Human-Environment Interactions 3

Christopher G. Boone
Michail Fragkias *Editors*

Urbanization and Sustainability

Linking Urban Ecology, Environmental Justice and Global Environmental Change

Springer

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Human-Environment Interactions

VOLUME 3

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Editors

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ISBN 978-94-007-5665-6 ISBN 978-94-007-5666-3 (eBook)
DOI 10.1007/978-94-007-5666-3
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2012955482

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

In the Anthropocene era, human activity has altered biophysical systems on a planetary scale, accelerating species extinctions, radically changing land cover, and contributing to rising global temperatures. Over the last half century, there has been growing recognition that the ability of earth's ecosystems to support unbridled resource use is limited. Indeed, many biophysical processes on which we depend are presently overburdened, creating new uncertainties about the long-term viability of societies. The grand challenge for the coming decades will be to transform the ways we think about and act upon the relationship between people and the environment in order to transition toward a sustainable future.

In this book, we focus on three themes that, when combined, contribute to sustainability scholarship and practice. The first is global environmental change, understood not as unidirectional human degradation of the biophysical world, but as the integration of social and ecological dynamics on multiple spatial and temporal scales. Global environmental change is meaningful only when we incorporate the feedbacks, cascading effects, thresholds, lags, and interactions between societies and ecosystems.

The second theme is urbanization. We live in the Anthropocene, but we are also living in the urban century. Cities are and will continue to be the primary human habitat, and urbanization processes will drive and respond to the challenges posed by global environmental change. Growing urban populations can create negative pressures on global ecosystems, but as centers of innovation and increased productivity, cities can also be the seedbeds of solutions to global sustainability challenges.

The third theme of the book is justice. Urbanization and global environmental change have created gross inequities, with some people, often the most vulnerable, suffering a disproportionate burden of ill effects. A focus on justice, however, can ameliorate existing and future inequities while addressing the fundamental normative underpinnings of sustainability.

Sustainability means more than surviving – it is about envisioning a desirable albeit plausible future and working toward that goal. The future will be urban and dependent on careful management of socio-ecological systems from local to global scales and from near to distant time horizons. We argue in this book that justice is a desirable sustainability goal, both from a moral stance and as a framework for reenvisioning the future of urbanization and global environmental change.

This book stems from a workshop on linking ecology, environmental justice, and global environmental change that we organized for the Open Meeting of the International Human Dimensions Programme on Global Environmental Change (IHDP) in Bonn, Germany, in 2009. IHDP is an interdisciplinary international scientific program that catalyzes and coordinates research on the human dimensions of global environmental change. Efforts focus on research, building research capacity, and international scientific networking. IHDP works at the interface between science, policy-making, and funding agencies to coordinate and generate scientific knowledge on socio-environmental systems and advance understanding of global environmental change processes and the consequences for sustainable development. At the 2009 IHDP Open Meeting, Fritz Schmuhl from Springer Press encouraged us to consider a book project based on the workshop theme. In addition to his patience, we are very thankful for his guidance and encouragement in seeing this project through to completion.

We have benefitted a great deal from being part of the Urbanization and Global Environmental Change (UGEC) project, a core initiative of the IHDP. The UGEC project has been an international leader in promoting the science and practice of urbanization and global environmental change. UGEC, through diverse science coordination actions, has helped shift scholarly attention toward gaps of knowledge regarding the bidirectional interactions and feedback loops between urban areas and the global environment. Many of the ideas in this volume originated in conversations with UGEC steering committee members, project associates, and in meetings supported by the project internationally. The National Center for Ecological Analysis and Synthesis, sponsored by the US National Science Foundation, provided support for three workshops that were incredibly fruitful in developing our thinking on the main themes of the book. The Baltimore Ecosystem Study and the Central Arizona Phoenix Long Term Ecological Research projects, supported by the US National Science Foundation, have helped us push the boundaries of urban environmental research and thinking. We also wish to express our thanks for the continued support of the Global Institute of Sustainability and the School of Sustainability at Arizona State University. As well as housing the UGEC International Project Office and providing key financial support, the institute and school have created a stimulating hub of thinking and practice on sustainability science. This book is very much an offspring of that unique and vibrant marketplace of ideas.

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Chapter 1
Towards a New Framework for Urbanization and Sustainability

Michail Fragkias and Christopher G. Boone

Abstract This chapter describes the overall framework that links literatures, ideas, and scholars from urban ecology, environmental justice, and global environmental change; these subdisciplines have so far remained largely separate but have great potential for intellectual synergy.

Keywords Urbanization • Urban ecology • Environmental justice • Global environmental change

1.1 Introduction

The social, economic and physical transformation dimensions of urbanization make it "one of the most powerful and visible anthropogenic forces on Earth" (Sánchez-Rodríguez et al. 2005). Many of the most important and significant changes associated with the impact of globalization are taking place in urban areas (ibid. 2005). Already habitat for half of humanity, cities will absorb more than 90% of future

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*,
Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_1,

population growth, most of which will occur in poor countries (United Nations Population Fund 2007). Rapid population growth concentrated in urban areas has significant implications for the long-term outlook for people and the planet. Urban areas are increasingly subject to new challenges and rising social and environmental inequities, especially in poor countries; but urbanization offers opportunities for developing sustainable solutions to pressing global environmental and social issues. (Sánchez-Rodríguez 2005).

This book links literatures, ideas, and scholars from urban ecology, environmental justice, and global environmental change that have remained largely separated but have great potential for intellectual synergy. Urban ecology has undergone significant transformations in the last decade as participants have shifted from a focus on ecology *in* cities to ecology *of* cities (Grimm et al. 2008). Treating cities as ecosystems in which people and the built environment are integral has opened possibilities for linking ecological and social dynamics. To date, however, most urban-ecological studies have focused on local systems. Scaling up findings from experimental plots to metropolitan areas has been a significant challenge, and few have linked to regional or global scales.

As a field, urban ecology has been wary of using scientific findings for advocacy, yet there is enormous potential for using such research to reach normative goals for a sustainable future. In contrast, environmental justice researchers (and activists) have been quick to use science to call for action. Over the last 30 years, environmental justice research has revealed how marginalized groups (ethnic minorities, indigenous groups, people in poverty) typically bear most environmental burdens. A variety of groups have used such research to shut down polluting facilities or reduce the emission of harmful chemicals. The environmental justice community has also called for fair treatment and representation in environmental decision-making bodies. However, many have noted (see Chap. 3 by Pickett, Boone, and Cadenasso) that there is little "environment" in environmental justice, as most research and action has focused on the impact of human activities, such as polluting industry, on other human beings. In addition, a great deal of environmental justice research and action centers around single, local case studies. Similar to urban ecology, most environmental justice research has not scaled up to generalize about environmental justice processes at regional or global scales. While the environmental justice movement has expanded to other countries, the vast majority of research is based in the United States, and few studies link local struggles to larger global processes. Global environmental change (GEC) research, on the other hand, works to explicitly link local and global and human and natural processes. While GEC offers an integrative framework, it could benefit from the detailed scientific work of urban ecology and the explorations into social dynamics and normative stances of environmental justice. Most critically, by linking ideas, theories, and frameworks from the three fields, this book will offer new insights on promising integrated pathways toward urban sustainability (see Chap. 4 by Boone and Fragkias).

1.2 Progress So Far: A Landscape of Thematic Linkages

Urban areas are complex, dynamic systems that reproduce and are produced by interacting socioeconomic, geopolitical, environmental, and ecological processes at multiple scales. These interactions create a diversity of impacts that can be grouped into two broad categories: those originating in urban areas that affect global environmental change and global environmental change that affects urban areas. Urbanization has started to become visible in the analysis of global environmental change, but the majority of research continues to focus on how urban areas impact global environmental change. In particular, the bulk of GEC research has focused on urban contributions to greenhouse gas emissions and biodiversity loss. Increasingly, however, more attention is being devoted to the study of the impacts of global environmental change on urban areas and the people who live in them, as well as responses in urban areas to GEC.

In discussing global environmental change, we should not overlook the change of human living conditions that has occurred through the global shift from rural to urban settlements – a defining global trend of the last 100 years. Importantly, most of the future world population growth up to 2030 is projected to occur in the rapidly growing cities of poor African and Asian nations (around 80% of the total) as well as in Latin America. Africa is urbanizing more quickly, and Asia is urbanizing with larger absolute gains than the rest of the world's regions. In China over the next 15 years, 350 million people will be added to cities, a number larger than the current total population of the United States. This will bring the total urban population in China to one billion, while increasing the number of cities with more than a million to 221. While we expect an increasing number of megacities (cities with population of over 10 million people), they are expected to contain approximately the same proportion of the world's urban population – around 15%; the majority of future urbanites will live in rapidly growing medium-sized or small developing-world cities, subject to many present-day urban pathologies (UN 2008). Not only will urban areas of primarily medium size absorb the majority of future urban growth, but the majority of the new urban residents are expected to be poor. While slums already constitute about 41% of urban living configurations in the developing world, urban growth in certain regions will come about with the formation of new slums. The actual effect of climate change on poor and vulnerable urban residents will depend on multiple stressors and a confluence of factors, such as the level of economic development of a city and its nation, the pace of demographic change, various ecosystem factors, urban spatial structure and function, and the wider institutional setting.

Today it is clear that urbanization is occurring faster and at larger volumes in locations that are at lower stages of economic development and face rapid demographic changes. City systems will continue to disproportionately affect ecologically fragile areas and contribute to the loss of agricultural land compared to other systems.

Urban growth is expected in coastal and arid ecosystems, particularly sensitive to the effects of climate change. Sprawling urban development is projected as a dominant trend (although this could be reversed by spikes in oil prices). Urbanization hotspots lack functions such as durable housing, access to improved water, key resources, and sanitation and suffer from the ill effects of overcrowding, high levels of unemployment, and social marginalization. Institutional support in these hotspots is typically weak and ineffective, lacking the rule of law and accountability while hampered by endemic corruption. Such factors, operating in concert with climate change impacts, create "stress bundles" that increase the probability of climate change as a dangerous phenomenon. These stresses are not confined to urban areas. Since cities connect nodes of production and consumption in regional and global networks, climate change stresses can ripple through other places and wider regions (Sánchez-Rodríguez et al. 2005).

Climate change is currently at the forefront of GEC realities. Through the efforts of communities such as the IPCC and its 2007 4th Assessment Report, we know that the increase in globally averaged temperatures is indisputable and that since the mid-twentieth century is very likely (90–99% chance) that most of the increase is anthropogenic. Other than the general increase of temperatures, sea level and frequency of natural catastrophes, and levels of economic losses, the collection of available conservative climate change models shows that it is very likely that hot extremes, warm spells and heat waves, will continue to become more frequent over most land areas; that heavy precipitation events will become more frequent over most areas; that it is likely that the area affected by droughts will increase; and that future tropical cyclones will become more intense, with larger peak wind speeds and heavier precipitation but uncertain change of total number (IPCC 2007).

Urban areas have begun to be considered a central element in the responses to climate change during the last few years due to a combination of factors of opportunity and risk. As the rapid urban transition to four billion urban inhabitants worldwide will occur (three-quarters of the population) by 2030, particularly in poor countries, the fact that between 50 and 80% of GHG emissions already originate in cities comes sharply into focus. On a positive note, cities are (or can be) places of economic growth and social well-being, important nodes for today's globalization, and the nexus of production, commerce, and gateways to the world's economy (Sanchez-Rodriguez et al. 2005). They are also potentially efficient users of infrastructure and resources due to economies of scale, promoters of more efficient urban forms and functions, and prime spaces for intervention. In cities there exist opportunities to change production and consumption patterns in order to reduce adverse effects on GEC and promote renewable sources of energy. Local strategies in metropolitan areas can lead to more local and global sustainable solutions.

Scholars have begun to explore complex links between ecology and environmental justice through new integrated, collaborative, transdisciplinary, and synthetic research on the dynamics of socio-ecological systems. In bridging the gap between ecology and environmental justice (EJ), researchers have focused on the intersection of questions on how to deal with limited resources and ecosystem services and how to increase equity and establish social cohesion at various levels; several key components of EJ are relevant (Shrader-Frechette 2002; Pickett et al. 2007). First, and at the core, is the component of distributive justice, which seeks to understand the distribution of environmental benefits and threats in relation to social groups, defined most often by race, ethnicity, and class. In many cases globally, communities characterized by both ethnic and class disadvantage live near environmentally threatening sites or under the threat of various environmental hazards. Second is the issue of participative justice, examining fairness and participation in environmental decision-making. At the local level, voices of marginalized groups are frequently not heard even in cases that have a direct bearing on marginalized groups' local environmental conditions, livelihoods, and quality of life. Transnational waste transfers and "biopiracy" of genetic material by international agencies and corporations are two global scale examples of participative injustice, where affected parties have little to no voice in decisions and actions (Pellow 2007).

While international pressure mounts for fast action toward established greenhouse gas (GHG) emission targets, populations with threatened livelihoods due to irreversible climate change and its expected shorter-term effects have to start considering adaptation options. As is the case with the majority of environmental problems facing humanity, anthropogenic climate change affects disproportionately the poor and marginalized across different scales – regions, nations, cities, and neighborhoods. While clearly climate change effects result in both winners and losers, the nations and cities that have been the largest emitters of GHGs for the last 100 years will not experience the bulk of the negative effects of climate change. The "goods" and "bads" of anthropogenic climate change are not distributed uniformly across populations in the developed and developing world or even across populations within developed countries and LDCs. Poor nations and populations have a reduced or nonexistent adaptive capacity that would help them protect themselves from the effects of climate change and thus face increased levels of vulnerability. At the same time, poor and marginalized urban residents worldwide often do not have a strong voice in the political arena with resulting weak representation in national and subnational policymaking. Environmental justice offers a mature and robust framework for citizens, policymakers, and scholars to understand the patterns and dynamics of uneven consequences of global and local environmental change.

1.3 Toward a Synthesis

This book adopts a broad view of environmental justice that incorporates distributive and participative justice, as well as an understanding of the social, economic, political, and cultural contexts of environmental problems, struggles, and resistance. It advances environmental justice scholarship by linking it to ecology and global environmental change and in doing so provides a framework for urban sustainability that is just and equitable (Boone 2008).

The present and future well-being of societies is intrinsically associated with the sustainable growth of their urban areas; this involves the ecosystem health and continued provision of ecosystems services within and around cities, justice in the distribution of environmental amenities and disamenities, justice in the recognition and participation of all affected parties, and wise responses to the challenge of climate change. This volume is an effort to synthesize new work on these themes – addressing jointly the major themes we discuss above.

Some of the primary questions that guide the discussions in this book include:

- How do major ecosystem services interact with climate change processes and what are the environmental justice implications?
- How does the distribution of environmental inequities, measured by the uneven distribution of ecosystems services, in conjunction with the uneven/differential impacts of climate change affect the vulnerability, resilience, and sustainability of urban socio-ecological systems?
- Are there major mechanisms that (can) link science, policy, and practice toward the goal of urban sustainability in the presence of interacting inequities? How can the imperatives of participatory justice inform such mechanisms?
- What do proposed levels of mitigation and adaptation action (as responses to climate change) mean for environmental justice worldwide? Is mitigation and adaptation action promoting urban sustainability under the prism of equity and justice?

1.4 Structure of the Book

The book is organized in 11 chapters. This chapter provides the overall direction of the volume. Chapters 2, 3, and 4 address conceptual themes, such as the ever-present critical question of how to define urban areas in an era of global environmental change, the connections of ecology and environmental justice in urban areas, and the connections of the relatively ignored theme of environmental justice to the wider discussion over vulnerability and sustainability. Chapters 5, 6, 7, 8, 9, 10, and 11 are empirical in nature; all of them cover at least two out of the three main themes in this volume.

Marcotullio and Solecki (*Chap. 2, What is a city? An essential definition for sustainability*) discuss the wide variety of definitions of the city and characteristics of the global urbanization process in the social sciences. Older debates in social science disciplines still bear relevance to current discussions that entail a more holistic understanding of the role of the environment, ecology, and natural resource management. Through the assistance of new geospatial technologies, definitions of the "urban" have multiplied and have become more relevant for any discussion over sustainability. The chapter provides strong foundations to discussions over the nature of urban areas in the remainder of the volume.

Pickett, Boone, and Cadenasso (*Chap. 3, Ecology and environmental justice: Understanding disturbance using ecological theory*) discuss the interconnections between the fields of ecology and environmental justice in urban areas, potential gains from further integration, and pathways for breaking down existing barriers in communication between academics and practitioners from both fields. The authors ask in particular how ecological theory may contribute to environmental justice scholarship. They focus on disturbance theory as an example because the spatial and temporal distributions of disturbance may relate to the spatial and temporal distributions of environmental threats, which inform distributive justice inquiries in environmental justice scholarship.

