.4 billion people (United Nations, 2012, Table 9, p. 20). More than half of these cities (273, with a total of 888 million inhabitants) are located in areas that are exposed to one or more natural hazards (p. 17).

Among the largest urban areas, only seven major cities, including Mexico City, are threatened by three or more natural hazards (United Nations, 2012, Table 9, p. 20). Flooding is the most frequent and greatest hazard for the largest urban agglomerations analysed (United Nations, 2012, Table 13, p. 23). All 39 of the cities with five million or more inhabitants are affected by floods. Most of them are located in or close to areas with a high risk of flooding, though not all are coastal cities (e.g., Mexico City and New Delhi). Drought is the second most frequent hazard, affecting all but 13 of the 39 cities. Fewer than half of the cities are exposed to cyclones. According to the United Nations report, Mexico City has a high risk of floods, a medium risk of landslides and a low risk of droughts (p. 18).

The rise in intensity and frequency of extreme weather events due to climate change requires not only consideration of the risks these events pose to increasing metropolitan populations, but more specifically to the urban poor, who live mainly in peripheral areas. In this context, the social, economic and environmental impacts of urban sprawl have received increasing attention from urban analysts (Aguilar and Escamilla, 2009; Arroyo and Corvera, 2011; Graizbord and Monteiro, 2011) and from policymakers. One main concern is adaptation planning, which considers the physical and social vulnerability and adaptive capacities of potentially affected communities.[8]

Linking Vulnerability, Adaptive Capacity and Urban Planning

It is important to differentiate between adaptation to an episode and adapting for the future—i.e., having the capacity to anticipate and prevent potential coming events (Giddens, 2010, p. 190). This distinction is central to any adaptation policy and requires both a diagnosis of, and a response to, vulnerability. To plan for adaptation, researchers and policymakers must understand vulnerability as an interaction among the socio-economic attributes of inhabitants, housing characteristics and the conditions in the surrounding environment or site. A central question for planning that researchers and policymakers must address, and which is also addressed in Chapter 1, is whether these factors are interrelated or whether vulnerability and risk levels might be reduced by improving only one of these.

In order to improve adaptive capacity, it is important to identify vulnerable areas along these three dimensions. As such, the following questions were considered for the MCMA:

1. What are the attributes of *individuals* living in the large and dispersed periphery of the MCMA?
2. What are the characteristics of *dwellings* in which these individuals and households live?
3. What are the conditions of the *immediate physical surroundings* in which the growing urban population lives?

In this chapter, adaptive capacity is understood as "the inherent capacity of a system (e.g., a city government), population (e.g., a low-income community in a city) or individual/household (e.g., dwellings and residential areas) to undertake actions that can help to avoid loss and can speed recovery from any impact of climate change" (UN-HABITAT, 2011, p. 130). The premise of this approach is that, while the vulnerability of individuals, housing and immediate surroundings are strongly interconnected and represent overall vulnerability, in many cases only one dimension will be vulnerable while the others are not. For example, high-income housing in Monterrey is vulnerable to heavy rain and landslides due to poor site conditions, but the population itself is not necessarily vulnerable.

Flooding affects specific areas of Iztapalapa in the Federal District that are characterized by poor infrastructure and site conditions, yet not all housing or the inhabitants are vulnerable depending on their characteristics and their individual attributes. The same can be said in relation to other delegaciones in the Federal District and in particular to peripheral metropolitan municipalities in the State of Mexico. (El Universal Estado de México, 2011a) For example, site conditions and housing characteristics in Nezahualcoyotl, a municipality in the eastern metropolitan periphery, increase risks of disasters in recurrent flooding but the inhabitants do not necessarily qualify as extremely vulnerable based on their socio-economic attributes. (El Universal Estado de México, 2011b)

Isolating the three dimensions of vulnerability allows for their prioritization in order to better tackle the potential threats that face city populations and physical and social infrastructure. This argument was taken by the Director of Disaster Management of SEDESOL when defining disaster prevention. He alluded to unsafe housing of poor people and risk-prone location (Aragón-Durand, 2009, p. 319), but the argument is valid also for unsafe housing of rich people in risk prone locations, as in Monterrey. In that case "risk reduction can be achieved through up-grading urban neighbourhoods and providing urban services" (Aragón-Durand, 2009, p. 320). Basic changes in people's attributes take decades and involve economic and social changes, difficult to achieve in the short run in which local and state authorities base their performance. Therefore, the argument reinforces the proposal to develop well focused and defined sectored strategies that, in practice, characterize the conventionally fragmented public administration structure and urban management organization in the city Government.

In addition, adaptation to climate change involves many actors, sectors and regions. Commercial and manufacturing activities will have to respond to events, such as heavy rains and flooding, that will affect their workers and the delivery of supplies, as well as the shipping of their products. Droughts will impact agricultural activities and force producers and populations living in rural areas to adjust their practices, including the use of electricity and water for irrigation. Health care and educational institutions, water and sewage networks, roads and mass transit, transportation and telecommunications services will also be increasingly impacted by climate change events. Finally, local governments, with limited planning resources (technical, financial, human) in partnership with private sector investors, will need to develop measures to mitigate the impacts of severe weather conditions and adapt to such hazards. These facts also reinforce the previous argument favouring a sectored planning approach focusing on specific components or dimensions of vulnerability.

Measuring Vulnerability and Its Spatial Distribution in the MCMA

The extant literature (Ministry of Public Works, 2012, p. 32; UNFPA, 2012, p. 106; Winchester and Szalachman, 2009, pp. 7-9; United Nations Development Programme [UNDP], 2007, p. 74) considers population subgroups—i.e., children, the elderly (especially women), recent immigrants, female-headed households (as proxy for lack of social capital) and those earning US$2 a day or less—as extremely vulnerable. Housing constructed with precarious materials and lacking in public services, such as running water, sanitation and electricity, is considered vulnerable if exposed to severe weather conditions, such as intense or prolonged rain events or heat waves. In addition, households with no refrigeration for food are at a disadvantage, especially in isolated conditions. Finally, a house affected by a flood represents an asset loss for the family, which is difficult to replace in the short run.