Boone and Fragkias (*Chap. 4, Connecting Environmental justice, sustainability, and vulnerability*) argue that justice is a core yet often ignored principle of sustainability. As a pillar of sustainability, it is well understood that the social dimensions of sustainability require a balanced approach along with the economic and environmental dimensions. When such issues (such as the issue of equity) are not taken into consideration, the overall concept and practice of sustainability is undermined. The authors argue that sustainability research and practice can benefit from a closer reading of environmental justice scholarship. At the same time, environmental justice can draw on sustainability principles of systems thinking, anticipatory action, and environmental stewardship to strengthen its methods and approaches while broadening its constituency. The authors suggest that centrally focusing on ideas of vulnerability can bridge environmental justice and sustainability and can also benefit from the convergence of ideas, principles, and practices of these fields.

Pincetl (*Chap. 5, Urban ecology and nature's services infrastructure: Policy implications of the million trees initiative of the City of Los Angeles*) analyzes major national efforts on tree planting programs and their purported environmental and social benefits. Trees offer a powerful symbol of nature in the city and, to advocates of such programs, are an obvious lever for the improvement of environmental quality. Job creation usually accompanies primary justifications for tree planting. Yet the science behind the environmental and social benefits remains meager, and in a time of budget austerity, the costs of planting trees and maintaining them are significant. As these programs have been implemented, they have also encountered unexpected resistance from residents. Pincetl then zooms into Los Angeles and the recent campaign to plant a million new trees to make the city the greenest in the United States and examines tree planting through a lens of urban sustainability. She discusses the challenges of transitioning from a sanitary city model to one of integrating nature's services to help reduce urban-ecological footprints. She points out that moving from a sanitary city (or modernist city) to a sustainable city involves complex changes in the rights and responsibilities of residents and the governance structure alike.

Pastor et al. (*Chap. 6, Risky business: Cap-and-trade, public health, and environmental justice*) focus on the relationship between GHG reductions, co-pollutants, and geographic inequality in California. They investigate in particular whether a cap-and-trade mechanism for GHG emission reduction could actually worsen the pattern of disparate pollution. They assemble a dataset of large GHG-releasing facilities in California, including power plants, cement kilns, and petroleum refineries; geo-code the facilities; attach publicly available emission information on PM, NOx, and CO_2; and link in block group level census data to carry out neighborhood-level environmental justice analysis. Perhaps unsurprisingly, they find patterns of environmental inequity. To assess what this implies for a trading system, they identify which industries and facilities are driving the environmental inequity and use this to suggest the potential for problems of unequal benefits under cap-and-trade.

Young (*Chap. 7, Urbanization, environmental justice, and social-environmental vulnerability in Brazil*) presents four case studies of Brazilian metropolitan areas – Curitiba, Baixada Santista, São Paulo, and Rio de Janeiro – on the bidirectional interactions of urbanization and global environmental change, incorporating frameworks of urban ecology and environmental justice. She utilizes distinct concepts and methodologies for the identification and characterization of environmental risk. In the context of climate change, the increase of intensity and frequency of extreme events such as storms, heavy rain, and heat waves, vulnerability of populations in metropolitan areas increases significantly. The case studies presented in this chapter have as a main focus the transformations in the landscape due to the urbanization process and the consequent environmental degradation in different regions of Brazil. Most of these studies involve the use of methods of analysis from techniques and geoprocessing tools (remote sensing and GIS) for the integration of spatial data. Risk is associated with society's susceptibility to environmental changes, seen not only as a result of a certain events but also as a consequence of a social process related to structural urban issues that are linked to political decisions and measures implemented in the course of history. Questions addressed in the chapter examine different dimensions and complementarities of land-use planning and the environmental changes caused by alterations in the dynamics of the local landscape.

Alves and Ojima (*Chap. 8, Environmental inequality in São Paulo City: An analysis of differential exposure of social groups to situations of environmental risk*) aim to operationalize the concept of environmental inequality, measuring the association between disadvantaged socioeconomic conditions and greater exposure to environmental risks through the use of geoprocessing methodologies. They offer a case study of the city of São Paulo, Brazil, analyzing situations of environmental inequality, based on the level of risk exposure of different social groups. Results show that people living in risky areas fall in lower socioeconomic categories and that the trend has worsened over time.

Barton (*Chap. 9, Climate change adaptation and socio-ecological justice in Chile's Metropolitan areas: The role of spatial planning instruments*) continues on the theme of spatial planning but focuses on the process of climate change adaptation as a socio-ecological justice challenge and applies his analysis to case studies in Chile, South America. He argues that metropolitan vulnerability to climate change is sustained by unresolved challenges due to preexisting distribution and equity issues and that a re-centering of the climate change agenda is required to confront these structural obstacles to effective adaptation. The cases of Antofagasta, the Valparaiso Metropolitan Area, and Greater Concepción reveal the complexity of urban vulnerability to climate change in the country and the socio-ecological roots that account for this complexity.

Bolin et al. (*Chap. 10, Double exposure in the sunbelt: The sociospatial distribution of vulnerability in Phoenix, Arizona*) discuss how rapid urban growth in the Phoenix metropolitan area in the USA for more than a century produced a durable, racialized landscape, with minorities concentrated in an environmentally degraded urban core and a largely white and relatively privileged population in the expanding zone of peripheral suburbs. As suburbanization has marched outward, new and different forms of environmental insecurity are appearing. While vulnerable people in the central city are exposed to a concentration of industrial hazards and victimized by the construction of transportation infrastructure, some peripheral populations face an emergent double exposure to both an imminent water resource shortfall as a result of regional climate change and to localized effects of the crisis of finance capital and resultant foreclosures and plunging home values. The authors explore how historic sociospatial and political economic processes produced the current landscape of environmental injustice in the Phoenix urban core and led to suburban expansion and the foreclosure crisis. They also explore how predicted climate change in the West has begun to reconfigure existing patterns of environmental risk and security due to its effects on water resource availability. Through an integration of these domains, the authors analyze the shifting patterns of sociospatial vulnerability and extend the conception of environmental injustice.

Fang, Huang, and Seto (*Chap. 11, Climate change, urban flood vulnerability and responsibility in Taipei*) focus on the theme of rapidly growing Asian capital cities and their vulnerability to climate change impacts. Although climate change mitigation and adaptation strategies have been drafted in many Asian cities, little is known about how a city's growth affects its vulnerability to climate change and how governmental agencies respond to climate risks. Nowhere is this more evident than in Taipei, Taiwan, a city whose population has doubled over the last 40 years, during which urban flooding has also increased. The authors use Taipei as a case study to ask three interrelated questions: (1) What determines a city's vulnerability to climate change impacts, especially flooding? (2) How do land-use regulations affect urban vulnerability to climate change? (3) What governmental agencies are responsible for regulations affecting the land use and ultimately climate change vulnerability? Their analysis indicates that the combination of unclear government responsibility and minimal coordination among governmental agencies has resulted in ineffective strategies to minimize flooding risk. Despite numerous policies, Taipei is still highly vulnerable to flooding, and the risks are not distributed equally among the population.

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Chapter 2
What Is a City? An Essential Definition for Sustainability

Peter J. Marcotullio and William Solecki

Abstract The debate over the definition of the city and the elements of the urbanization process has a long history in the social sciences. These debates highlighted the significant differences in social outcomes between studies that defined cities as social entities and those that examined cities as strictly social processes. With increasing interest in environmental and resource management concerns, the debate over what a city is and what are the processes of urbanization have taken on even greater importance. While, in one sense, it has become easier to identify "the urban" due to new imaging and mapping technologies, taking the definition of cities as simply entities has important consequences for our ability to identify sustainable pathways. There is much that environmental and ecological studies can bring to the definition of the city, but a there is also much that these studies can learn from previous social research. By focusing on cities as entities and ignoring social processes, these new studies may conflate numerous developmental processes, and at the same time ignore the fundamental aspects that define the urban, resulting in a misunderstanding of social, economic and environmental consequences.

Keywords Definition of city • Urbanization process • City as entity • City as quality • Urban ecosystem approaches

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_2,

2.1 Introduction

The debate over the definition of the city and the elements of the urbanization process has a long history. In the past, these debates were embedded in social controversies, and they highlighted the differences between cities as social entities and cities as determinants of social processes and events. This debate pushed scholars to refine their understanding of what objects of study might be most accurately called urban and also has helped to further explore the causes of urbanization, identify the emergence of cities, and examine the influences on dense settlement on social processes. With increasing interest in environmental issues and resource management challenges, the debate over what is a city and what defines urbanization has reemerged. Much of the urban environmental literature, however, treats the city as an entity (focused on physical aspects) and often conflates urbanization with other processes. Despite and perhaps because of the incorporation of new technologies that allow researchers to map urban land uses and correlate environmental change with the increasing share urban populations, some of the urban ecological literature is falling into previously identified traps. The threat is that environmental policies are broadly antiurban. It is therefore critically important to reassess the lessons learned from social research on the definition of cities and urbanization. At the same time, there is much that environmental and ecological studies of cities can bring to our fundamental understanding of urbanism and urbanization, particularly through the treatment of cities as integrated systems. In order to gain from these new insights, however, researchers need a clear focus on the meaning of our particular object of study. What we as urban environmental researchers understand as the defining characteristics of urban is important, not just to enhance comparative ecological research, but is also crucial to teasing out the environmental benefits and costs of dense settlement from those of a number of related development processes.

Moreover, understanding the meaning and limitations of the definition of the city and urbanization is crucial for sustainability. For example, all too often, the underpinning of environmental discussions of cities confuses the effects of concentrated settlement with growing populations, affluence, ecosystem service consumers, and waste producers. As such cities are portrayed as resource consumers and biodegraders. The target of policy, therefore, is the city and urbanization, rather than affluence, consumption, and population growth. If we spread the same population with the same consumption habits across the landscape, however, environmental damage would in most cases increase. Dense settlement is not the primary factor in many environmental trends but could be part of the solution. Urbanization has been linked to a number of important processes that help promote sustainability, such as lowering fertility rates, lowering energy consumption per capita and concentrating population geographically. Finally, cities offer important opportunities for the poor, including social services and employment. Preventing urbanization, particularly in the developing world, translates in prohibiting the social mobility of the poor, and hence misspecification of urban policy has important environmental justice implications.

This chapter attempts to promote a balance understanding of urbanization. In order to do so, we revisit the different popular definitions of the city and urbanization used in the social science literature. We then turn to examine how environmental research defines cities and urbanization to show that there are some commonalities between these two research agendas in terms of their definitions. We also present an important trend in urban ecological studies that is questioning how cities are conceptualized and using new and powerful models and analytic frameworks that can add much to our knowledge of cities.

2.2 Urban Definitions and Perspectives in the Social Science Literature

It has never been easy to define a city at one particular time in history and even more difficult to identify the determining characteristics of one that is applicable to all ages (Carter 1983). The definition of a city is associated with the notion of urban origins and inspired by the contemporary forces of change. Any definition of a city has always been underpinned by the identification of characteristics that set it apart from agricultural or pre-civilized settlements. Notions of the city are only possible with an understanding of how cities grow and how urbanization patterns materialize. The social science literature points out that these connections have been difficult to isolate, if not analyze.

In general, the definition of the city can be divided into two perspectives: those that focus on the city as an entity and those of the city as a quality (Pacione 2001). Within each of these general categories, there have been debates as to what indicator or process is the most accurate in defining urban spaces.

2.2.1 The City as an Entity

The city as an entity focuses on the identification of the dense settlements in space. There are, at least, four methods used by urban study researchers to define the location of cities based on demographic, economic, administrative, and functional definitions.

Demographic: Urbanization is often defined by the percent of the population living in urban centers (over a specific threshold). Berry (1973) pointed out that the most widely accepted theories on the effects of cities on social relationships is based upon population characteristics of the city: concentration, size, density, and heterogeneity. This method, starting with Weber (1967 [orig. 1899]) and formally standardized by Tisdale (1942), highlights the change in population size and density scales along a village to town to city continuum. The measure is simple, often used by demographers and others, to identify the level at which societies have achieved urban lifestyles (Davis 1972). It is given in this method that we understand the spatial allocation of population and use similar spatial definitions for urban land use.

It is most unfortunate, however, that the indicators of city size and urbanization in many large countries in the world are inaccurate. This is due, in part, to the difficulty of undertaking a population census, or not releasing this information consistently or and at frequent intervals (Satterthwaite 2007).

Economic: Another important method to determine the location of cities is the identification of the urban economic base (percent nonagricultural work). The notion that cities are defined by a marketplace and trade-commercial relationships took hold in the early twentieth century (Weber 1958). The importance of the marketplace highlighted two different theories of urban origins. The most widely held view is that cities emerged in regions in which agriculture was sufficiently productive to generate a surplus that feed enough people so as to facilitate population concentration. Moreover, those in urban areas were then free of agricultural demands to engage in other types of economic activities (Bairoch 1988). While this perspective on the historical emergence of cities vis-à-vis agriculture holds dominance among urbanists, there is an alternative viewpoint. The idea of economic activity as defining cities has lead to the notion that cities emerged first as marketplaces and centers of trade rather than after agricultural dominance. Once developed, cities, as concentrated economic innovation centers, helped to induce agriculture (Jacobs 1969). Notwithstanding these differences, the idea for those using this method is to identify locations in space where certain types of economic activities occur, including mostly nonprimary sector employment and activity. Many countries use this indicator to identify urban spaces. In India, for example, a settlement must have more than 75% of the adult male population engaged in nonagricultural work to be classified as urban.

Administrative: Towns and cities also can be defined according to legal or administrative criteria based on their role as administrative and government center. Administrative methods to define urban areas base distinctions upon political considerations. For example, in the USA, nonurban counties that may have similar economic structures, population densities, and demographic characteristics as urban counties and are functionally linked to a city through a number of processes are not considered urban strictly because they fall outside the political jurisdiction of the city. New York City has five counties, and while connected to the surrounding counties in New York, Connecticut, and New Jersey, these other counties are not part of the strict definition of the New York. At the same time, in China, large political boundaries that are defined as urban include both urban and very rural populations. In this way, Chongqing municipality has a population of approximately 32.8 million people, including 23.3 million farmers.

Functional: Another method to define cities is through examining the functional aspects of different spaces. The functions identified reflect the (economic, social, and physical) extent of urban influence. The notion was developed from a variety of different early writings including those of Friedmann and Miller (1965) on the "urban field," Berry (1973) on the "daily urban system," and Gottmann (1961, 1976) on the megalopolis. All noticed that cities were expanding rapidly after WWII, overreaching administrative and political boundaries. Hence, the true size of the city went beyond what was politically defined. The way in which to locate a city was to identify the types and intensity of functions within a space and the extent defined by the functional linkages. Researchers in Asia used the idea of extended urban areas to identify "extended metropolitan" and "mega-urban" regions (McGee 1991, 1995). Most recently, analysts have noted that the economic and political function of some cities extends over the entire planet. The "global cities" literature, in part, defines a set of cities by their attributes in terms of numbers of international connections, be they transnational companies or international passengers (Short and Kim 1999; Lo and Yeung 1998). Recent work in this area attempts to expand the list of urban functional characteristics, previously limited to economic, fiscal, and strategic, to include livability and ecological aspects (Institute for Urban Strategies 2010).

Over time, however, the urban study literature has not settled on a single acceptable method to define a city by its spatial location. While scientists agree that cities have more people, living more closely together, surrounded by larger facilities, and undertaking higher-level administrative functions than towns or villages, as of yet, there is no consensus on the method, indicator, or threshold for any of these characteristics. Not only do different methods provide varying results, but studies that use similar methods with different thresholds have also resulted in dissimilar findings. Hence, Satterthwaite (2007) has noted that depending upon the administrative boundaries chosen to study a number of large cities, the population size of these entities can vary significantly. The result is the often-cited variety of definitions used by the UN's *World Urbanization Prospects*, the world's major source of figures on the number, share, and growth rate of cities and national urbanization characteristics. In any version of this document, there can be over 40 pages of definitions of urban, in the appendix, listed by nation defining different criteria and cutoff points. Not all of these definitions allow cities in different countries to be directly comparable (McGranahan et al. 2005; Brockerhoff 2000), although researchers often use these data to compare urban size, growth rate, and urbanization levels between countries. As a result, the social science community has understood that while convenient, defining an area as urban as an entity is an ultimately arbitrary decision (Timberlake 2010) and that this type of definition cannot be used in isolation to identify the impact of the urban on social, behavioral, or economic change. This later aspect of defining cities promoted the search of qualities that define "cityness."