Immediate surroundings may represent an advantage or a disadvantage to a household or community. For example, as Baker (2012, p. 53) argues:

> . . . traditionally, vulnerable individuals and communities have managed risk through ad hoc coping techniques that draw on their local knowledge of hazards and community resources. There is substantial literature that discusses ad hoc adaptation to illustrate the strength of social capital. In slums where social networks and kinship ties are stronger, communities are more resilient. Older communities have stronger social networks than newer settlements, where residents may be more transient. Active internal leadership in close-knit communities can organize relief and rehabilitation more effectively and efficiently. This is especially the case for fast-onset events that require temporary relocation; at these times, residents rely on their existing social capital and existing networks.

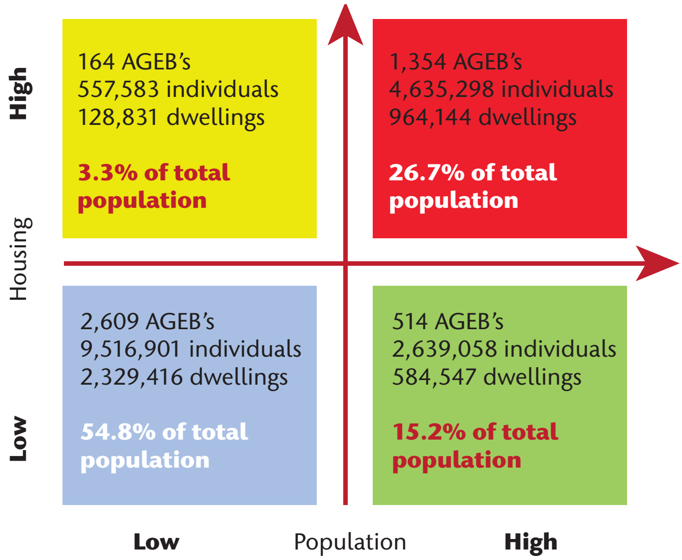
The degree to which a squatter settlement may or may not provide the necessary conditions to foster solidarity (social capital) may depend on how recently it was settled and on whether or not community leadership has developed. The size of a community is also at play: Smaller communities usually lack appropriate physical and social infrastructure and public services; on the other hand, there may be a greater sense of solidarity among their inhabitants.

In 2010, Graizbord and colleagues applied a cluster analysis to the 4,641 urban basic geographic statistical areas (AGEBs)[9] into which the MCMA is divided in order to identify groups showing similar statistical values based on the above-mentioned socio-demographic attributes and housing characteristics.[10] By placing resulting clusters along the two axes of the graph (Figure 9.2), it was possible to assess low/high vulnerability and then map its spatial distribution (Figure 9.3).

The study found that 7 per cent of the population across the MCMA was made up of women aged 65 or older, and almost 22 per cent of households were headed by women. Among the working-age population, only 8 per cent was living on less than US$2 a day. Adults (age 18 and over) with no secondary education represented up to 60 per cent of the MCMA population. Of course, these indicators were not distributed evenly across the urban area. For example, the study found AGEBs where 100 per cent of inhabitants settled recently (within 5 years) and in which virtually all dwellings were constructed with precarious building materials (e.g., corrugated cardboard).

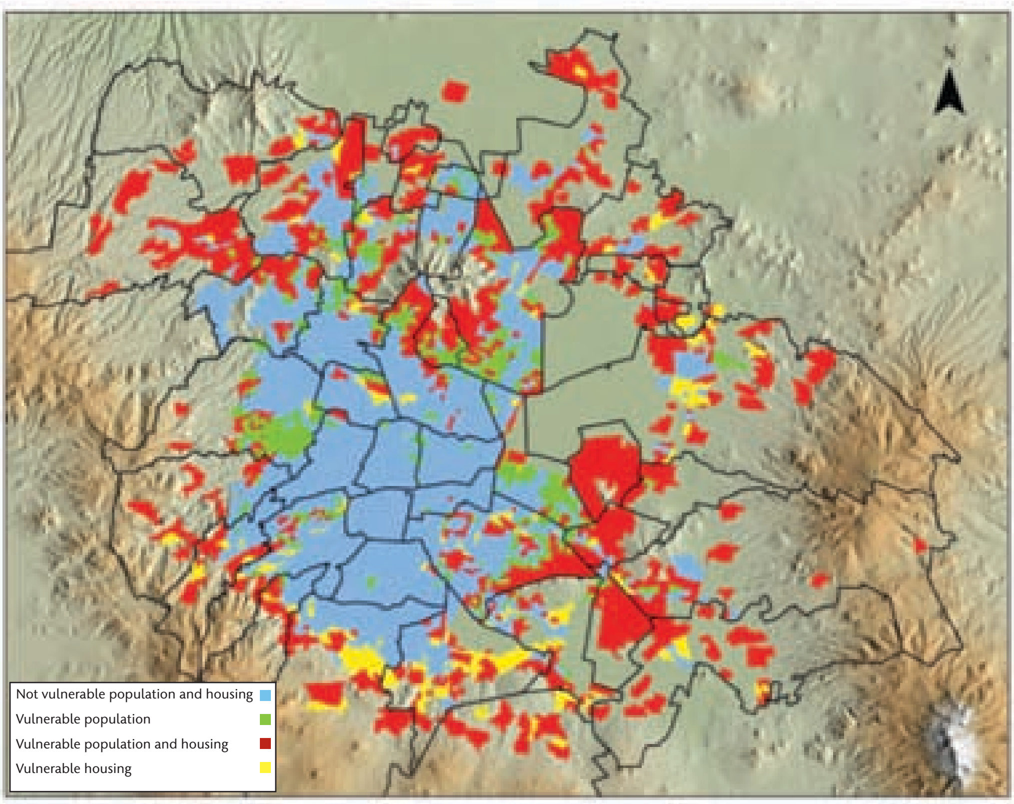
The study also found that high vulnerability based on population attributes and housing characteristics affects close to 27 per cent of the MCMA population (4.6 million inhabitants) and close to a million dwellings in 1,354 basic geographic statistical areas. Figure 9.2 shows that 3.3 per cent of the population, or little more than half a million residents, live in 164 AGEBs classified by highly vulnerable housing characteristics but not necessarily by their socio-demographic attributes. The matrix also shows that more than half of the total MCMA inhabitants are not considered vulnerable according to their socio-demographic attributes or the conditions of the dwellings in which they live. However, the entire population in the MCMA is susceptible to risks if exposed to severe weather conditions.

Figure 9.2: Housing and Population Vulnerability Matrix



Source: Results from a cluster analysis applied by Graizbord et al. (2010) for León et al., 2010.

Figure 9.3: MCMA: Spatial Distribution of Vulnerability



Source: Based on results from the cluster analysis applied to census data for all 4,641 MCMA's urban Basic Geo-Statistical Areas (AGEBs), INEGI, 2000.

The policy implications of these observations direct primary attention to those AGEBs that are classified as highly vulnerable according to their individual attributes and housing characteristics (the upper right hand quadrant in Figure 9.2). As Figure 9.3 indicates, central city areas correspond to AGEBs with low housing/population vulnerability, while AGEBs in the periphery of the MCMA suffer from relatively worse conditions due to higher populations and housing vulnerabilities. Inhabitants in the MCMA's southern, western and northwestern areas occupy housing built on steep slopes of 15o or more. Housing in the southeast and eastern sections of the MCMA is highly susceptible to flooding. In both cases, populations are susceptible to risk due to geophysical conditions.

Exposure to Hazards

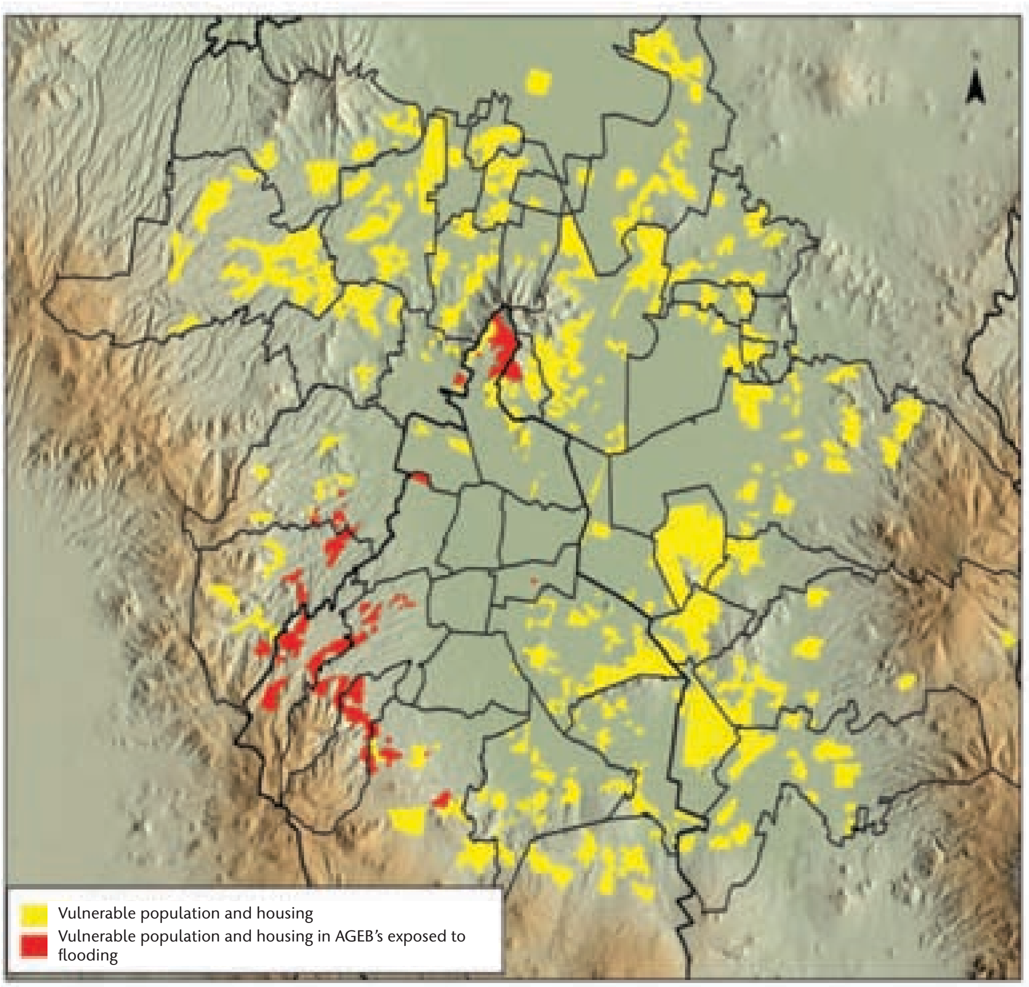
Vulnerability is an important environmental, social or economic risk factor, but only if the population is exposed to hazards.[11] In constructing any possible scenario, it is therefore necessary to consider exposure. Over the last 25 years, the National Meteorological Service has recorded events during which the amount of rain reached 20 or more millimeters an hour within the MCMA. Historically, the southern part of the metropolitan area, which has the highest altitude and is the most valuable conservation area, has been most affected by heavy rains, and these have tended to be concentrated mostly in the western sierra separating the Valley of Mexico from the valley of Toluca. It is expected that in the future the frequency and concentration of these events in the southern [and western] part of the valley will intensify (León et al., 2010). This is especially worrisome given that the area is experiencing unregulated urban expansion.

Strategic responses will have to involve protecting these areas from deforestation, preventing or relocating illegal settlements and controlling land-use changes. These measures should be a priority in order to maintain the environmental services that the southern conservation zone still provides to ensure the welfare of its inhabitants and the valley's ecological health.

Other events, such as heat waves, have been registered for the last ten years, and temperatures of 30°C or more are expected to intensify in the future. High temperatures affect the most arid part of the Valley of Mexico; they also generate heat islands in the centre north of the city due to a compact urban fabric with few open and green areas. In the Graizbord et al. (2010) study, a cluster of AGEBs in the Central City show a relatively high percentage of women aged 65 and older, as well as female-headed households. However, other indicators of population vulnerability or precarious dwelling characteristics have not been identified in these AGEBs.