2.2.2 The City as a Quality

Perhaps the original theory that attempted to explain how cities differed from nonurban spaces in terms of their qualities was articulated by Maine (1861) who saw urbanization (and modern life in general) as defined by the increasing emphasis on more formal, legal, and institutional conditions of life and the dissolution of family dependency and individual obligation. Underpinning this thinking was that the city, as opposed to the countryside, contains qualities and processes that both revolutionized social life and created tensions and challenges for societies. For Tonnies (1955 [orig. 1887]), urbanization of the nineteenth century, along with the emergence of the modern state, science, and large-scale trade, generated the increasing importance of contractual obligations among individuals, whose roles were becoming more specialized. *Gemeinschaft* and *Gesellschaft* are the terms he used to describe a key set of difference between village and city (or between traditional and modern). Other sociologists, such as Durkheim (1984 [orig. 1893]), Simmel (1997 [orig. 1903]), and Sumner (1906), built their theories on these foundations, creating a persuasive argument that the dramatic changes occurring in some societies at this time where experienced more intensively by the increasingly greater proportion of population that were living in urban centers. Redfield (1953) summarized some of the tensions through his folk-urban dichotomy, the evolutionistic contrast between preliterate, homogeneous, religious, familial, personalized, primitive, and peasant (rural) communities and the literate, heterogeneous, secular, individualized, and depersonalized (urban) parts of society.

The negative aspect of this view emphasizes that "cityness" creates less healthy, vigorous life and hence social deterioration. It was Wirth (1938), however, who wrote the single most widely accepted theory of the effects of cities on behavior and social relations. He synthesized these ideas by accepting that urbanization meant large, dense, heterogeneous population settlements and derived from the attributes the negative qualities noted by others as the consequence. For example, Wirth theorized that the larger size of the city produced greater volumes of human interaction, which spread interpersonal dependence over more people creating less dependence upon any one person. As a result, contacts become impersonal, superficial, and transitory. Combined with other aspects of urban life, individuals could not help but experience anomie, alienation, and ultimately deviance. This negative view of what cities offer has been strongly held by intellectuals (White and White 1962) and has carried over into the environmental literature (Brown 2001a).

Subsequent writers have used these powerful concepts to identify the beginnings of cities suggesting that urbanism evolved with the particular set of functionally integrated institutions, first devised some 5,000 years ago, to mediate the transformation of relatively egalitarian, ascriptive, kin-structured groups into socially stratified, politically organized, territorially based societies (Wheatley 1971). The "Urban Revolution" of Childe (1950) included 10 features which distinguished new cities from the older Neolithic villages. For example, some of his features were size (new cities differed in population by an order of magnitude than villages), structure of the population (the importance of occupational specialization), public capital (the share of population devoted to the erection of monumental buildings and full-time artists), records and exact sciences (the growth of script and mathematics and which are intimately bound up with "civilization"), and trade (the establishment and maintenance of a network of trade routes). These characteristics indicated significant variance of cultural and social organization across space.

Related approaches to define the quality of cities attempted to move power to the center of the analysis and focus attention away from the influence of urbanism, per se, to the larger socioeconomic context in which cities are situated. So for instance, some global city researchers focus more on the "world city formation process" (Friedmann 1986) and the processes associated with the globalization that are occurring with these cities (Taylor 2004; Sassen 1991, 1994). The characteristic of the "global city" is not an identity but rather an intensity continuum defined by sets of urban and nonurban processes. Those cities linked to global economic, social, and political flows are undergoing similar processes and therefore becoming more alike.

Other social science scholars have gone beyond the confines of urban influence and urban areas to seek out fundamental characteristics that define urban patterns. Some scholars argue, for example, that more than globalization, the entire mode of production of an economy defines social structure, which is then reflected in urban form, function, and processes (Gordon 1978). Analysts have argued that the specification of the capitalist world economy as a single interactive spatial system over long periods of time is needed to fully understand urbanization (Chase-Dunn 1975; Chase-Dunn and Manning 2002). Along these lines, scholars such as Harvey (1989, 1990) have argued that there is no need to separate the urban realm from the larger sociopolitical system. He concludes that while urbanism (as a way of life associated with residence in an urban area) has a distinctive structure and character, it only exists and is maintained by a larger framework created by the forces of capitalism. In arguments like this, researchers reject notions of "spatial fetishism" (which assign causal power to space in determining human action) and rather emphasize the role of urban spaces in the capitalist system.

Most recently, "postmodernists" have attempted to put space back into the urban equation. They have done so by emphasizing the differences among cities around the world and the difficulty of ascribing any set of universal forces to define cities (Robinson 2002, 2004). Ironically, these studies base an understanding of cities on the notion of the declining urban-rural divide (Webber 1963), suggesting that telecommunication technologies are helping to redefine space and therefore what is urban (Soja 2000). The perspective, however, does not overemphasize the influence of globalization; global forces have not created convergence but rather combine with local dynamics. The confluence of local and global scale influences has added new dimensions to the notions of propinquity, density, and social heterogeneity (Amin and Graham 1999). In doing so, this line of research attempts to recapture the importance of space and at the same time recognizes the multi-scaled influences to which urban residents are increasingly interacting.

What has become abundantly clear by the social research focused on defining cityness is that it has lead to a greater understanding of the complexity of development. Increasingly, this complexity is not limited to within the city. While interactions and processes within urban areas matter, there are scales beyond the local that are important to defining urban social life and organization. Moreover, identifying the urban and its impacts on social conditions is growing more difficult due to four factors. First, given varying and unique contemporary forces of urban change, urbanization, globalization, and development processes are currently acting on cities differentially, creating new and different types of cities, some of which have characteristics never seen before (Marcotullio 2005). These new forces of change have resulted in shifts in the scale, rate, and form of urbanization patterns, both across space and time. Hence, we can no longer relay on previous research and definitions to accurately model today's conditions. In the physical sciences, this is called the non-analogue world. It is important in this case, because previously many urban planning practices and policies were considered transferable from the developed to developing world. This may no longer be appropriate given the different development contexts of these two worlds. Second, the urban sphere has not only been influenced by larger-scale forces but has grown beyond its own boundaries and threatens to encompass social life in nonurban places (Lefebvre 2003). Rural residents now exhibit many of the characteristics and behaviors previously only associated with urban residence. A rural farmer and university graduate can partake in international foods, watch TV, surf the Internet, and through it, sell his or her grain on the Chicago Mart (Friedmann 2002; McGranahan et al. 2005). This makes it difficult to separate out what are strictly urban social processes and what are not. Third, new forces of change are more complex and interrelated than during previous periods, creating extremes in social conditions and making it more difficult than efforts in the past to isolate and identify the fundamental characteristics of the city and urbanization from other processes (Massey 1996). Fourth, and fundamental to these other characteristics, the notion of the "spaceless city" highlights the importance of scale and the ability of new communication and transportation technologies and the forces of globalization to amplify or attenuate urban processes. Defining multiple scales at which social, political, and environmental processes operate creates obvious challenges for defining spatially fixed entities and qualities of these spaces.

2.3 The Definition of Urban in the Environmental Change Literature

Into urban research have stepped ecologists and environmental and physical scientists. Their attention to cities at this point in time is due largely to two global trends. First, more people are now living in cities, and solutions to environmental and ecological problems will therefore be most likely found in a focus on centers of human concentration (UNFPA 2007). Indeed, according to some, we have now entered the "century of the city" or the era of the "Asticene" (Seto et al. 2010, p. 2).[1] Second, environmental problems have taken center stage in the global agenda. Previously, environmental concerns were largely local, but with the rise of awareness of the global environmental crisis, concerned researchers have turned to global systems analyses in which cities and the urbanization process are often portrayed as the villains (Brown and Jacobson 1987; Brown 2001b; Srinivas 2000; Odum 1991).

The definition of cities in urban environmental studies, however, differs from those in the social sciences in that for environmental researchers and ecologists, cities are often taken for granted. That is, within the ecology and environmental science literature, very limited attention is given to the definition of cities; the urban tends to be assumed, not defined (NcIntyre et al. 2000).

[1] This term is suggested as an alternative to "Anthropocene," as anthropos (humans) are fundamentally and primarily astos (urban).

When cities are defined, they have most often been conceptualized as entities separate and distinct from "natural" or rural areas. The undisturbed, nonhuman-dominated natural areas of Earth have been the primary purview of ecologists and environmentalist for the last 150 years, and this view still holds sway in the community (Collins et al. 2000; Corbyn 2010). Urban ecology studies, until recently, were seen as nontraditional and have only gained legitimacy in this field by comparing ecological aspects of the urban area to what is found in the "natural" world. As entities, environmental and ecological researchers rely on the definition of city as either by population or some variant of "built-up area," or specific "land-use" (residential, commercial, urban, etc.) type, in reference to natural areas (NcIntyre et al. 2000).

The identification of cities as built space in this literature is not uncommon. It has been used by those examining changes in natural systems with increasing urbanization in space-for-time substitution experiments: rural-to-urban transect analyses (McDonnell et al. 1997; McDonnell and Pickett 1991). Alternatively, "urban" is considered in gradients of land use from pristine natural environments to cultivated landscapes consisting of a matrix of agriculture land to suburban landscapes which include low to moderate density housing and urban landscapes of the most intense human influence dominated by building road and other paved surfaces (Forman and Godron 1986). Another alternative is to use impervious surfaces, which stand as a proxy for human settlement and hence human impact (Sutton et al. 2009).

These studies have been aided by new technologies for geographical information system and satellite imagery analyses that help sort out boundary and other geographical concerns (Skole 2004; Wolman 2004). Several excellent databases can be used to identify urban areas in this way. For example, a recent review demonstrated that there are ten global urban or urban-related maps of urban extents (Schneider et al. 2009). Increasingly, urban environmental scholars seem to rely on the information from these types of studies to identify cities.

While these technologies have provided valuable insight and enhanced the ability of researchers to compare conditions within and around spaces across the globe, they suffer from some of the same early deficiencies articulated by their social science counterparts. These studies are based upon an arbitrary method to define the urban, and by focusing on the city as entity, they tell us precious little about the processes associated with urbanization that are responsible for outcome and change. In the first case, for example, the ten global databases that are currently used to identify urban areas vary by more than an order of magnitude. So the set that defines the smallest set of densely populated places suggests that there are 276,000 km^2 of urban areas on the planet, while the dataset with the largest estimations for urban area suggests there are 3,524,000 km^2. In the second case, as with the social science literature, using a single indicator as the definition of a city can result in conflating the many different processes that occur within cities. Hence, rather than exploring the unique contributions of urbanization on environmental change, all aspects of human life, whether they occur within or outside of urban areas, are too often rolled up into one super variable: the city. The classic example of such a method is the urban ecological footprint (Wackernagel and Rees 1996). In this case, the analysis of the consumption activities that occur in urban areas and their resultant emissions are all identified as being urban. There is little attempt to separate the other forces at work that might also help to sustain ecological footprints. Even less frequent is any attempt to compare the footprints of urban to rural residents. Hence, what might be the result of affluence is often conflated with urban. This not only gives a false impression of the impacts of urbanization on the environment, it can lead to policy misspecification. As such, some commentators have associated cities and urban life directly with high resource consumption (Brown 2001a) without demonstrating that indeed people of similar income, class, status, etc., in cities consume more than those living in nonurban spaces. In other cross-national studies, urbanization turns up significantly correlated to environmental impact. While urbanization is related to industrialization, GDP growth, and rising incomes, the dynamics of these interactions are poorly understood. All too often nations with high urbanization levels are identified as the least sustainable. But is this relationship due strictly or primarily to living close together?

In an attempt to supplement the definition of the city as entity, some environmental researchers have adopted the term "urban ecosystem" to identify the qualities of urban areas (Douglas 1981; Millennium Ecosystem Assessment 2005; Sterns and Montag 1974). Those that use the urban ecosystem concept argue that cities have ecological structure and functions, as do their counterparts in the natural world.

Urban ecosystem ecologists separate their research from urban ecology as difference in "ecology of cities" from "ecology in cities" (Grimm et al. 2000). Two characteristics help to make this distinction. First, urban ecosystem studies include both physical and social dynamics and processes (McGranahan et al. 2005), which are typically not included in ecology in city studies. Over the past few years, through the use of the urban ecosystem concept, research frameworks have emerged to integrate the socioeconomic dynamics within urban space and relate these to environmental outcomes (Machlis et al. 1997). Researchers participating in the Long-Term Ecological Research (LTER) stations (Baltimore and Phoenix) in the USA, for example, have used this framework and other integrated models.

Second, urban ecosystem studies emphasize the multi-scale relationship between cities and the environment. That is, rather than considering the city as a bounded entity, urban ecosystem studies focus on the activities and processes that occur in urban areas and how they impact environments near and far. Unfortunately, there are few of these types of studies, and even among these, integration between biophysical and human and economic components is limited (McDonnell et al. 2009). Even so, among these urban ecosystem studies, the focus on what is urban is often missing (NcIntyre et al. 2000).

2.4 New Trends in the Urban Ecosystem Literature

Moving forward in this decade of urban sustainability research, new frameworks that take into account recent trends in the urban ecosystem literature can potentially lead to a better understanding of cities and the urbanization processes, as they relate to the environment. These studies start with an attempt to identify the distinct aspects of dense settlement, as opposed to identifying difference of ecological conditions in urban and nonurban areas. Some examples of these types of studies include those comparing the impact of energy consumption of urban residents to those of nonurban or national levels (Brown et al. 2008), questioning the heretofore taken for granted impact of cities on the global climate system (Dodman 2009; Dodman and Satterthwaite 2009) and comparing the food consumption patterns of urban residents to their rural counterparts across different income gradients (Stage et al. 2009). These analyses highlight the ecological and environmental differences and impacts of and between urban and nonurban areas as defined and associated with socioecological factors in these two types of spaces. In this way, findings point out differences between both the independent variables (socioeconomic events and ecological dynamics within different spaces) and are related to the dependent variables (environmental and ecological outcomes), and the environmental benefits and costs of dense settlement can be more effectively analyzed (for a review see, Marcotullio et al. 2011). These studies attempt to tease out the impacts of dense settlement from other forces associated with development and hence define what are the fundamental differences between urban and nonurban realms.

These studies also share three basic elements that are also evident in the social science literature, including an analytical understanding of the relative role of local and global processes, the multiple functionality of urban areas, and the importance of dense settlement alone in providing benefits but also imposing costs to sustainable development goals. As discussed, the social science literature is rich with studies analyzing the relative role of globalization on localities and connections between local and global socioeconomic processes. Defining cities using this integrative approach can be useful for urban ecologists and environmental scientists as they begin to develop integrative frameworks for the understanding of the relative role of local processes of environmental change and global environmental change (such as climate change).

Social scientists have long been recognized urban areas as serving multiple roles and functions within societies: as administrative, religious, and intellectual centers and as critical sites for capital accumulation and economic function. Decades of research across different fields have concluded that there is no one definition that can fit all cities. Indeed, the focus on the ecological function of cities has further expanded this category to include cities as sites for ecological processes, change, and energy flows, both locally and regionally and beyond, as well as sites that can enhance biodiversity through the bringing together of numerous alien species in new flora and fauna assemblages. Defining cities using multiple criteria is necessary to inform policy on how to accommodate a variety of activities and processes within and between urban areas. That is, we need to define trade-offs, as opposed to defining optimized conditions.

Finally, cities from both the ecological and societal perspectives have been presented at the vanguard of emerging conceptual models, which include integrated coupled systems that have both human and natural components. A central element of coupled systems is associated with sustainability science and the relative role of resource consumption (food, energy, and water) and environmental transformations – both local and nonlocal. Several components of the city-sustainability interface include resource scarcity, spatial urban development, environmental transitions, and system tipping points. Using this type of model allows researchers to fully integrate the social, economic, and environmental urban system analysis into research and helps to define both the benefits and costs of urbanization and dense settlement, as opposed to conflating a number of processes on the urban aspects of life.

2.5 Conclusion

Urban ecologists and urban environmental researchers have not fully engaged in the debate over what is a city. At the same time, however, there are some urban ecosystem studies that have a powerful potential to bring back into the debate over what cities are, the dimensions of space – size, density, distance, direction, territory, and location. Urban ecological studies essentially agree in that they conceptualize and study space as more than a medium in which economic, social, political, and historical processes are expressed, but rather demonstrate that space matters in determining the urban development and the nature of the relationships between different social groups within cities and between individuals and the environment. Notwithstanding this important starting point, we argue that urban ecological studies often pay too little attention to what is fundamentally urban and what is not. This may be due to the ease in which urban land use can be identified through satellite and mapping technologies. Urban ecosystem analysts are examining the qualities of urban areas in multiple aspects: biological, chemical, social, and economic. In doing so, they pay more attention to the unique environmental benefits and threats of dense settlement and examine both the differences in the natural features affected by urban activities as well as the social components that define the patterns of these activities.