A multifaceted and complex relationship exists among the individual, his or her housing and the immediate surroundings in terms of vulnerability and exposure to hydrometeorological events. Gender issues, for instance, are often overlooked in assessments of vulnerability and risk.[12] The social roles imposed on men and women determine the risks confronted by each, and gender differences must be considered in light of the socioeconomic status of women (Neumayer and Plümper, 2007; IPCC, 2007, p. 730).[13] In addition, the important role women play in increasing adaptive capacity must

Figure 9.4: Vulnerable Population and Dwellings in AGEBs Exposed to Heavy Rain



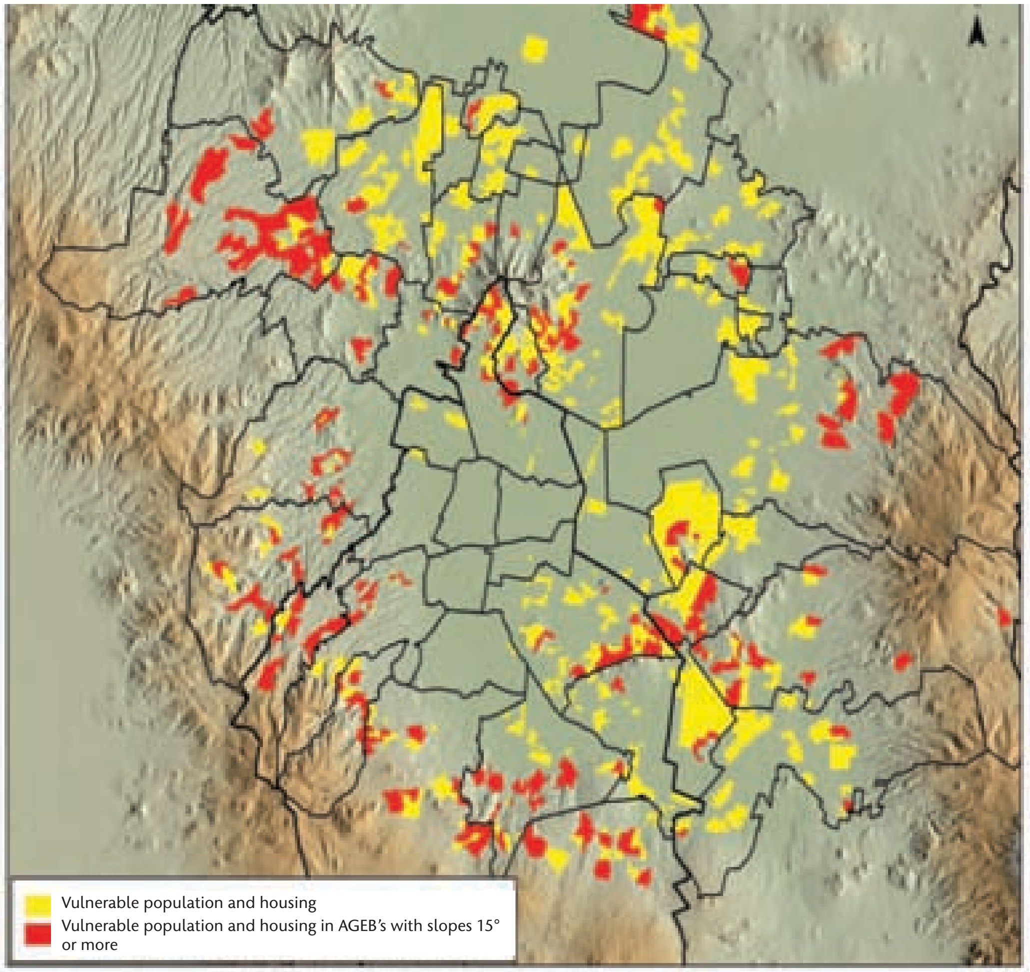
Source: Based on Leon et al., 2010.

be recognized. Women function as agents of change and informally increase adaptive capacity and risk management through their role in maintaining community networks and building social capital (Vincent et al., 2010, pp. 5-6).

Exposure to Hazards in the MCMA

Once data for the three dimensions of population, housing and immediate surroundings were analysed, highly vulnerable AGEBs located in areas exposed to intense rain events, landslides and heat waves were identified (see Figure 9.4).[14] Table 9.3 shows different events and combinations of such events. There are more than 800 AGEBs with vulnerable populations and dwellings that are not located in exposed areas but which are characterized by poverty. It is expected that future hydro-meteorological events will extend to additional territories in the metropolitan area and will gradually affect those AGEBs, unless their socioeconomic conditions are improved.

Figure 9.5: Vulnerable Population and Dwellings in Areas of Hill Slopes 15° or More



Source: Based on Leon et al., 2010.

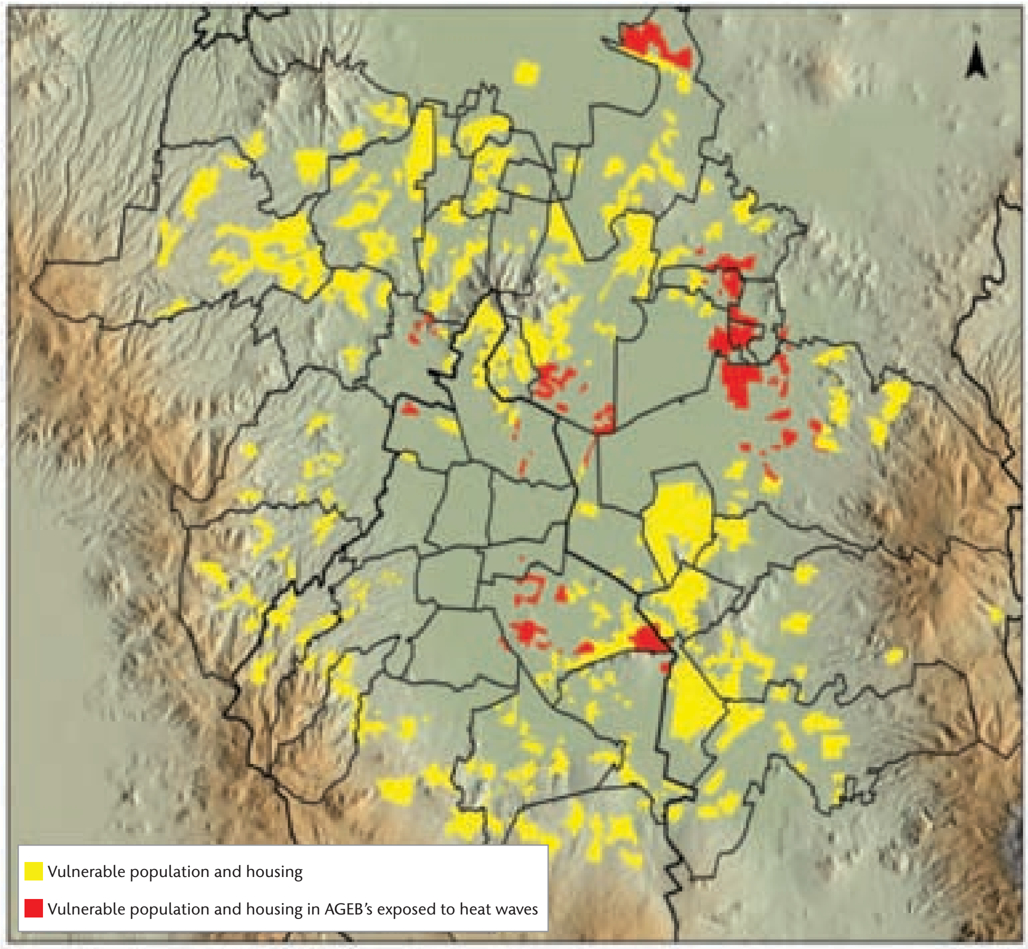
Table 9.3: MCMA: AGEBs with Vulnerable Population and Dwellings Exposed to Hydro-meteorological Events