There are many social and economic challenges and benefits associated with urbanization and cities. Throughout our history, we have overcome many of the negative aspects of close living, including infectious disease epidemics, the urban mortality penalty, and social dysfunctions. As more of the world's population concentrates in cities, the task of making them contribute to a global sustainable pathway will flounder on our ability to mediate negative and accentuate positive environmental and socio-economic impacts. We can only do this if we have a clear understanding of what cities are. Cities are more than locations on a map and the qualities of "cityness" or the processes and characteristics unique to these spaces must be included in our analyses if we are succeed.

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Chapter 3
Ecology and Environmental Justice: Understanding Disturbance Using Ecological Theory

Steward T.A. Pickett, Christopher G. Boone, and Mary L. Cadenasso

Abstract The different cultures of social equity and ecological science can be bridged by an enhanced understanding of the occurrence of environmental hazards and benefits. Knowledge about ecological disturbance improves understanding of how socio-ecological systems respond to the events that disrupt the structure of systems and the flows of resources within them. It is important to recognize that not all instances of a kind of event, such as fire or flood, will be equally disruptive. In part this is because there are many ecological modifiers, such as biological structure of an ecosystem, topography, and the specific weather and other conditions in place before and during an event, that affect individual events. Furthermore, the human, institutional, and infrastructural capitals available in different locations operate along with biophysical factors that modify disturbance and the response to it. Biophysical response to disturbance is motivated by successional capacity, the resource base of the site, and the neighboring landscape context. Environmental injustices are remarkably persistent due to biophysical patterns of these modifying factors in space. Ecological theory embodies the understanding of disturbance patterns through time and space, lays out the assumptions about the structure of affected systems, and extends the knowledge base beyond the memory of people who must plan for and react to environmental disturbances and stresses.

Keywords Disturbance • Successional capacity • Topography • Equity • Ecological modifiers

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*,
Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_3,

3.1 Introduction

The current relationship between ecology and environmental justice seems guarded at best. Concerns in science about objectivity make many ecologists reluctant to become involved in a topic area that is perceived to be the province of activists. Furthermore, because environmental justice focuses on race and class (Peña 2005), it may seem irrelevant to the questions that motivate most natural scientists. Practitioners and scholars of environmental justice may, likewise, harbor concerns about the science of ecology. Environmental justice emerged originally from the grassroots in communities of color and resonated with the experience and motivations of the civil rights movement (Bullard 1990). These communities have often been neglected by mainstream society, and the fact that they originated the fight for environmental justice with little or no help from academic scientists may lead them to be suspicious of ecological researchers. In addition, the demographic and racial composition of the ecological community is different from the racial or class characteristics of many communities where the environmental justice movement is more active.

A further differentiation of the two cultures is their seemingly different goals. Environmental justice is rooted firmly in the "brown" agenda of environmentalism, focused on ameliorating conditions to meet immediate basic human needs, especially health and well-being. Ecology, in its application, tends to favor the "green" agenda of environmentalism, arguing the need for interspecies equity and protection of nature as keys to sustainability (McGranahan and Satterthwaite 2002). Thus, a gap has existed between the practitioners and thinkers about environmental justice and most ecologists. This chapter examines one way to bridge the gap. We ask how ecological theory may contribute to environmental justice scholarship. We focus on disturbance theory as an example because the spatial and temporal distributions of disturbance may relate to the spatial and temporal distributions of environmental threats, which inform distributive justice inquiries in environmental justice scholarship.

3.2 Components of Environmental Justice

In order to evaluate how to bridge the gap between ecology and environmental justice (EJ), we employ four key components of EJ (Shrader-Frechette 2002). One deals with the distribution of environmental benefits and threats in relation to social groups, defined most often by race and class. There is no need to repeat the litany of environmental injustices here, as documentation of the association of disamenities with the locations occupied by communities of color or residents with fewer socioeconomic resources is large and convincing (Downey 2006; Bullard 2005; Mohai and Saha 2007). Indeed, in many cases communities characterized by both ethnic and class disadvantage live near environmentally threatening sites or under the threat of various environmental hazards. Cases are found around the world (Pellow 2007).

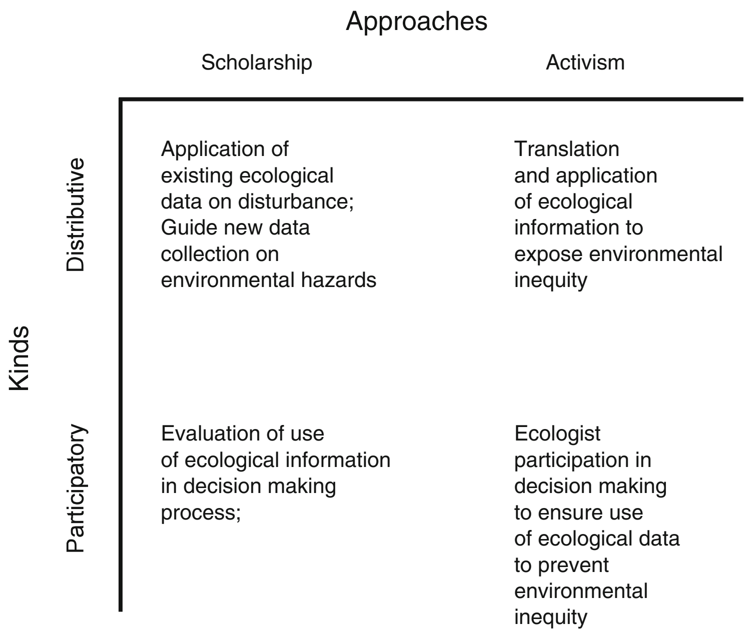

Fig. 3.1 The four components of environmental justice, arranged along two axes to describe a conceptual space for the consideration of the relationship of EJ to ecological theory. Environmental justice exists as two kinds: distributive and participatory. Approaches to environmental justice include scholarship and action. Although ecologists, as citizens, may participate as activists in environmental justice or take part in the environmental decision-making process to ensure that ecological knowledge is brought to bear in the democratic dialog leading to those decisions we assume that many ecologists, as professionals, will most likely participate in the scholarship of EJ, making their theory and knowledge available in evaluating whether environmental decisions in fact lead to equitable distribution of environmental benefits and risks

The second aspect of EJ reflects the degree to which affected communities participate in the decisions that result in the location of environmental disamenities or exposure to environmental hazards (Cutter 2006; Peña 2005). This is referred to as participative justice. The issue is whether all communities, regardless of location, race, and class, have been able to play a fair and equitable role in making decisions that affect their environment. At a minimum, it suggests that affected communities are recognized as legitimate voices in the process of decision-making (Schlosberg 2007).

The remaining two components of EJ are activism and scholarship. EJ emerged as a social movement within affected communities. This is the activist component. The scholarship component evaluates the theory and evidence concerning EJ, as well as the nature of controversies in the political arena (Pellow and Brulle 2005a, b). Of course, individuals may be both activists and scholars of EJ, although there is no necessary congruence of the two.

The four components of EJ (Fig. 3.1) suggest different ways in which the science of ecology can relate to it. Ecological knowledge contributes mainly to the issue of distributive justice, rather than participative justice. Ecology can provide data and interpretive power concerning the distribution of environmental benefits, risks, and hazards relative to the locations where particular racial groups and classes reside. Participative justice addresses the social, political, and legal processes available for environmental decision-making. Ecologists may, of course, be present and involved in participative EJ, where they might contribute, or improve the use of, ecological knowledge. However, the provision of scientific information would seem to be the primary way that their professional expertise could be applied to EJ. Discussion of personal activism as a way for ecologists to participate in EJ is outside the scope of this chapter, as it would be considered by most to be a personal rather than a professional choice.

3.3 Nature and Sources of Just Allocation

Because ecological theory is most relevant to the distributive component of EJ, that leads to a focus on just allocation of environmental goods and ills. Just allocation can be interpreted or measured in three ways. First, it can be defined as an equal distribution of environmental amenities and disamenities across all socioeconomic conditions. Second, just allocation can be measured as costs that are in proportion to benefits of the activity that creates the amenity or disamenity. For instance, if white communities benefit economically more than black communities from a factory that releases toxics, a just allocation would be that whites would bear the costs of that facility by living closer to that polluting facility than black residents. A third way to define just allocation refers to the ability of all communities, regardless of race or class, to respond to environmental hazards. This can include the ability to resist or avoid hazards, but there is also the just allocation of ability to respond effectively to hazards that cannot be avoided.

The ability of people to meet the challenges of resistance or response depends on several types of capital that are well understood in the social sciences (Ostrom 1990, 2005; Costanza 1996). First is human capital. This refers to the knowledge and understanding possessed by individual people. Social capital refers to the ability of groups to understand, organize, make effective decisions on, and influence their social and biophysical environment. The third kind of capital is that expressed in buildings, infrastructure, and other aspects of the engineered or built environment. Financial capital, perhaps the most often considered resource differentially available to groups in the contemporary world, is conspicuously related to ability to get out of harm's way or to respond to unavoidable environmental loss once it has occurred. Finally, natural capital is associated with the locations occupied by different races or classes because it embodies environmental goods and services as well as the environmental threats present in some locations. Natural capital also includes the nature of some environments and the ability of environments or their features to resist or recover from threats or disturbance events. Natural capital, as the source of biophysical hazard, is our main topic in the remainder of this chapter.

However, to understand the different capacities of various social groups to avoid, resist, or respond to natural disturbances, the remaining kinds of capital will come into play.

3.4 Opportunities to Link Ecological Theory with Environmental Justice

There are three potential benefits of bringing ecological theory to bear on the issues raised by EJ. One is the opportunity to put more "environment" in environmental justice. Because EJ has been predominantly a social movement, focused on distribution and participation, it has dealt with knowledge and perceptions that are primarily social (Pellow and Brulle 2005a). What does mainstream ecology have to add to the insights and practices expressed in the social realm? Second ecology may contribute to understanding why environmental injustice is seemingly so persistent. What ecological factors are associated with stationary environmental threat and hazard? The final opportunity is the ability of sound scientific theory to "remember" hazardous environmental patterns and processes that people and their institutions may be prone to forget. What hazards are likely to affect particular places over the long term? Each of these potential benefits will be discussed in turn.

From the perspective of the science of ecology, distribution of environmental hazards comes down to the spatial arrangement of factors that generate disturbance and stress or that make a particular location disproportionately susceptible to disturbance and stress. Some of these environmental detriments are distributed based on human actions. Industrial facilities that release toxins into the air, water, or soil are clearly human artifacts. The location of these may, as we demonstrate later, be related to an ecological template such as slope or topography. Furthermore, the spread or spatial distribution of risk from the hazard may depend upon biophysical factors such as wind patterns or groundwater movement. However, the main kinds of factors we wish to consider directly are "natural" or biophysical agents of environmental hazard.

Biophysical hazards take the form of disturbances and stresses. These are terms with specific meanings in the discipline of ecology. Disturbance refers to events that disrupt the structure of a system (Pickett et al. 1999, 2000; White and Jentsch 2001; Peters et al. 2011). Stresses reduce the level of function or the rate of metabolism in ecological systems (Pickett and White 1985). Attempting to identify relevant causes and consequences of disturbance and stress can be confused without a clear system model. A system model must indicate (1) components of the system, (2) relationships or connections between system components, (3) kinds of dynamics the system can experience, and (4) system boundaries in space and time. Although discussion of disturbance and stress would follow parallel arguments, we focus on disturbance here for the sake of brevity.

Once these four characteristics have been specified in a system model, it is possible to say what factors, acting at what temporal and spatial scales, might alter the structure of the system (Jax et al. 1998). Some aspect of the architecture[1] of a physical system must be altered by disturbance. For example, a forest canopy can be disrupted by wind blowing a tree down or snapping a tree crown, leaving a gap in the formerly continuous cover. To consider a contrasting system, the digging of desert porcupines for the bulbs of perennial geophytes breaks the soil crust formed by microbes and their secretions and leaves a small pit approximately 15 cm deep in which seeds of annual plants, water, and organic matter accumulate. In both examples, the physical disruption of the system indicates that the event – wind or digging – resulted in a disturbance.

There are a variety of kinds of agents that have the potential to cause disturbance in ecological systems (Dale et al. 1999; White and Jentsch 2001). Major potential agents of disturbance can be summarized as fire, lightning, wind, flood, earth movements, earthquakes, and the deposition of ice and snow. It is important to recognize that not all occurrences of these factors will in fact cause a disturbance, as technically defined. Therefore, it is not appropriate to label the factors a priori as disturbances (Peters et al. 2011).

A seemingly simple agent, such as fire or wind, in fact represents a variety of specific instances (Hadley 1994; Boose et al. 1994; Foster 1988). Each kind of occurrence has a different capacity to alter the structure of systems in its path or sphere of influence. Indeed, some occurrences will not produce a disturbance at all. Other occurrences will produce huge changes in the ecological systems in their path. Furthermore, even when a disturbance does occur and the structure of a system is altered, not all components of that system may be affected by the disturbance or respond to the disturbance to the same degree. The complexities of disturbance require great care in their specification (Pickett et al. 2000; Johnson and Miyanishi 2007; Peters et al. 2011).

Disturbances to system structure can alter important characteristics of systems such as resource availability, species composition, and the presence or intensity of environmental regulating factors (Huston 1994; Frelich et al. 1993; Basnet 1993; Pulliam and Johnson 2001). For example, a disturbance that results in the loss of canopy trees may increase light near the ground, increase nutrients that would have been taken up by the intact trees, and increase rainfall that reaches the soil. New species or individuals may be released from competition by these altered resources, thereby taking advantage of the disturbance (e.g., Collins and Pickett 1988).

The purpose of the examples is to show the functioning and significance of what might be called natural disturbance. However, this simplifies ecosystems by neglecting the near universal role of humans in inhabiting or managing ecosystems. Luken (1990) suggests that managing disturbance is one of the main ways that humans

[1] The term "architecture" is used in this chapter in two senses. Here, it refers to the three-dimensional structure formed by the dominant plants in an area and the other physical structures that the biological organisms and processes generate. Hence, the modifier "biotic" is used in this case. In other locations in the chapter, architecture is used in its usual way to mean built structures and the other constructed artifacts of human settlement.

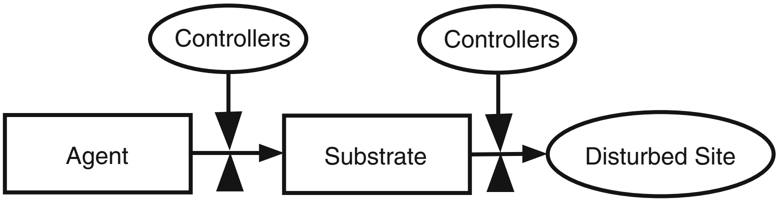

Fig. 3.2 A schematic, general model for the action of agents and controllers on environmental heterogeneity. This model applies to the distribution of all environmental hazards or benefits as they are heterogeneously distributed across space. However, the examples presented in this chapter focus on disturbance. The specific scales or intensities of action, the specific agents of disturbance or stress, and the nature of the substrate upon which an agent may act all must be specified in a model for the impact of disturbance and the nature of its control to be understood or predicted. The action of the agent and the response of the substrate may be controlled by various factors, and this may affect the kind and intensity of disturbance that results. Controllers are discussed in the text (Modified from Pickett et al. 2000)

generate the structures, compositions, and functions that they desire in ecosystems. For instance, gaps in a forest determine the composition of the overstory, but canopy disturbance and response to the disturbance can be managed through silviculture. Fire, another fundamental agent of natural disturbance, requires fuel, oxygen, and temperature (Pyne 2001). If one of these is missing, fire cannot spread. Management of fuel around structures is a reliable way to reduce the chance that those structures will be consumed by approaching wildfire. Similarly, management using ground fires to prevent the formation of a dense understory in fire-prone forest is a strategy to reduce the chance of crown fires in all but the most severe fire weather. These are two among many examples that suggest the power of understanding disturbance in systems managed, conserved, or inhabited by people (Chapin et al. 2003; Gutman et al. 2005).

The effects of disturbance can be modified by a variety of ecological conditions at the site in question (Pickett and White 1985; Vandermeer et al. 1996; Walker 1999; Pickett et al. 2000; Reice 2001; Peters et al. 2011). The generalization is that any given instance and intensity of a potential disturbance agent can act on different kinds of substrate to different degrees (Fig. 3.2). Three key kinds of modifiers exist: biotic architecture, topography, and weather. These modifiers can act together or separately.

The complexity, height, or other features of biotic architecture can affect what kind of impact a particular agent or occurrence will have (Pickett and White 1985). For example, the same severity of windstorm will have different effects in a grassland, a savanna, and a closed canopy forest. A forest canopy tied together by vines may suffer more damage resulting from a high intensity wind than a canopy not so well knit together.