Hydro-meteorological risks	AGEB*	%	Population	%	Dwellings	%
Floods	48	3.55	179,019	3.86	38,909	4.04
Landslides	288	21.27	1,004,586	21.67	208,546	21.63
Heat waves	117	8.64	367,450	7.93	76,771	7.96
Floods and Landslides	59	4.36	251,118	5.42	53,455	5.54
Landslides and heat waves	23	1.7	62,449	1.35	13,175	1.37
*Subtotal exposed to risk**	*535*	*39.52*	*1,864,622*	*40.23*	*390,856*	*40.54*
Total vulnerable	*1,354*	*100*	*4,635,298*	*100*	*964,144*	*100*

Source: Based on: León et al., 2010.

* One AGEB has not been included in any category due to ambiguity in data so the figures in the raw subtotal are not exactly the sum of each column.

Figure 9.6: Vulnerable Population and Dwellings Affected by Heat Waves



Source: Based on Leon et al., 2010.

The data show that almost 180,000 inhabitants of, and 40,000 dwellings in 48 AGEBs are exposed to flooding. Figure 9.4 shows that the southwest and western peripheral areas are particularly vulnerable, affecting almost 4 per cent of the metropolitan population.

More than one million vulnerable metropolitan inhabitants occupy 200,000 dwellings located predominately on high slopes (one in five inhabitants across 288 AGEBS) (Figure 9.5).

Heat waves affect 367, 450 inhabitants and 76,771 dwellings located mainly in the 117 AGEBs east of the MCMA's core area and the northeastern municipalities. Also affected are a few AGEBs north and northwest of the Federal District and some in the adjacent municipality of Tlanepantla, a dense and consolidated polluted industrial zone (Figure 9.6). Around 8 per cent of the vulnerable population in the MCMA is affected.

Climate Action in Mexico City

The Climate Action Program of Mexico City (PACCM) was established as a mechanism to keep track of existing Federal District Government (GDF) programmes. Its objective is to “integrate, coordinate and promote public and private actions, and reduce environmental, social and economic risks imposed by climate change” (Gobierno del Distrito Federal, 2008, p. 35). The PACCM states that an adaptation programme is “to be fully implemented by 2012” (p. 35). Adaptation measures are promoted to reduce vulnerability and moderate possible harm, to prevent risks and to take advantage of any opportunities that climate variability offers to the city and its periphery (p. 51). As part of the implementation strategy, the GDF has established an Inter-Institutional Commission for Climate Change to coordinate, follow up and evaluate its actions (Quiroz, 2011, p. 71).

Many adaptation actions were adopted from other GDF programmes and policy instruments such as the Green Plan, which serves as a climate change policy framework.[15] These measures are related to “identifying hazards and vulnerability” and “increasing existing adaptation capacities”, among others (Quiroz, 2011, Table 3.4, p. 85). In addition to these specific actions, the PACCM proposes “early alert” components for the short and medium terms. These include monitoring hydro-meteorological events, protecting native vegetation and attending to vulnerable populations. Special attention is given to hill slopes in the western part of the Federal District on which poor people settle illegally and that are exposed to intensive rain and landslides. The PACCM also recognizes the ecological value of these landforms in providing environmental services, such as biodiversity and facilitating the filtration of water to the aquifer.

The measures outlined in the PACCM, while necessary as preventive actions, are not sufficient. It is critical for adaptation policy to consider not only monitoring measures and the implementation of conservation initiatives, but to encourage social, cultural and institutional changes. While the PACCM includes education and capacity-building strategies for different departments within the city Government, such as education, civil protection and social development, the relative success of these strategies is still to be demonstrated when more intensive and frequent hydro-meteorological events occur. Moreover, improving adaptive capacities will also depend on citizen participation and information sharing.

Some basic shortcomings of the PACCM are worth noting. First, there are few effective channels and mechanisms to promote community participation. Also missing are communication strategies to effectively generate and provide information that would help exposed and vulnerable populations improve their knowledge of what to expect, and what to do, in the event of threats by different hazards (Quiroz, 2011, p. 87). León and colleagues (2010)[16] identified two additional shortcomings, stating that “disaster risk in Mexico City is handled in a reactive manner” and that there is an “evident need to improve the sharing of information among the relevant government agencies”, which would include not only those within the GDF but also the local authorities (e.g., municipalities) throughout the metropolitan area. More localized vulnerability analyses, based on a detailed assessment of the characteristics of the changing population, and particularly its housing and access to services, can help to address these shortcomings. Such assessments can provide geographic information on shortcomings in adaptive capacity, provide better information to support disaster risk reduction and contribute to a common framework for sharing data across government agencies that incorporates the demographic, social and economic dimensions of vulnerability.

Conclusion

Several authors recognize, and Baker (2012, p. 3) effectively argues, that policies intended to address climate vulnerability and "natural" hazards have links to many sectors and, therefore, "come with important synergies that are best captured through system wide approaches." Likewise, comprehensive urban planning is critical to integrated approaches that address such vulnerability, but this "can often be challenging, given the many institutions involved in managing cities".