Topography affects the outcome of many potential disturbance events. Whenever tornadoes reach the ground, they damage forest canopies, regardless of the steepness of a slope or the direction the slope faces. Hurricane or cyclone winds, in contrast, affect only forest stands on slopes facing the direction from which the storm approaches (Walker et al. 1991). The steepness of slopes affects the probability of landslides or avalanches. Fire also interacts with topography in complex ways, based on steepness and fire-generated winds (Pyne 2001). Topography, including funneling effects of bays, can influence the degree of damage from storm surges or tidal waves. Of course, very near the source of a tsunami, no coastal landform of moderate height may escape damage.

The weather conditions in place during the occurrence of a potentially disturbing event can modify the impact of that event. For example, whether the soil has been saturated by rain affects whether a given windstorm will uproot trees, snap their trunks, or leave them intact (Myster and Fernández 1995). The degree of soil saturation will also govern whether landslides occur, either under the influence of earthquakes or after a given rainstorm.

Biophysical agents of disturbance do not occur in a sociocultural vacuum. Ecosystems with a human imprint will suffer the effects of a given biogeophysical event differently, based on the nature of that imprint (Barry 1997). The human imprint will also affect the capacity of a system to respond to disturbance (Dow 2000; Colten 2005; Klinenberg 2002), which is a key EJ component. Several sociocultural modifiers of disturbance must be taken into account.

The first are built architecture and infrastructure. As an example, we will use architectural modifiers of fire and flood. The impact of a given fire in an inhabited ecosystem will very much depend on the nature of the built component of the system (Pyne 2001). Wood roof shingles will succumb to a fire that would leave buildings roofed with ceramic tile or other flame resistant materials unscathed. The susceptibility of wood construction is recognized in ordinances requiring brick construction, or the periodic interposition of brick party walls in row house developments (Olson 1997). One of the many drivers of comprehensive land use zoning, which dates to the 1920s in the United States, was the need to reduce risk of industrial fires in residential areas (Pyne 2001). The arrangement of buildings, the provision of wide streets for fire fighting equipment, and even the standardization of fireplug fittings are infrastructural features that reflect experience with catastrophic urban fires in the past (Olson 1997; Gilliland 2002). Architecture and infrastructure can also affect response to flood. Stilt construction in floodplains or coastal zones reduces the impact of moderate flooding disturbance events, and levees and flood control pumps are common infrastructural responses (Colten 2005).

The legacies of human management and land use can modify the impact of specific ecological agents. Fires will be more intense in forest stands that have long experienced fire suppression and the consequent accumulation of fuels in the understory (Christensen et al. 1989). Landslides may affect hillslopes with road cuts more severely than those without roads (Jakob 2000). Recently or long-grazed grasslands can have less intense fires due to the removal of biomass by managed herds of grazers (Zimmerman and Neuenschwander 1984). If these situations affect areas in which houses or other structures are embedded, the controllers are relevant to social structures and processes.

Perception of risk is an important modifier of the actual damage to human populations that results from ecological disturbances. People may fail to evacuate a hazardous area upon declaration of an emergency if recent instances of the same

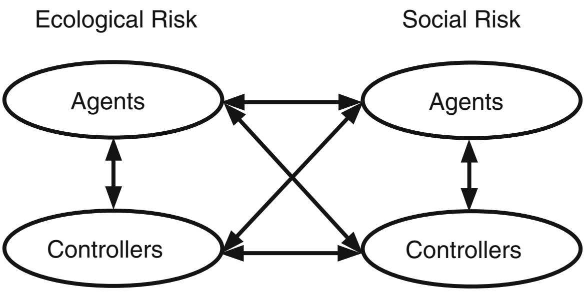

Fig. 3.3 Potential relationships between ecological or biophysical and social agents of disturbance or, more broadly, hazard and the controllers on the intensity of action of those agents. The reciprocal interactions between both agents and controllers are possible and between social and biophysical agents and controllers. Examples of both biophysical and socioeconomic controllers are given in the text

kind of event have been mild. This may especially be the case where the actual severity of a recent event was considerably less than predicted. Furthermore, perceptions of risk may be dampened by a sense of security resulting from the coverage by insurance or the expectation that governmental response will take care of the population or the damage (Platt 1999). Finally, a plethora of research shows that memories are short and risks from natural hazards are quickly forgotten or ignored (Cutter 2006; Dow 2000). People often put themselves back in harm's way once the flood has receded, the burned buildings are rebuilt, or the volcano goes dormant. Of course, choices on where to live are based on many other social factors and personal priorities quite independent of perceived risk.

The ultimate effect of a particular ecological event in human ecosystems relates to the capacity of human institutions to respond to the event. Here the term institutions refers to both formal and informal associations and persistent and transitory aggregations of people (Ostrom 1990). Families, communities, agencies, congregations, corporations, and the like are all institutions. Severity of the effects of disturbances and the cost in human suffering and mortality often depend as much on the capacity of institutions to respond as on the intensity of the event itself. Again, the differentials in the capacity of available institutions may be associated with class and race and, as a consequence, an environmental justice issue.

The discussion above identifies the significance of both social and biophysical aspects of risk. There is, in essence, a two-dimensional matrix of integrating social and biophysical factors that modify the impact of disturbance or stress that occurs at any given time and place. The biophysical dimension includes consideration of the kinds, severity, duration, frequency, and spatial configuration of ecological disturbances and stresses. That is, ecological risk is described by identification of the agents of disturbance and stress. The biophysical dimension of the risk matrix also includes knowledge of the factors that modify or control the agents. The second dimension of the matrix considers the social agents that can act within the system of interest and the factors that modify the action of those agents (Fig. 3.3). Social agents can of course generate disturbance and stress, but the focus in this chapter is on biophysical causes. Social disturbances and stresses are therefore not addressed here, though there is a very rich literature that deals with the social dynamics of risk and natural hazards (see Cutter 2006 for a good summary).

The point of a matrix of biophysical and social modifiers of disturbance is to emphasize that there are no such things as purely ecological disturbances or stresses in inhabited or managed ecosystems (Pickett et al. 2011). Biophysical agents may often provide the bulk of the energy and the forces that can act in a particular event. However, where the events strike and how much physical damage they cause is the result of human actions, artifacts, and management. Similarly, human agents of disturbance and stress do not take place in a vacuum. This is also true of actions that are intended to be beneficial, profitable, and enjoyable or produce otherwise socially desirable ends. All human actions take place within a biophysical template and within the constraints of the prevailing weather and longer-term climate cycles (Pickett and Cadenasso 2009).

To this point, we have discussed the ecological agents of disturbance, their modification by other ecological factors, and their interaction with social factors. EJ is, in part, the result of differential distribution of the risks of biophysical disturbance and stress. However, the response to disturbance and stress has ecological components as well. The ecological control of response to disturbance is also relevant to EJ as discussed below.

3.5 Spatially Heterogeneous Response and Ecological Effects of Stress and Disturbance

In ecological systems, response to stresses and disturbance is determined by several kinds of capacities, all of which are likely differentially distributed across space. Such heterogeneous biophysical capacities can affect the way that human residents and institutions in turn respond to a disturbance event (Pickett et al. 2011). First among the biophysical characteristics is the successional capacity of the system. This can be seen primarily as the availability of species to colonize or reestablish in disturbed sites (Glenn-Lewin and van der Maarel 1992; Pickett and Cadenasso 2005). If the natural successional capacity of the ecosystems inhabited by privileged groups is greater than that inhabited by disadvantaged groups, this will contribute to environmental injustice for the residents of the less responsive successional patch.

A second biophysical feature of systems that determines their ability to recover is the availability of adequate resources to support regrowth of new species. In general, sites that have more resources available will permit faster invasion (MacMahon 1981). This principle is most forcefully seen in the contrast between primary and secondary successions (Walker and del Moral 2003). Primary successions are often quite slow because they occur on sites where resources have been reduced by the initiating disturbance (Pickett and Cadenasso 2005). If biogeophysical resource availability for succession in ecosystems inhabited by privileged persons is greater than that in disadvantaged communities, then the natural capital of those communities is unjustly distributed. Alternatively, if greater resource availability supports growth that must be managed using human or financial resources, that may place an undue burden where those social and economic resources are limited. In other words, biological resources for succession may be inequitably distributed, and whether the concern is with lack or abundance of resources is determined by the socioeconomic context of a specific location.

The third important effect on how ecosystems recover from stress and disturbance is landscape context. The spatial context in which stressed or disturbed patches are embedded affects the recovery that the system can achieve (Turner et al. 1994). Flow paths of late successional species, limiting resources, additional disturbance agents, and control agents on ecosystem structure and function are all potentially affected by the configuration of the surrounding landscape. If a landscape is highly fragmented, late successional species may have difficulty permeating the matrix to reach a disturbed site. Limiting resources, especially biotic ones, may likewise have difficulty reaching a site in a fragmented landscape. In contrast, certain agents or intensities of disturbance, such as fire, may be inhibited in their movement by landscape fragmentation. Disease agents are also sensitive to fragmentation. Other effects of landscape context are possible. In general, fragmentation as a landscape constraint on ecosystem recovery may disadvantage communities that do not have resources or access to networks to compensate for that fragmentation. Taken together, the effects of successional capacity, resource availability, and landscape fragmentation can be differentially distributed relative to social groups that themselves have different capacities to respond to environmental disturbances and to overcome the biophysical control on responses to disturbance.

3.6 Environmental Injustice Persists

In spite of the fact that environmental burdens have been known to be disproportionately associated with locations inhabited or used by minority communities and those having fewer economic resources, such injustice persists. Certainly, there are powerful social and economic reasons (Pellow 2000; Peña 2005; Gordon and Harley 2005; Benford 2005; Buckley 2010). However, the pattern persists in part because a persistent environmental template also exists in some places. Topography, for example, is part of the puzzle in explaining patterns of human health threats and environmental injustice. The association of low-lying areas with disease and increased mortality is an example (Hinman 2002). Although earlier eras erroneously attributed the association to miasmas or “bad air,” contemporary scientific understanding relates the pattern to the increased incidence of waterborne pathogens and bacteria (Melosi 2000). Low-lying areas are, even in arid settlements, those where waterborne disturbances and threats accumulate. It is true that humans have become the dominant earthmoving agent on the planet

(Hooke 2000) and that over time cities generally become flatter by the cutting down of hills and filling in of lowlands (Olson 1997). Still, the basic underlayment of topography remains in place.

The associations of ethnicity and class with distribution of toxic release inventory (TRI) sites in Baltimore, Maryland, are a subtle case of persistent social injustice. TRI sites in Baltimore City are disproportionately associated with white working class census blocks (Boone 2002). This is true for analyses reflecting the presence of a TRI site within a census block and analyses based on including all census blocks within a buffer around the sites. Although this example does not link communities of color with pollution, as many studies have done, it still reflects a history of racial disadvantage, and the underlying environmental template is, again, topographic. In the industrial heyday of Baltimore, de jure and de facto segregation favored whites with residences near the factories and disfavored blacks by segregating them in neighborhoods farther away (Power 1983; Orser 1994). The prime location of factories in Baltimore in the mid-nineteenth to twentieth centuries was in the lowlands closest to the harbor. This proximity to the docks was an advantage for the factories, which was converted to the advantage of short commuting distances for white workers. Therefore, the example shows the persistent effects of social disadvantage – first enforced by legal segregation, then by institutional bias in finance, and later by tradition. A social lesson from this example is that mitigating environmental risk can be beneficial to all ethnic groups. The intentional social injustice of housing segregation of African-Americans is associated with an unintentional inequity for working class whites realized decades later.

3.7 Theory Remembers

Ecological theory constitutes the conceptual structure and empirical substance of ecological knowledge. To this point, we have suggested that ecological theory offers two things to EJ: a refined understanding of disturbance with an enhanced ability to anticipate environmental hazards and an understanding of the biophysical basis for the persistence of environmental burdens. One major contribution remains – the ability to generalize about the role of biophysical disturbance as environmental hazard.

Why is it important to use theory as a mnemonic device? One reason is that the treatment of natural disturbance in the media is poor (Elfring 1989). Natural disturbance is known to most people through headlines, often accompanied by captivating video. It is important to recognize that such reportage comes with its own theory (Smith 1992) and accompanying assumptions which are contrary to the ecological understanding of the events.

Disturbance, in the popular mind, is not supposed to happen. In the context of human settlements, disturbances are breaches of the social contract (Pyne 2001), with a consequent loss of property, utility, or life. Most reporting of disturbance therefore follows an “urban fire model” (Smith 1992). If a building in a city burns, someone has perpetrated a crime or been negligent. The responsible party must be punished, and restitution made. Much of this model is inappropriate for biophysical disturbances, which are at least partially caused and modified by uncontrollable natural agents (Elfring 1989; Christensen et al. 1989). The urban fire model when applied to reporting natural disturbances has several negative characteristics: it sensationalizes the event, and it portrays the event as unique. When reportage uses human memory as its reference, it is easy to understand how the sensational and unique features of an event might be emphasized. However, ecological theory offers a different view.

Ecological theory, as a specific technical tool, lays out the assumptions needed to understand a process or structure in the material world. Theories also comprise concepts, definitions, a body of data, generalizations from data, models of various kinds, and a synthetic framework to tie the components of theory together (Pickett et al. 2007).

For EJ, ecological theory can substitute for some of the inappropriate aspects of how people deal with disturbance in settled landscapes. Theory extends the scope of understanding and explanation beyond the time period covered by the memory of the oldest long-term residents. It brings relevant data and generalizations, originating in other systems, to a new system. Theory also reveals the mechanisms behind disturbance and the potential for response.

Some of the specific highlights of ecological disturbance theory that emerge from a broad literature (e.g., Huston 1994; Bormann and Likens 1979; Connell and Keough 1985; Clark 1991; MacMahon 1998; van Hulst 1992; Tilman and Pacala 1993; Pickett et al. 1987; Chesson and Case 1986; Pickett et al. 1999; Wu and Gao 1995; Vandermeer et al. 1996) for EJ are these:

- Multiple kinds of disturbances and stresses occur in a site or region.
- Different kinds of disturbances and stresses often interact.
- Disturbance and stress recur through time, sometimes after long intervals.
- Disturbance and stress are often "patchy," or heterogeneously distributed.
- Temporal regimes and spatial mosaics of disturbance can be summarized for an area.

Many of these insights can be encompassed in the concept of disturbance regime. The concept refers to the probabilistic distribution of disturbance in time and space. Ecosystems, landscapes, and regions will exhibit a pattern of risk of disturbance that reflects the disturbance regime (Reice 2001; Peters et al. 2011). They will also exhibit a mosaic of patches in different stages of recovery from disturbance. In human ecosystems, with the desire to return use and capital value to high levels, the period of post disturbance succession in buildings, infrastructure, or function may be short. However, even when the direct results of a disturbance are remedied, legacies often persist. Such legacies may exist in the form of regulations, zoning, infrastructure to mitigate the effect of the potential disturbance agent, or patterns of differential social distribution. Most fundamental, however, is the insight that biophysical disturbance, as a major risk factor in human ecosystems, is a persistent component of both wild and built environments.

3.8 Conclusions

The ecological theory of disturbance can help link the science of ecology and EJ. There are several advantages of this linkage. First is the ability of theory to remind policy makers and the public about the ongoing nature of biophysical disturbance regimes. Second is the interaction of biophysical and social factors in determining environmental risk as well as capacity to recover. The theory of disturbance can support education about how the interaction of social and ecological processes contributes to environmental injustice. Ecological theory, and the data and generalizations it contains, can inform people about environmental risk factors, the nature of exposure to various kinds of environmental hazards, and the resources and constraints that affect response. This knowledge can be applied to help prepare for recovery. In what places should such efforts be focused? What kinds of events will most likely trigger a need for response?

The biophysical theory outlined above also has a role in helping to frame public discourse on disturbance and recovery. It can help move beyond the sensationalism that is so prevalent in media reporting of disturbances. Ecology teaches that disturbances that have their motive force in biophysical events are not singular and unprecedented in the long term. Such catastrophic events are not unexpected, and they have both social and biophysical components and consequences. Society needs to be better able to deal with the ecological component in the pursuit of EJ. Highlighting an ecological theory that connects with the process of distributive EJ gives ecological scientists a road map for linking with scholarship on EJ and for application of ecological information to EJ problems.

An emerging framework exists for environmental justice theory (Pellow 2000). This theoretical concept divides the scope of concern into four constituent features: (1) stakeholders, (2) environmental racism, (3) environmental inequity, and (4) environmental justice (Fig. 3.4). The stakeholders are those persons and groups that engage in formal and informal negotiation to frame an environmental issue in terms that satisfy their overlapping interests. Environmental racism is the pattern of discrimination based on environmental hazards that results from policies and intentional decisions disfavoring particular ethnic groups. Environmental inequity is the interaction between environmental quality and social hierarchies. Although this is usually cast in terms of environmental burdens (Pellow 2000), it can also extend to exclusion from environmental amenities (Boone et al. 2009). Environmental justice is a solution to the problems of environmental inequity and environmental racism and includes the provision of sustainable, safe, productive, and nurturing communities for all people (Pellow 2000). Pellow (2000) emphasizes that the formation of environmental inequity is a process with a temporal dimension (Fig. 3.5). Initial stakeholder groups may intentionally or unintentionally exclude some persons and groups with a legitimate interest in the environmental outcome of the negotiation. When previously unrecognized stakeholders perceive and react to an environmental burden, the issue can be redefined. Thus, feedbacks, with the recognition of differential impacts that had previously been ignored, are a part of a process defining and

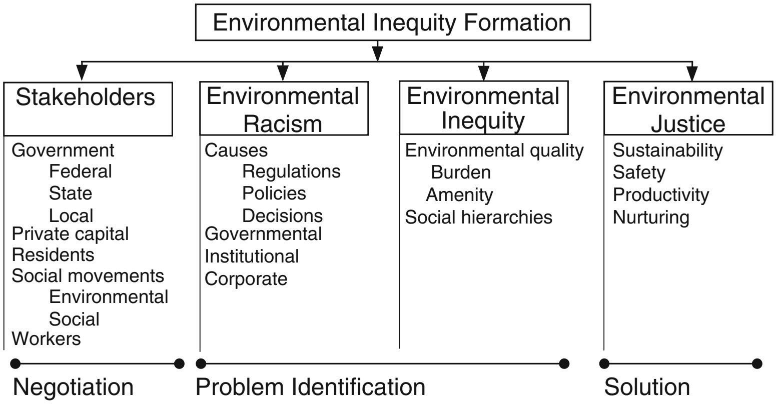

Fig. 3.4 A diagrammatic framework for a theory of environmental injustice based on Pellow (2000). The schematic, hierarchical form parallels that used for ecological theories (e.g., Cadenasso et al. 2003). The top level of the hierarchy identifies the process of concern as the formation of environmental inequities. The second lower level of the hierarchy indicates that rather than being a simple "perpetrator-victim" interaction, the formation of environmental inequity results from the interactions of multiple stakeholders and is based on either environmental racism or a resulting environmental inequity. Environmental justice is the positive outcome and opposite of either environmental racism or injustice. The third or lowest level components of the hierarchy describe more fully the nature of the middle level phenomena. For example, the kinds of stakeholders or the sources of inequity are identified. Note that this framework adds amenities along with burdens as potentially inequitably allocated aspects of environmental quality (see, e.g., Boone 2002). Ecological information on distributive injustice is likely to apply to understanding environmental inequity. Similarly, ecological methods and data can help evaluate the attainment of environmental justice. At the bottom of the diagram, the components of the framework are identified as to whether they contribute to negotiations that establish environmental conditions, identification of the problem of differential allocation of environmental benefits and hazards among groups, or solutions to differential allocation

dealing with environmental inequity. The nodes where ecological information and perspectives can be most influential are made clear through using the framework for environmental justice theory (Fig. 3.4).

What might an agenda be for theoretical or basic ecology in light of the pressing concerns of EJ and the theoretical structure it exhibits? Ecologists can add breadth and refinement to the database on environmental hazards. There is a rich and active field of environmental hazard scholarship (Cutter 2006). Ecologists can add more places and better understanding of the role of local and specific controllers to the information policy makers and the public need. In addition, ecologists can contribute to understanding the synergies across space and through time among environmental hazards. Cumulative impacts of exposure to multiple hazards have increasingly become a concern among EJ scholars and activist (Morello-Frosch et al. 2011). Ecologists can contribute tools and approaches to working with multiple factors operating on different but connected scales of space and time.

Ecologists can help educate communities about environmental hazards that may not be obvious from daily or recent historical experience. Biophysical events that

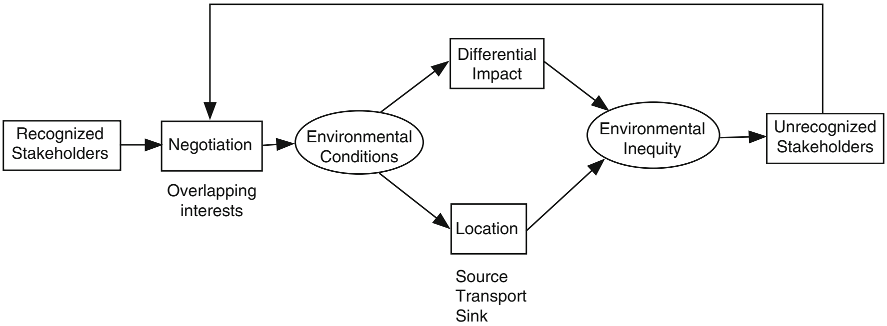

Fig. 3.5 A model template showing the possible interactions of the components of the framework for environmental inequity (From Fig. 3.4, cf Pellow 2000) through time and identifying specific outcomes important to the formation of environmental injustice. Starting from the left, a group of recognized, empowered stakeholders is assembled. The second step in the model is the negotiations among these stakeholders in which their overlapping interests are identified. As a result, a set of environmental conditions is established. These may be conditions or hazards susceptible to being identified and measured by ecologists and other scientists. Differential effects may obtain for different social or racial groups or for persons residing in different locations. Pellow (2000) emphasizes that environmental inequities may arise throughout the life cycle of a product or commodity and exist at the source, in transit, or where the product is used or disposed. Such differentials are perceived as environmental inequities and are subject to measurement or assessment by ecologists and other scientists. Where these inequities are seen to affect stakeholders who were not identified in the initial negotiations, activism or political will may result in a renegotiation of the environmental conditions. This process view of environmental inequity identifies two nodes of interaction with the science of ecology

initiate disturbance recur over the long term and affect spatially extensive areas. No areas are immune to some sort of ecological disturbance. Hence, hazard should be evaluated not in terms of whether, but how often and by what mechanism. This contribution of understanding mechanism would substantially contribute to and compliment EJ scholarship (Sze and London 2008).

Ecologists can link more effectively with social and environmental hazard researchers. Ecologists have been largely absent from inhabited ecosystems since early in the history of their profession. If the profession wishes to contribute its perspectives and knowledge to the concerns of EJ, it will have to be better informed as a discipline about what others, who developed the expertise to work in human settlements, have learned. Ecology is a recent immigrant to the city, and we may well need to look to the help of "settlement houses" informed by other disciplines to make our way in the unfamiliar territory.

Ecologists can link with urban designers, regional planners, architects, and developers to help infuse contemporary ecological knowledge into the thinking and practice of those disciplines. This is consonant with the vision of the Ecological Society of America to promote the idea of "designer ecosystems" (Palmer et al. 2004), in recognition that the human presence is already widespread, and that with increasing human population, human agency will only become more pervasive in ecosystems (United Nations Population Fund 2007). The knowledge of ecology concerning environmental risks and hazards can link ecology and design. Substantive understanding by ecologists of the motivating theories, practical assumptions, and socioeconomic realities of urban design and development will be required to translate the insights from ecological theory into this crucially important realm of ecological application (McGrath et al. 2007).

This chapter has proposed that there is a significant relationship between ecological theory and EJ. Ecology can help put more environment in EJ research and perhaps its practice as well. It does so in part by contributing data and models of disturbance and stress, noting the complex controls on the agents of these kinds of change in human ecosystems. Second, it has shown that ecology has something to say about the persistence of environmental injustice. The long-lasting ecological template that continues to affect human ecosystems, even after massive earth movements and infrastructure engineering, is remarkable. This template has a role to play in the differential distribution of environmental benefit and burden. Third, ecological theory remembers the role of disturbance regimes in the face of short human memory and the dominance of short-term, personalized, and sensational reporting of environmental disturbances and hazards.

From the other side of the coin, environmental justice research can contribute to the study of ecology in important ways. By unraveling the social dynamics of environmental justice, social science research can inform ecology about how human structures and functions alter the Earth's surface and, in so doing, illuminate the role of human beings in shaping ecological structures and processes. Recognizing, measuring, and analyzing the feedback relationships between the patterns and process of environmental justice and ecology remain a challenging but potentially very rewarding goal.

We hope these insights can contribute to improving the public dialogue and understanding of ecological disturbance regimes for the study and practice of environmental justice. As the world increasingly urbanizes, and as the concentration of wealth in virtually all societies becomes more acute, the need for an ecological contribution to environmental justice becomes all the more pressing.

Acknowledgments We thank Charlie Nilon and George Middendorf for providing the stimulus for this chapter. This is a product of the Baltimore Ecosystem Study, LTER, with support from NSF DEB 0423476, BCS-BE 508054, and SBE-HSD 0624159.

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Chapter 4
Connecting Environmental Justice, Sustainability, and Vulnerability

Christopher G. Boone and Michail Fragkias

Abstract Justice is a core yet often ignored principle of sustainability. However, sustainability for some at the expense of others undermines the principles and practice of sustainability as a force for positive change. In this chapter, we argue that sustainability research and practice can benefit from a closer reading of environmental justice scholarship. At the same time, environmental justice can draw on sustainability principles of systems thinking, anticipatory action, and environmental stewardship to strengthen its methods and approaches while broadening its constituency. Vulnerability science can bridge environmental justice and sustainability and can also benefit from the convergence of ideas, principles, and practices of these fields.

Keywords Systems thinking • Anticipatory action • Environmental stewardship • Procedural justice • Distributive justice

4.1 Introduction

Justice is a core yet often ignored principle of sustainability. In efforts to find ways to reduce harm to the natural systems that support us while seeking ways to expand economies and improve livelihoods, many neglect or simply pay lip service to justice as a central sustainability principle. Yet, sustainability for some at the expense of others undermines the principles and practice of sustainability as a force for positive

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_4,

change. A case in point is the shipment of highly toxic materials from wealthy to poor countries. Such a transfer might improve environmental conditions in the rich world and save high costs of treating and disposing of toxic wastes, but it subjects vulnerable populations in poor countries with weaker environmental monitoring to lethal materials (Pellow 2007). It is the figurative equivalent of sweeping the dust under the rug – ignoring the problem does not make it go away nor is it the right thing to do. Indeed, high-profile cases of "toxic colonialism" in the 1980s touched a nerve in the international community, leading to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1992). The Basel Convention was an important step forward in righting environmental wrongs, but it has not fully restricted international transfer of hazardous waste, including for so-called recycling purposes (Steady 2009). Recycling of electronics has also drawn increased scrutiny for health risks to handlers who are often located in poor countries with scant or poorly enforced workplace protections (Xing et al. 2009).

Environmental justice is a well-established field of scholarship and social activism that draws attention to, and seeks ways to ameliorate, such injustices. In this chapter, we argue that sustainability research and practice can benefit from a closer reading of environmental justice scholarship. At the same time, environmental justice can draw on sustainability principles of systems thinking, anticipatory action, and environmental stewardship to strengthen its methods and approaches while broadening its constituency. Furthermore, vulnerability science can provide an important bridge between the two spheres of environmental justice and sustainability while also benefiting from the convergence of ideas, principles, and practices from these fields of inquiry.

4.2 An Evolving Environmental Justice

Environmental justice emerged in the United States in the 1980s as a social movement and field of inquiry in response to the growing concern that poor and racial/ethnic minority populations were disproportionately burdened with the worst environmental conditions. Early studies showed, what many activists had long suspected, that the location of hazardous waste and toxic release facilities correlated most strongly with racial and ethnic minority populations, even when controlling for income (Mohai and Saha 2007). Such findings suggested that racial and ethnic discrimination guided decisions about where to concentrate toxic and polluting facilities. Drawing on hard-won social justice battles from the Civil Rights era, activists and scholars lobbied for new legislation that made information about hazardous pollutants part of the public domain (Emergency Planning and Community Right-to-Know Act 1986) and inspired the creation of an Office of Environmental Justice in the Environmental Protection Agency (EPA) (1992) as well as an environmental justice executive order (1994) mandating all federal agencies to consider environmental justice in their operations.

Over the last decade, the purview of environmental justice has continued to expand. Although research on toxics continues, environmental justice scholars and activists have begun to examine the role of privilege rather than disadvantage alone as a factor in the distribution of both environmental goods and bads (Pulido 2000; Grineski et al. 2007). Privilege and power can be very effective at deflecting unwanted land uses or pollutants as well as attracting environmental amenities such as clean air or parks and recreation areas. A refocusing on privilege and power can also draw attention to justice concerns about fairness of processes. Whereas early work focused on outcomes, increasingly environmental justice scholarship has examined, or at least called attention to, the need for understanding the process or causal mechanisms of injustice (Boone et al. 2009). This can include the processes that lead to unjust outcomes but also injustice of the process itself. Fairness in the application of environmental law and removing barriers for citizen participation, especially for the most marginalized, in environmental decision-making are two examples of process justice. The struggle of marginalized groups for recognition in environmental decision-making has also been a subject of interest to environmental justice scholars and activist groups (Young 1990).

4.3 Opportunities for Convergence

A key principle of sustainability is systems thinking (Gibson 2006). Sustainability shares this principle with other sciences, such as engineering and ecology. Systems thinking emphasizes that processes are linked at multiple temporal and spatial scales and cannot be understood, let alone altered, without recognizing such connections. For example, the consumption of goods relies on several upstream (production, delivery) and downstream (waste, reuse) processes that extend well beyond the immediate moment and place of purchase or use. A single act within such complex systems can lead to unintended consequences, such as the exploitation of child labor or the elimination of wildlife habitat (Smith et al. 2006). Embedded in the purchase of a computer are the energy, materials, and labor that may come from great distances and affect livelihoods and the environment far removed from the purchaser. Older computers may be recycled using children or other workers in poor countries who are exposed to toxic materials as they crush circuit boards to retrieve tiny amounts of valuable metals (Williams et al. 2008).

Although environmental justice activists and scholars understand the unfair burdens that arise from systems of production and consumption, most of the emphasis is placed on the "here and now." This occurs for good reasons, as single local incidents such as the establishment of a trash incinerator can galvanize a community to resist an unwanted activity, often more so than the impact their actions (such as consuming goods) may have on labor conditions in a far-flung poor country.

Environmental justice has been similarly constrained by a focus on reaction rather than proactive decisions. This "militant particularism" (Harvey 1996) has served the environmental justice movement well in bringing to light the everyday injustices that occur, but to move beyond proximate causes and effects and to seek enduring opportunities for change, environmental justice would benefit from the broader systems perspective that sustainability prescribes. To a degree, this has begun as the environmental justice movement and scholarship have moved beyond the United States and taken root in other regions of the world (Omer and Or 2005; Claudio 2007; Okereke 2008). Development of environmental justice in other countries has encouraged the beginning of comparative studies, which draw increasing attention to global processes and connections. However, environmental justice should embrace more seriously how global and local processes are linked and how present conditions and processes are shaped by the past and may guide the future. The chapters in this volume from regions other than North America point to the growing interest in an environmental justice perspective for addressing persistent inequities and understanding the consequences of local and global environmental changes for the most vulnerable.

Sustainability is a future-oriented science whereas environmental justice tends to focus on the present and, to a certain degree, the past. This is not to suggest that a focus on present and past wrongs is unnecessary or not worthwhile. Indeed, valuable lessons can be learned from environmental justice struggles that can be applied to future plans. However, environmental justice would benefit by shifting from a dominant blaming approach to framing a more just future. Similar to environmental justice, sustainability incorporates a normative stance or what ought to be. Through such sustainability mechanisms as scenarios and visioning, many of the struggles of environmental justice, from equitable outcomes to recognition justice and fair application of the law, can be addressed and incorporated into long-range planning (Okereke 2008). Because sustainability anticipates future conditions, both probable and normative, an environmental justice informed and inspired by sustainability could focus on prevention rather than solely on the burden of curing well-entrenched injustices.