At this local level, urban planning and management involves, among other things, land-use control and public participation. With urban expansion occurring in marginal areas such as flood plains, water catchments and steep hillsides, land-use planning must institute measures to respond to new urban settlements (illegal or inadequate) and establish the necessary channels to institute a continuous dialogue with new settlers and the population that will potentially be affected by climate risks and natural hazards.[17] The urban poor are on the front line, and more than 4.6 million individuals have been identified as poor (Figure 9.2). They are particularly vulnerable to climate change and natural hazards because of how and where they live (Figure 9.4) and because of the lack of reliable basic services in their immediate surroundings. As Baker notes (2012, p. 8), when a disaster hits, impacts can include the loss of basic services, damage to or destruction of homes, reduction in or loss of livelihoods, threats to food security and the rapid spread of malnutrition and water- and vector-borne diseases.

Urban environmental conditions, as one of many interacting components, remain the responsibility of the city Government. In fact, as mentioned by Baker:

> . . . city governments are the drivers for addressing risks. Local governments play a vital role in providing basic services that are critical to improving the resilience of the urban poor. . . . City officials build resilience by mainstreaming risk reduction into urban management. Adapting to climate change and reducing disaster risk can be best addressed and sustained over time through integration with existing urban planning and management practices (p. 2).

Significant financial support is needed, Baker observed (2012, p. 2), and in response to this need she insists that "local governments need to leverage existing and new resources to meet shortfalls in service delivery and basic infrastructure adaptation". While urban areas are indeed exposed to the severe impacts of climate change, cities are best prepared to improve the adaptive capacity of the population and to implement adaptation policies and risk management strategies. However, the way in which Mexico City is evolving seems to restrain the capacity to coordinate the many actors and institutions involved in urban management (both public and private) or to strengthen local governments in order to enable them to control land-use changes. These are critical challenges to integrating approaches to address uncertainty, to responding and adapting to more intense and frequent climatic events and to determining where new urban expansion and development should be directed.

Notes

1. This paper is based on a study prepared by teams at El Colegio de Mexico and the Universidad Nacional Autonoma de Mexico (UNAM). A first version was presented as a power point in "Population Dynamics and Climate Change II: Building for Adaptation", organized by UNFPA, IIED, CEDUA/El Colegio de México, El Colegio de Mexico, 13-15 2010. Authors of the original study were Boris Graizbord, Jaime Ramirez, Emelina Nava and Raul Lemus of El Colegio de Mexico, Victor Magaña, Luis Galvan and Carolina Neri of UNAM, Rafael Gonzalez Franco, consultant, and Cuauhtemoc León, coordinator. It is the product of the first phase of an international research project examining megacities in Asia and Latin America, including the Mexico City Metropolitan Area (MCMA). The purposes of this project were to model climate variability risk and provide city governments with guidelines for the design and implementation of climate change adaptation strategies. (See: "Annex 6: Mexico City Case Study" in Baker, 2012, pp. 217-233.)

2. The author would like to thank José Luis González, Omar López and Raúl Lemus for their help in updating the maps and tables, Diana Graizbord for reviewing the English version and the editors for suggesting numerous changes and revisions.

3. See: "Prologue" in Galindo, 2009, p. 7.

4. From 2000 to 2006 and 2007 to 2012.

5. In most of the existing literature, a metropolitan zone includes municipalities that are integrated in functional-economic terms to the core area (the original city). However, this chapter defines the Mexican metropolis as a physically continuous urbanized area, including the core area (i.e., the Federal District), all 16 *delegaciones* (i.e., boroughs) of the city and adjacent communities and municipalities in the State of Mexico.

6. Half of the Federal District (the southern part) is considered a "conservation area" and suffers from illegal, piecemeal settlement, which might be negligible in quantitative terms but is very critical qualitatively in environmental health, as well as in terms of mobilizing people for adaptation purposes.

7. An *ejido* is an area of communal land used for agriculture on which community members (*ejidatarios*) individually occupy and farm a specific parcel. The *ejido* system was introduced as an important component of the land reform programme when Lázaro Cárdenas became president in 1934. An ejido would be established and the original petitioners (landless farmers) would be designated as *ejidatarios* with certain cultivation/use rights. Ejidatarios did not actually own the land, but they were allowed to use their allotted parcels indefinitely as long as they did not fail to use the land for more than two years. They could even pass their rights on to their children. (See website: http://en.wikipedia.org/wiki/Ejido, accessed 10 June 2012.) As a result of the legislative reform in 1992 of Article 27 of the Mexican Constitution, the new mechanisms under which ejido land may be disestablished in order to prevent irregular urban growth (mainly by an informal alienation process) have been unsuccessful (Olivera, 2005). There are two main reasons for these results. According to Olivera, ejidatarios still do not have the complete autonomy to control their own land as federal and state governments still maintain several options to modify the ejidatarios' decisions, and planning agencies and municipal governments frequently have a limited administrative and financial capacity to exercise effective authority over land development processes.

8. In operational terms relevant to planning, short-term adaptation refers to "behavioral modifications in response to changed or changing conditions", while long-term involves "changes in structure, morphology (e.g., urban sprawl vs compact city growth), or physiology of populations that enhance their ability to survive and reproduce in the prevailing environmental conditions" (Dunster and Dunster, 1996, p. 6).

9. Área Geo-estadística Básica or AGEB: INEGI's statistical geographic unit for census data.

10. Variables used in the cluster exercise were: population 18+ with only primary school; women 65+; recent immigrants; female-headed households; workers with less than US$2/day salaries; dwellings with precarious materials in walls and roofs; with no water and sanitation; without refrigerators; and privately owned.

11. Not all hazards are "natural". Hazards can refer to an "object, condition, or (natural and/or human) process that threatens individuals and society in terms of production or reproduction" (Robbins et al., 2010, p. 81).

12. *Gender blindness* is the lack of consideration of risk due to gender in climate change analyses and the exclusion of women in decision-making on climate change. Gender blindness exacerbates gender inequality and poverty in general and becomes a barrier to success in response to climate change (Otzelberger 2011, pp. 4-5).