Another limitation of environmental justice is that it has neglected or underplayed the importance of the biophysical environment, both as an object of concern and as part of the dynamic processes that lead to injustice (Pickett et al. 2007). In part, this reflects the historical trajectory of the US Civil Rights movement and the general disregard, early on, of urban environmental issues by national mainstream environmental organizations. At the same time, draping social justice concerns in the environment matched an expanding interest in environmental issues, allowing groups to make old struggles politically palatable to a wider constituency of environmentalists. Sustainability research and practice advocates very strongly for protecting the environment for its instrumental value and to a lesser degree its intrinsic value. A core argument of sustainability is that we depend ultimately on Earth's systems to support human life (instrumental value) and that we take a lot of those services for granted. An emerging opportunity for environmental justice is to examine the outcome and process justice of how those Earth systems, sometimes termed "ecosystem services," are managed. For example, governments and nonprofit groups around the world have initiated programs to increase urban tree canopies because of the multiple ecosystem services and benefits from trees in metropolitan areas. Trees can provide shade, mitigate extremes of climate, reduce human vulnerability to heat stress, provide habitat for wildlife, absorb pollutants, reduce loads on stormwater systems, and add value to properties (Donovan and Butry 2010). In anticipation of likely regulations on greenhouse gas emissions, municipalities are promoting increased tree planting and improved stewardship for carbon sequestration and storage benefits (Cumming et al. 2008). Whereas municipalities embrace the benefits of increasing tree canopy cover, little attention has been paid to the environmental justice implications of such investments. Measuring the distribution of ecosystem service benefits from urban forests in relation to social groups is one potential avenue for integrating biophysical environment characteristics into environmental justice. Equally compelling is to comprehend the justice of decision-making regarding urban tree canopy goals (Pincetl 2010). An urban tree canopy program that considers only the voices of environmental scientists would not fit the recognition justice concerns of environmental justice nor the scenario and visioning principles of sustainability. A focus on process is important because a proper and just delivery of ecosystem services can help to ameliorate environmental injustices and unsustainable practices.

Some scholars have also stressed the importance of protecting Earth's systems for their own sake because they have intrinsic value that may not have significant or immediate value to human life and livelihood (Elliot 1997; Rolston 2003). An environmental ethic embodied in sustainability that seeks to protect ecosystems from the hegemony of the market has merits that could inform a broader environmental justice. Environmental justice, with its emphasis on justice and equity, could be a fruitful forum for dealing with the question of intrinsic value of nature in sustainability (Schlosberg 2007).

4.4 Vulnerability Science as a Bridge

What we have suggested thus far is that sustainability and environmental justice could mutually benefit from a closer relationship in scholarship and in practice. One potential bridge to facilitate that interaction is vulnerability science. The field of vulnerability is itself a convergence of multiple intellectual streams, from risk hazards research, political economy, political ecology, and more recently from ecology (Turner et al. 2003; Adger 2006). Vulnerability offers a framework for understanding the dynamics of human-environment relationships, with an emphasis on reducing or eliminating harm to people and to a lesser degree the environments that support them. Vulnerability science has developed sophisticated ways to measure human exposure to harm, the differential sensitivity of social groups to harm, and differences in adaptive capacity or the ability to respond or "bounce back" after the harm occurs (Cutter 2003). Related to the idea of adaptive capacity is the ecological concept of resilience, or the ability of ecosystems to adapt to change while maintaining ecological structure and function (Walker et al. 2004). The concept of resilience has ecological origins, but it has been applied to socioecological systems, where resilient societies are understood as less vulnerable and better able to deal with perturbations, shocks, and surprises than less resilient societies (Janssen and Ostrom 2006; Buchmann 2009).

From sustainability and environmental justice perspectives, one limitation of vulnerability science and resilience is a paucity of normative stances. Despite innate

Table 4.1 Differences in primary approaches and concerns of environmental justice, vulnerability, and sustainability

	Primary normative emphasis	Key metrics	Primary spatial scale	Primary time scope
Environmental justice	Fairness	Uneven environmental burdens, unfair decisions, impacts on marginalized communities	Local	Immediate
Vulnerability	Risk reduction and strengthened adaptive capacity	Exposure, sensitivity, and adaptive capacity to hazards	Regional	Immediate to near future
Sustainability	Ecological integrity and intergenerational equity	Long-term preservation of ecosystem services; human development indices	Global	Long-term future

concerns of reducing harm to vulnerable populations, justice is rarely uttered next to discussions of adaptive capacity or resilience. An expanded notion of vulnerability, however, can easily incorporate principles and practices of sustainability and environmental justice. Similar to sustainability, vulnerability adopts a systems approach to understanding the relationship between people and the environment. It argues that there are thresholds of harm that can be avoided with a proper understanding of exposure, sensitivity, and adaptive capacity of both social and biophysical systems. Another similarity is that vulnerability is anticipatory. A driving force behind vulnerability is to anticipate change to mitigate or adapt to potential harm. A broader conceptualization of vulnerability can also meet the demands of environmental justice. New vulnerability research that draws from political economy and political ecology perspectives is sensitive to the structural forces that lead to marginalization. Eakin and Luers (2006) proclaim that vulnerability is "inherently about ethics and equity" (p. 388). However, it is not clear to what degree social justice will become a fundamental metric as opposed to an ideal in vulnerability analyses (Bolin 2006). Continued attention to the struggles highlighted in environmental justice scholarship and activism is, therefore, a necessary step for developing an enhanced vulnerability science, one that can bridge sustainability and environmental justice principles and concerns.

4.5 Perspectives and Integration

Environmental justice, sustainability, and vulnerability begin from different stances. In Table 4.1, we highlight differences in the primary normative emphasis, key metrics, primary spatial scale, and primary temporal scope of each of these approaches to understanding human-environment relationships. For environmental justice, the primary normative emphasis is on justice as fairness, with a strong moral underpinning of doing what is right. Although environmental justice studies often include some aspects of risk analysis, they do not rely on the burden of proof to make their case. Rather, environmental justice studies use the necessary evidence to make a persuasive case, but call upon judgments of fairness as the primary motive for what one should do. In vulnerability science, although the normative is not as explicit as in environmental justice, reducing risk and strengthening adaptive capacity are implicit goals in the research. Although vulnerability pays some attention to the biophysical system, its primary emphasis is on reducing susceptibility of people to harm. Sustainability is driven by the normative goal of human development but with a strong emphasis on the need to maintain ecosystem services over the long term, driven largely by the goal of being fair to future generations.

The normative goals inform the type of metrics that predominate in each domain. For environmental justice, a great deal of effort goes into measuring whether or not environmental burdens are unevenly and unfairly distributed, especially as it affects the lives of marginalized populations. Fairness in decision-making related to environmental issues (including the built environment) is another key analytical method in environmental justice research. For vulnerability science, measuring exposure, sensitivity, and adaptive capacity of people (and to a certain degree the biophysical environment) to hazards is a central activity. Sustainability research is broader in scope than environmental justice and vulnerability but tends to focus on metrics that tell us something about the long-term viability of Earth's resources and ecosystem services and the interrelated implications for human development.

For the majority of environmental justice studies, the primary spatial scale is local, and the time scope tends to be narrow, usually concerned with remediating immediate needs and concerns. Vulnerability science, because it attempts to anticipate susceptibility using measurements of the current state, tends to be immediate to near future in its time scope. Partly due to its origins in hazards research, vulnerability science tends to focus on scales of biophysical drivers such as floods, pest invasions, or hurricanes, which are typically examined on regional levels. Sustainability has been driven by the need to understand and anticipate projected threats to the viability of Earth's systems to maintain people and societies over the long term. Although a good deal of sustainability research focuses on local and regional scales, ultimately it is the concern for planetary boundaries (global scale) and what that means for future generations that motivates sustainability science.

Clearly, this is a simplified characterization of environmental justice, vulnerability, and sustainability, but it is useful for thinking about the strengths of each approach and how they might be combined for a richer understanding of human-environment dynamics. Of the three, sustainability provides the broadest umbrella for including the normative goals, principal metrics and analytical methods, and primary spatial and temporal scales of each of the approaches. A fundamental challenge is to find ways to empirically link all three stances in ways that can strengthen the goals of each. One potentially fruitful way is the development of simple but meaningful indicators.

Indicators have the potential of condensing large amounts of data and information into simple, easy to understand metrics. Effective indicator projects use data that are relatively straightforward to collect and compile over time so that trends can be visualized. A sustainability indicator should be able to provide a clear sense to users if trends are getting better, worse, or not changing (Singh et al. 2009). For example, the

United Nations' Millennium Development Goals initiative measures every year the number of people whose income is less than one US dollar (purchasing power parity) per day. This is a simple but powerful indicator of poverty that can be tracked over time and space and measured, in this case, against the goal of halving the number of people living in poverty between 1990 and 2015 (http://www.mdgmonitor.org).

Many urban sustainability plans have developed indicators for tracking progress toward specific goals. The City of Baltimore, Maryland, drafted a sustainability plan that includes seven priority themes: cleanliness, pollution prevention, resource conservation, greening, transportation, environmental education and awareness, and the green economy. One of its greening goals is to "protect Baltimore's ecology and biodiversity," and one of the annual metrics is the Benthic Index of Biotic Integrity. This measures the health of aquatic species, which is a good indicator of stream water quality and ecological integrity overall. In an effort to mitigate global climate change (in part driven by local threats of sea level rise), the plan calls for a 15% reduction in GHG emissions, which are tracked every year, between 2010 and 2015 (http://www.baltimoresustainability.org).

In Baltimore's sustainability plan, there is explicit mention of social equity as part of the sustainability goals, and this plan can serve as an example of ways to begin incorporating environmental justice measures into sustainability metrics. For instance, in an effort to make the city a healthy and livable place, one goal is to "provide safe, well-maintained recreational space within ¼ mile of all residents." The plan also includes measures of transportation equity, using average travel time and costs to work by community. The goal of the indicators is to track progress in improving mobility especially for low-income households.

Where the Baltimore and other urban sustainability plans fall short, however, is in linking local concerns to global processes and consequences. For understandably practical reasons, urban sustainability plans focus on improving the lives of local constituents, but how local actions affect people living elsewhere in the world is seldom raised. While cities may be at the forefront of mitigating climate change by developing plans to reduce GHG emissions (Rosenzweig et al. 2010) or encourage carbon sequestration through greening programs, there is little recognition of how consumption patterns, for instance, affect livelihoods and working conditions and ultimately sustainability elsewhere in the world. The tendency toward localism creates weak ties with global scales of analysis that are required for sustainability (Seto et al. 2012).

Sustainability has a strong future orientation with an emphasis on long-term planning. It is a normative or design science in that it encourages intervention to achieve a desirable future (Wiek et al. 2011). Deciding what is desirable invites stakeholder engagement, which is an opportunity for addressing environmental justice concerns and providing a mechanism for strengthening adaptive capacity (reducing vulnerability) through knowledge, awareness, and community building. One tool for organizing such efforts is a sustainability scenario. In sustainability science, scenarios are used to develop plausible but desirable futures and often use participatory processes that emphasize and build on stakeholder engagement. Once that desirable future scenario is envisioned, it is possible to "backcast" to the present in order to determine how to best move toward the desired future condition (Robinson et al. 2011).

The desired sustainable future in the scenarios can be defined by indicators, which can also be used to track success toward scenario goals. For example, the sustainability plan for New York City, PlaNYC, began with extensive stakeholder engagement to solicit ideas from residents for what the city should look like in 2030. Based on these sessions and input from experts, the city developed a scenario for New York that showed marked improvement for affordable housing, better access to parks and open space, cleanup of contaminated land, water quality and supply, transportation choices, reduction in energy consumption and reliability of supply, air quality, diversion of solid waste from landfills, reductions in greenhouse gas emissions, and reduced vulnerability to climate risk (City of New York 2011). Each of these goals has indicators for tracking progress, updated on a yearly basis. The plan has explicit attention to vulnerability and to a certain degree environmental equity (access to parks and air quality differences), but environmental justice could be more prominent in the city's sustainability plan (Rosan 2011). Similar to Baltimore's sustainability plan, the New York effort tends to focus on city-scale issues. Nevertheless, the scenario process that incorporates measurable indicators offers a great deal of promise for empirically linking the analytical frameworks of environmental justice, vulnerability, and sustainability.

4.6 Conclusions

For nearly 30 years, the environmental justice movement has championed the rights of disadvantaged groups and fought to make sure that the "environment" should include central city neighborhoods as much as wilderness or tropical forests. Initially a marginal movement based in the United States, environmental justice has successfully become a working principle of nonprofit groups and governments in many parts of the world. However, opportunities exist to better incorporate environmental justice's ideas, methods, and principles into sustainability, which has been broadly accepted and adopted in the global arena. Sustainability is typically understood and implemented as a balance between environmental and economic priorities; social justice needs to be an equal consideration, and environmental justice scholars and activists should continue to make sure that it is. At the same time, environmental justice has an opportunity to hitch its wagon to the sustainability train and embrace some of the attributes of sustainability that make it so tenable. Climate justice exemplifies how this may occur, where the principles of environmental justice have combined with the global-level systems thinking, biophysical concerns, and anticipatory principles of sustainability. From vulnerability, climate justice research and protests have also drawn attention to the differential impacts that are likely to occur, especially in developing countries, and the lack of institutional and other means for mitigating or adapting to such change. Convergence of the ideas, principles, and practices from environmental justice, sustainability, and vulnerability could be a very powerful mix for effecting positive change, from local neighborhoods to global systems and from now into the future.

Acknowledgments Portions of this chapter were first published in Boone, Christopher G. (2010). Environmental justice, sustainability, and vulnerability. *International Journal of Urban Sustainable Development* 2 (1–2), 135–140.

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Chapter 5
Urban Ecology and Nature's Services Infrastructure: Policy Implications of the Million Trees Initiative of the City of Los Angeles

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Abstract Cities across the United States have embarked on major tree planting programs for their purported environmental and social benefits. Trees offer a powerful symbol of nature in the city and to advocates of such programs, an obvious measure to improve environmental quality. Yet the science behind the environmental and social benefits remains meager, and in a time of budget austerity, the costs of planting trees and maintaining them are significant. As these programs have been implemented, they have also encountered unexpected resistance from residents. Los Angeles has embarked on a campaign to plant a million new trees to make the city the greenest in the United States. Using this example as a case study, this chapter examines tree planting through a lens of urban sustainability, discussing the challenges of transitioning from a sanitary city model to one of integrating nature's services to help reduce urban ecological footprints. Moving from a sanitary city (or modernist city) to a sustainable city involves complex changes in the rights and responsibilities of residents and the governance structure alike.

Keywords Ecosystem services • Urban tree canopy • Urban sustainability • Green infrastructure • Governance

5.1 Introduction

Cities across the United States have embarked on major tree planting programs for their purported environmental and social benefits. Trees, a type of ecosystem service, offer a powerful symbol of nature in the city. To advocates of nature in the city, urban

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_5,

forests seem an obvious measure to improve environmental quality, public health, and the quality of life. Yet the science behind the environmental and social benefits remains meager, and in a time of budget austerity, the costs of planting trees and maintaining them are often overlooked (Pataki et al. 2011a, b). Further, most urban tree programs rely on an uneasy mix of public-private collaboration, with cities setting standards for street trees, nonprofits often partnering in the implementation of the programs partners in planting, and residents held responsible for street tree maintenance. These are novel forms of managing infrastructure.

As these programs have been implemented—though the majority of trees in cities are to be found on private property and most of those in wealthier neighborhoods (Zhu and Zhang 2008; Heynan et al. 2006; Iverson and Cook 2000)—they have also encountered unexpected resistance from some residents, largely in low-income communities of color. This raises questions about priorities for improvement of such neighborhoods and the role of a greening strategy that may impose more burdens on residents. And so greening raises paradoxical trade-offs for environmental justice. On the one hand, trees play an important role in cooling the atmosphere (Pincetl et al. 2012), but on the other hand, their maintenance imposes costs on communities that can least afford them. Hence, governance questions and equity are intertwined in the creation, deployment, and maintenance of urban ecosystem system services and should be examined closely.

Los Angeles has embarked on a campaign to plant a million new trees to make the city the greenest in the United States. Using Los Angeles as an example, this chapter examines urban ecosystem services for greater urban sustainability, and discusses the challenges of transitioning from a sanitary city model to one of integrating nature's services to help reduce urban ecological footprints. Moving from a sanitary city (or modernist city) to a sustainable city involves complex changes in the rights and responsibilities of residents, priorities of government and nonprofits, and the governance structure itself. As the Los Angeles example demonstrates, ecological benefits of green infrastructure are contingent on specific places and local attributes such as climate, soils, and latitude. As Evans (2011) cautions, and the Los Angeles example shows, much of the current urban ecosystem studies that are being developed attempt to have standing as generalizable urban ecological science. Yet to be successful in making cities more sustainable, programs like tree planting for its multiple benefits must take local ecological, political, economic, and social conditions into account. Unlike modernist sanitary city infrastructure where uniform metrics could be applied (sewage sanitation systems, water delivery systems) and the systems are largely invisible and paid for through taxes, green infrastructure is sensitive to location, visible, and, in its present form, requires new forms of participation and fiscal support for its success.