13. The highest numbers of victims from the 2004 tsunami in Asia were women and children. Recurrent flooding in Bangladesh results in women's death rates that are five times higher than men's. These results are due to discrepancies in their social roles and are clearly related to women's limited access to information compared to men, who receive information through their jobs and in public spaces (Neumayer and Plümper, 2007).

14. These events are specified by Magaña (2010) as follows: intense or heavy rain: more than 30 mm in 24 hours; steep slope: 15º and more; heat wave: 3 consecutive days with 30º C and over.

15. The Green Plan's ten actions (Website: www.sma.df.gob.mx/sma/links/download/archivos/10acciones-enfrentar-cambio-climatico.pdf, accessed 17 September 2012), all within the Federal District jurisdiction, are related to mitigation except for the "recovery of rivers"—probably the closest action to adaptation. For a metropolitan environmental action plan, see: Comisión Ambiental Metropolitana, 2010.

16. See: Annex 6 in Baker (2012, p. 227).

17. Hazards (or "risks" in economics literature) are potentially damaging physical events or phenomena that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. A distinction made in the disaster literature is the definition of a disaster as the effect of a hazard on society as a result of a combination of exposure and vulnerability. Disasters, not hazards, cause deaths and damage (World Bank and United Nations, 2010).

References

Aguilar, A. G., e I. Escamilla. (coords.) 2009. *Periferia Urbana. Deterioro ambiental, y reestructuración metropolitana*. México: UNAM, Miguel Angel Porrúa.

Aragón-Durand, F. 2007. *Unpacking the Social Construction of* ´Natural´ Disasters *through Policy Discourses and Institutional Responses in Mexico: The Case of Chalco Valley´s Floods, State of Mexico*. Ph.D. thesis. London: Development Planning Unit, University College London.

Arroyo, J. e I. Corvera (comps.). *Desarrollo insostenible. Gobernanza, agua y turismo*. México: Universidad de Guadalajara, Profmex/World, Juan Pablos.

Baker, J. L. (ed.) 2012. *Climate Change, Disaster Risk, and the Urban Poor: Cities Building Resilience for a Changing World*. Washington, D. C.: The World Bank.

Comisión Ambiental Metropolitana. 2010. *Agenda de Sustentabilidad Ambiental para la Zona Metropolitana del Valle de México*. México: Comisión Ambiental Metropolitana, Secretaría del Medio Ambiente del Gobierno del Distrito Federal, Secretaría de Medio Ambiente del Gobierno del Estado de México, Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), Consejo de Ecología del Gobierno del Estado de Hidalgo, El Colegio de México y Embajada Británica

CONAPO. 1994. *La población de los municipios de México, 1950-1990*. México: CONAPO-FNUAP.

Diario Oficial de la Federación. 1992. *Decreto por el que se reforma el artículo 27 de la Constitución Política de los Estados Unidos Mexicanos*. Tomo CDLX, No. 3, 6 de enero.

Dunster, J., and K. Dunster. 1996. *Dictionary of Natural Resource Management*. Vancouver: UBC Press, University of British Columbia.

El Universal Estado de México. 2011a. "Vecinos temen por daños en casas tras inundación", 14 de septiembre, Website: www.eluniversaledomex.mx/busqueda.php?palabra=inundaci%F3n, last accessed 14 October 2012.

________. 2011b. "Lluvia inunda colonias de Neza", 6 de octubre." Website: www.eluniversaledomex.mx/nezahualcoyo/nota22841.html, last accessed 14 October 2012).

Gallegos Toussaint, R. (coord.). 2011. *Programa Especial de Cambio Climático para el priodo 2013-2020 con acciones adicionales y análisis de potencial*. México: Programa de Naciones Unidas para el Medio Ambiente (PNUMA), Agencia Francesa para el Desarrollo (AFD), Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

Galindo, L. M. (coord.). 2009. *The Economics of Climate Change in Mexico*. (Synopsis, Spanish and English versions.), Mexico: SEMARNAT.

Giddens, A. 2010. *La Política del Cambio Climático*. Translated by F. de Bustillo. Madrid: Alianza Editorial SA. Originally published: 2009. *The Politics of Climate Change*. Cambridge, United Kingdom: Polity Press.

Graizbord, B. 1999. "Planeación urbana, participación ciudadana y cambio social." *Economia, Sociedad y Territorio* 2(5): 149-161.

Graizbord, B., y F. Monteiro (eds.). 2011. *Megaciudades y cambio climático*. Serie Cuadernos de Trabajo. Número 7. Programa de Estudios Avanzados en Desarrollo Sustentable y Medio Ambiente (Lead-México). México: El Colegio de México.

Graizbord, B., con la colaboración de J. Ramírez, E. Nava, y R. Lemus. 2010. "Evaluación del riesgo urbano para la adaptación: El caso de la Zona Metropolitana de la Ciudad de México" (mimeo). Contribución para el proyecto coordinado por Cuauhtemoc León, *Pobreza y cambio climático*. México: Gobierno del Distrito Federal, noviembre.

Granados, A. 2012. "Vulnerabilidad de la población al cambio climático por género en México" (mimeo). Paper to be presented at the V Congreso de la Asociación Latinoamericana de Población, Montevideo, Uruguay, 23-26 October.

INEGI. 2010. *XIII Censo general de Población y Vivienda*, México.

________. 2005. *II Conteo de Población y Vivienda*, México.

________. 2000. *XII Censo general de Población y Vivienda*, México.

Intergovernmental Panel on Climate Change (IPCC). 2007. *IPCC Fourth Assessment Report (Working Group II)*. Cambridge, UK: Cambridge University Press.

León, C., et al. 2010. "Pobreza urbana y cambio climático para la Ciudad de México" (mimeo).

Magaña Rueda, V. 2010. *El Uso de los Escenarios Regionales de Cambio Climático para la Gestión del Riesgo*. Powerpoint presented at Reunión Internacional Preparatoria hacia la COP 16 sobre Adaptación al Cambio Climático: Perspectiva Científica, México City, 29 September 2010. Cited in: "Pobreza urbana y cambio climático para *la Ciudad de* México" (mimeo), by León, C., et al. 2010.

Ministry of Public Works. 2012. *Atlas of Urban Vulnerability in Spain: Methodology and Contents*. Madrid: Ministry of Public Works, Government of Spain. http://siu.vivienda.es/portal/index.php?option=com_content&view=article&id=103&Itemid=157&lang=en, last accessed 24 October 2012.

Neumayer, E., and T. Plümper. 2007. "The Gendered Nature of Natural Disasters: The Impact of Catastrophic Events on the Gender Gap in Life Expectancy, 1981–2002." *Annals of the Association of American Geographers* 97(3): 551–566. Cited in: "Vulnerabilidad de la población al cambio climático por género en México" (mimeo), by A. Granados. 2012. Paper to be presented at the V Congreso de la Asociación Latinoamericana de Población, Montevideo, Uruguay, 23-26 October.

Olivera Lozano, G. 2005. "La reforma al Artículo 27 Constitucional y la incorporación de las tierras ejidales al mercado legal de suelo urbano en México." *Scripta Nova* 9(194[33]. Revista electrónica de geografía y ciencias sociales. Universidad de Barcelona. Website: http://revistes.ub.edu/index.php/ScriptaNova/article/view/949, last accessed 24 October 2012.

Otzelberger, A. 2011. *Gender-Responsive Strategies on Climate Change: Recent Progress and Ways Forward for Donors*. BRIDGE/Institute of Development Studies. Cited in: "Vulnerabilidad de la población al cambio climático por género en México" (mimeo), by A. Granados. 2012. Paper to be presented at the V Congreso de la Asociación Latinoamericana de Población, Montevideo, Uruguay, 23-26 October.

Gobierno del Distrito Federal. 2008. *Programa de Acción Climática de la Ciudad de México 2008-2012 (PACCM)*. México: Secretaría del Medio Ambiente del Distrito Federal. Website: www.sma.df.gob.mx/sma/links/download/archivos/paccm_documento.pdf, last accessed 24 October 2012. Cited in: *La política del cambio climático en la Ciudad de México: Análisis de las estrategias de mitigación y adaptación en el PACCM*, by D. E. Quiroz Benítez. 2011. Tesis de Maestría en Estudios Urbanos, El Colegio de México, junio.

Poder Ejecutivo Federal. 2009. *Programa Especial de Cambio Climático, Diario Oficial de la Federación (DOF 28/08/2009).*

Website: www.semarnat.gob.mx/programas/Documents/PECC_DOF.pdf, last accessed 28 September 2012.

Quiroz Benítez, D. E. 2011. *La política del cambio climático en la Ciudad de México: Análisis de las estrategias de mitigación y adaptación en el PACCM*. Tesis de Maestría en Estudios Urbanos, El Colegio de México, junio.

Robbins, P., J. Hintz, and S. Moore. 2010. *Environment and Society: A Critical Introduction*. Gloucester, United Kingdom: Wiley-Blackwell.

United Nations. 2012. *World Urbanization Prospects: The 2011 Revision*. New York: Population Division, Department of Economic and Social Affairs, United Nations.

UNDP. 2007. *Human Development Report 2007/2008: Fighting Climate Change: Human Solidarity in a Divided World*. Basingstoke, United Kingdom: Palgrave McMillan. Website: http://hdr.undp.org/en/media/HDR_20072008_EN_Complete.pdf, last accessed 24 October 2012.

UNFPA. 2010. *Population Situation Analysis (PSA): A Conceptual and Methodological Guide*, New York: United Nations Population Fund.

UN-HABITAT. 2011. *Cities and Climate Change: Global Report on Human Settlements 2011*. United Nations Human Settlements Programme. London and Washington D. C.: Earthscan.

Vincent, K., et al. 2010. *Gender and Community-based Adaptation. A Guidebook for Designing and Implementing Gender-Sensitive Community-Based Adaptation Programmes and Projects*. New York: UNDP.

Ward, P. 1980. *México: una megaciudad, producción y reproducción de un medio-ambiente urbano*. México: Alianza Editorial.

Winchester, L., and R. Szalachman. 2009. *The Urban Poor's Vulnerability to the Impacts of Climate Change in Latin America and the Caribbean: A Policy Agenda*. Paper presented at the Fifth Urban Research Symposium: Cities and Climate Change: Responding to an Urgent Agenda, Marseille, France, 28-30 June 2009. Washington, D. C.: The World Bank. Website: www.unfpa.org/webdav/site/global/users/schensul/public/CCPD/papers/Winchester%20and%20Szalachman%20Paper.pdf, last accessed 7 October 2012.

Wisner, B. 2003. "Disaster Risk Reduction in Megacities. Making the Most of Human and Social Capital", Pp. 181-196 in: *Building Safer Cities: The Future of Disaster Risk*, edited by A. Kreimer, M. Arnold, and A. Carlin, Washington, D. C.: The World Bank.

The World Bank and United Nations. 2010. *Natural Hazards, UnNatural Disasters*. Washington, D. C.: The World Bank. Cited in: *Climate Change, Disaster Risk, and the Urban Poor: Cities Building Resilience for a Changing World*, edited by J. L. Baker. 2012. Washington, D. C.: The World Bank.

A needed upgrade in planning for adaptation to climate change

A flurry of extreme weather events, together with projections that grow more somber with every new scientific advance, have dramatically highlighted the need to respond more effectively to the threats already upon humankind. In the midst of a rapidly expanding global adaptation agenda, it is of primary importance to get adaptation and its constituent parts right, in order to generate the most appropriate and effective interventions. Reacting to events after they occur is no longer sufficient; we increasingly need to anticipate and reduce the suffering and the enormously damaging impacts coming events will cause. This book addresses a major gap in adaptation efforts to date by pointing to the vital role that an understanding of population dynamics and an extensive use of demographic data have in developing pre-emptive and effective adaptation policies and practices.

Politics and an oversimplified understanding of demographic dynamics have long kept population issues out of serious discussions in the framework of climate negotiations. Within adaptation actions, however, this is beginning to change, and this volume is intended to provide a framework for taking that change forward, towards better, more evidence-based adaptation. It provides key concepts linking demography and adaptation, data foundations and techniques for analyzing climate vulnerability, as well as case studies where these concepts and analyses illuminate who is vulnerable and how to help build their resilience.

UNFPA

iied

EL COLEGIO DE MÉXICO

GRAND DUCHY OF LUXEMBOURG
Ministry of Foreign Affairs

ISBN: 978-0-89714-001-0

Sales no: E.13.III.H.2

ISBN 978-0-89714-001-0
90000>
9 780897 140010