5.2 The Rise of Ecosystem Services as Green Urban Infrastructure

With the concern about environmental degradation and the increased concentration of the world's populations in cities, attention has turned to the ability of cities themselves to mitigate their impacts through different strategies, including intentional deployment of ecological services such as urban forestry, low-impact development standards, among other "green" infrastructure methods (Benedict and McMahon 2006; E.P.A. 2009; ASLA 2010; Center for Neighborhood Technology Green Infrastructure 2010; Lukes and Kloss 2008; Bitting and Kloss 2008; Bélanger 2009; Rees and Wackernagel 1996).

Trees are often singled out for their special benefits (McFarland 1994). These benefits include the following:

- Increased property values
- Increased economic development
- Reduced surface water runoff rates and volume
- Increased energy conservation benefits
- Production of oxygen and cleaning of air
- Reduced noise pollution
- Improved human health
- Provision of wildlife habitat
- Maintenance and improvement of surface water quality
- Buffers between different land uses
- Traffic control
- Aesthetic screening

The largest cities in the United States have embarked on million tree planting programs—New York and Los Angeles—and many more are actively planting and promoting trees, including Seattle, Chicago, and San Francisco. The US Forest Service has been actively supporting these programs by providing technical assistance including urban tree canopy analysis and calculations of potential benefits from planting more trees. A Forest Service urban tree canopy cover analyses by McPherson et al. (2011), for example, calculated for Los Angeles a $1.33 billion to $1.95 billion benefit over a 35-year period in aesthetic or other benefits: 8% stormwater runoff, 6% energy savings, 4% air quality, and less than 1% in atmospheric carbon. For New York, Forest Service researchers Peper et al. (2007) calculated environmental benefits at about $5.2 billion a year.

Ecosystem services and their value for human well-being was pointed out by the now classic volume edited by Gretchen Daly (1997) and further elaborated by the 2005 United Nations Millennium Assessment. Classic works such as *Design with Nature* (McHarg 1969), *The Granite Garden* (Spirn 1984), and *Cities and Natural Process* (Hough 1995) provided the groundwork for considering cities as potential sites of remediation, pointing out that natural processes continue to exist in cities, and well-designed cities can take advantage of these processes for cooling, recreation, biodiversity conservation, groundwater recharge, and human health and well-being.

In the twenty-first century, the potential value of urban ecosystem services for improving the urban environment has impacted the popular literature and imagination, and tree planting programs are an application of these ideas. Interestingly, little fundamental ecosystem science has taken place in specific cities examining these claims for their veracity and possible disamenity impacts (Pincetl et al. 2012; Saphores and Li 2012; Li and Saphores 2011; Pincetl 2010a, b; Pataki et al. 2011a, b;

Lyytimaki et al. 2008). The US Forest Service has developed tools to quantify urban forest benefits, as the examples above show, based on urban forest cover derived from national satellite (Landsat)-based maps and census data and a computer model (UFORE) that quantifies urban forest structure and functions. UFORE quantifies species composition and diversity, diameter distribution, tree density and health, leaf area, leaf biomass and other structural characteristics, hourly volatile organic compound emissions, total carbon stored and net carbon sequestered annually, as well as hourly pollution removal by the urban forest and associated percent improvement in air quality throughout a year (Nowak and Crane 2000).

5.3 From the Sanitary to the Sustainable City

The modern sanitary city (in its ideal) is sustained with distantly sourced water, power, and materials, is managed by professionals in city bureaucracies, and provides urban infrastructure broadly, similarly, and at the same cost basis to all, in the public interest. The sanitary city arose out of the infrastructure needs of modern industrial cities that concentrated more people than cities had ever done previously. They required greater inputs to fuel industry and support human populations. Insalubrious conditions and resulting death and disease from inadequate (indeed undeveloped and yet to be invented) infrastructure provoked social and technological innovation and reform (Melosi 2000). These resulted in the application of biological science to water purification and treatment, engineering to road construction, power plants, sewage treatment plants, and new building techniques, and created infrastructure networks that Graham and Marvin write "constitute the largest and most sophisticated technological artifacts ever devised by humans" (2001:10). Kaika and Swyngedouw (2000) point out that technological networks—water, gas, electricity, information—are the mediators through which the transformation of nature into city takes place.

In the United States, modern infrastructure was an intrinsic part of the progressive reform movement, an ambiguous political movement composed of business interests seeking efficient infrastructure, and government to improve business capacity and growth and social reformers advocating the eight-hour working day, unionization, and better working and housing conditions (Pincetl 1999). Together they transformed American government from cities to states, to the nation's capitol. Reforms included the creation of a nonpartisan civil service made up of professionals overseen by appointed boards and commissions, the institutionalization of municipal accounting procedures, reformed tax systems, and the construction of infrastructure based on standardized norms established by professional societies. Infrastructure became the domain of highly technical and technocratic institutions (like Departments of Sanitation), driven by ostensibly depoliticized rationalities of engineering. Infrastructure and its performance became normalized, taken for granted, black boxed, and, in a sense, banal (Graham and Marvin 2001). And to work best, to be efficient, infrastructure needed to be uniform across urban space;

hence, there was a democratization of these services. Clearly beneath the universalizing rhetoric of modern cities, there was inequality, contradiction, and struggle, as well as cultural and historical specificities.

The sustainable city starts from a different premise, one of self-reliance, of the rediscovery of natural processes in specific places that can substitute, replace, remediate, or supplement the black box engineered infrastructure that relies on inputs from far-flung places and produces wastes that can impact local and distant environments. Green infrastructure is an important component of the sustainable city, aiming to reduce the city's impact by remediating pollution at the city level itself, or by enhancing the reliance on local resources such as water, through techniques such as reinfiltration of stormwater. And, of course, sustainability is premised on a balance between equity, environment, and economy, attempting a fusion of the three that produces cities that are more livable and have less negative impacts on the global environment.

Sustainability requires new knowledge and a different approach. For a city to become more environmentally sustainable, an understanding of local ecological processes and resources is necessary. The ecological/environmental component of urban sustainability is fundamentally a function of local conditions: soil, climate, latitude, and physical geography. The economic and social potential of sustainability will equally be a function of the locality. Poor, deindustrialized cities will require different strategies than wealthier ones.

In essence, the difference between modernist sanitary cities and sustainable cities is that for cities to be sustainable, they must start with where they are and maximize local inputs. Any local green infrastructure is effective only to the degree that the physical geography is appropriate to the ecosystems chosen for that place. For example, reinfiltration of stormwater in places with heavy clay soils is problematic. Likewise, planting urban trees in places that were not forested raises questions about their adaptability without changing local growing conditions.

Urban forestry programs and quantification of benefits, however, do not take local conditions much into account. The Forest Service's UFORE, for example, is based on studies of trees in scattered cities across the USA or trees in forests that have been generalized to show the benefits of urban trees for all cities. Values such as pollution removal are based on, for example, a "hybrid multilayer big-leaf tree" and generalized to the entire urban forest.[1] Palm Springs, a city in the desert where paloverde trees have been planted, whose leaves are needle-like, if it used UFORE, would surely overestimate pollution removal of its urban forest. Trees also require water. In arid regions, water is often imported and pumped. So while the urban forest reduces the urban heat island and the need for heating and cooling, it also requires the generation of electricity for pumping the water. Water use by trees is not included in the UFORE program. Data on trees is purely descriptive of the physical attributes of trees.

[1] http://nrs.fs.fed.us/tools/ufore/local-resources/downloads/UFORE_Summary.pdf (Last accessed: May 4, 2012)

More worryingly, UFORE is being used to calculate benefits of the urban forest as the basis for mitigating pollution impacts. For example, Connective Electric Utility negotiated to have $1 million of an air pollution fine donated to the New Jersey Tree Foundation for a massive urban airshed reforestation project in the Camden, NJ, area. Volunteers are planting shade trees in the communities most directly affected by the air pollution that lead to the fines. Similarly, the Southern California Air Quality Management District has provided fine monies to the Los Angeles Million Tree planting programs (Pincetl 2010b). While urban trees most likely have some impact, the range may differ widely depending on geographic location and the species composition of the urban forest. Unintended consequences such as increased water demand are unaddressed. In addition, there are no site-specific studies showing the direct relationship between the urban tree canopy and electricity bills for heating or cooling. There is data that shows that the ambient air is cooler in places with trees, but not that residents have used less power in those places.

Using green infrastructure and ecosystem services effectively suggests that the constraints of local physical geographic conditions be understood and that research be done that is city specific. Unfortunately, the approach to this new type of infrastructure has tended to be a continuation of the standardized technical engineering approach of the twentieth century sanitary city—assuming trees function uniformly and applying the model broadly to disparate biophysical and socioeconomic, historical, and cultural situations.

5.4 Equity, Economy, and Governmental Services

Green infrastructure, unlike conventional engineered infrastructure, is decentralized, site specific, and uses biological processes, sometimes referred to as living machines, a term coined by John Todd, a biologist referring to using ecologically engineered technology to restore, conserve, or remediate sewage or other polluted water. This approach uses diverse communities of bacteria and other microorganisms, algae, plants, trees, snails, fish, and other living creatures. Green infrastructure is context dependent and requires new knowledge—a tree that may be suited for a coastal condition may not fare well inland, as in Los Angeles, where the microclimate is much harsher. The ways plants, soils, and microorganisms may interact in specific locations will affect desired infrastructure results.

Green infrastructure also requires an urban fabric that is configured so there is room for vegetation and soils to perform their remediation work. Further, skilled, routine maintenance is necessary to ensure the green infrastructure is functioning, much like a garden needs tending. Living infrastructure therefore has new requirements: biological knowledge, different configuration of urban space, and spatially distributed maintenance on a routine "horticultural" basis.

In essence, implementing living infrastructure may need the kind of fundamental changes that were necessary for the sanitary city to come about, including new government agencies staffed by professionals with new expertise, new rules and codes for the urban fabric to accommodate living infrastructure, new sources of funding, and a new division of labor between public and private lands and actors.

Presently the living infrastructure of cities—trees, parks, open spaces—is not managed for its environmental attributes. It is treated as an amenity and managed by departments whose budgets are often the first to be cut in times of austerity. Unlike police departments, fire departments, or sanitation and water departments, the importance of street trees or parks to the functioning of the city seems minor, despite exhortations to the contrary by health professionals and ecosystem services advocates. The cost of their maintenance is not factored into specific billing, like for water, power, or sanitation services. Attempts like UFORE to quantify the benefits of trees to cities have not yielded new municipal accounting standards to acknowledge or charge for the benefits, even were UFORE metrics uniformly applicable to all cities in the nation, and the benefits of trees were truly significant.

Lack of funding for urban ecosystem services infrastructure has led to the creation of innovative public-private partnerships. Most tree planting programs in the country rely on private property owners to plant more trees on their properties, or to increasingly plant, and to maintain street trees in residential areas (or Business Improvement Districts in commercial zones), or to collaborate with the nonprofit sector to plant and maintain trees on public property. The structure of such public-private partnerships has been little explored (Pincetl 2010b) but like many public-private partnerships that have arisen with the decline of state funding, these collaborations have profound implications for the transparency, legitimacy, and accountability of local government (Staeheli and Koddras 1997; Pincetl 2003).

In many cities, low-income neighborhoods of color have lower tree canopy cover than more affluent neighborhoods, and less parks and open spaces as well, which poses an additional challenge (Wolch et al. 2005; Grove and Burch 1997). While such neighborhoods tend to have equal water and sanitation infrastructure as other parts of the city—perhaps less well maintained—amenities such as trees or parks are another matter. Thus, given the current structure of urban forestry, it appears that to achieve greater equity in tree canopy cover, efforts will have to be redoubled in disadvantaged neighborhoods, calling on residents to participate at a higher level than neighborhoods that already have more trees. So far, most of the literature does not point to many successes (Heynan et al. 2006; Tate 2000) and Merget and Wolff (1976) point to the tendency of higher-income residents to contract to the private sector to fill in when the city no longer provides infrastructure services, leaving lower-income areas to fend for themselves with limited resources. The equity implications of increasing tree canopy cover in such neighborhoods have not been well explored. Whose responsibility should it be to increase the numbers of trees and who should maintain them? Might there be other physical improvements to low-income neighborhoods that improve environmental quality (like reducing the urban heat island) that are less burdensome on the residents? Green infrastructure advocates have not explored these possibilities.

5.5 Los Angeles Million Trees

When Mayor Villaraigosa was elected for his first term in 2006, he promised to plant a million more trees in Los Angeles to make it the greenest city in the United States. The aim of the Mayor was to increase the tree canopy cover to arrive at the target that is now seen as appropriate for an arid climate city: 25%. With a tree canopy cover of 21%, the city compares well to New York City at 23 and 20% for Baltimore (McPherson et al. 2008), especially since the region was not forested to begin with. According to McPherson, the nonprofit American Forests developed the widely adopted tree canopy cover (TCC) targets that reflect constraints posed by regional climate and land use patterns. American Forests recommends an average citywide TCC of 25% for cities in arid climates, while for temperate cities, TCC recommendations are 40% (http://www.americanforests.org/resources/urbanforests/treedeficit.php). Somehow these targets have become normalized as desirable, just as the targets for park acreage per capita (approximately 10 acres per 1,000 people) determined by the nonprofit National Recreation and Park Association.[2]

The mayor, advised by a campaign consultant, decided to embrace urban forestry as a campaign platform (Swiller, A. 2007. Personal Interview with author, December 12). At the time, it seemed like a cheap, quick, and easy program that could be done through a local nonprofit. "Planting trees should be as simple as LED street lights . . . they look pretty, they are good for the urban heat island, they improve the quality of life, they sequester carbon, and there are good social impacts" (Swiller ibid.). Nearly 5 years later, approximately 250,000 trees are alleged to have been planted, though there is no publicly available information on sources of funding, expenditures, locations of trees that have been planted, clear recommendations about trees to be planted, and planting schedules by neighborhoods. Publicity for the program has also disappeared. The thousands of trees that were provided through the tree give away programs were not tracked to determine whether they were planted or died. Again, it is difficult to know due to the poor reporting information.

Million Trees Los Angeles is an example of the potential governance challenges posed by mixed public and private enterprise conducting the implementation of green urban infrastructure. There is difficulty in tracing participants, funding, responsibilities, and evaluating effectiveness from any measure: numbers of trees, appropriateness of species for the climate, choice of planting areas, cost/benefit of the program, and tree survival rates. In contrast, modernist sanitary city programs are explicitly integrated into city budgets, subject to hearings and comment, and expected to be accomplished effectively as they depend on taxpayer funding. With blended funding from foundations, businesses and other contributions (such as settlement money and fines), reliance on

[2] The National Recreation and Park Association (NRPA) was created in 1965 by the merger of 5 organizations: the National Recreation Association, the American Institute of Park Executives, the American Recreation Society, the National Conference on State Parks, and the American Association of Zoological Parks and Aquariums. The NRPA has issued guidelines for park acreages per capita that are widely accepted as fact.

existing programs, and in-kind contributions (Pincetl 2010b), a city-led program like Million Trees Los Angeles has no transparency or accountability to the public.

While it could be argued that in this period of fiscal austerity and devolution of government programs, embarking on programs that rely on nongovernmental partners is innovative, showing flexibility and ingenuity, the transition is an uneasy one as the public still expects traditional reporting and legitimacy from government. Further, in a program like tree planting, the ambitious goals will not be met without public participation. This includes planting trees and maintaining them since even with the nonprofit partners that have been enlisted, the implementation of a new tree infrastructure is beyond the capacity of this bootstrap operation. For low-income neighborhoods to arrive at the tree canopy cover of their wealthier counterparts and contribute to the goal of 25% canopy cover, residents are going to have to get to work.

This too raises questions about municipal services. Under the old modernist model, people paid taxes and received services—perhaps inequitably distributed, but residents could always protest and appeal at city hall. Wealthier neighborhoods subsidized poorer neighborhoods as part of the social compact (Graham and Marvin 2001) because it was believed that the city would function better if there was equity in its infrastructure.

The aspirational green infrastructure attempts to achieve public benefit through private cost—enlist the residents to help improve their own neighborhood, and/or contract with local nonprofits. The complex issues of expertise—choosing the right trees for the climate and geography, planting and maintaining them for their services, assessing their performance, and coordinating urban forestry with other green infrastructure programs such as water reinfiltration—today are skirted and replaced with UFORE measurements that treat all places the same and rely on generic trees. City departments that are considered nonessential like street tree departments or parks departments can wither: Those services can be supplemented by nonprofits and volunteers.

5.6 Serious Sustainability

A serious approach to urban sustainability, however, requires a bit more rigor. If green infrastructure is to succeed in providing the services that are touted, then, just like any infrastructure, it needs to be grounded in empirical knowledge. The knowledge then has to be incorporated into urban management systems by experts. If, in this era of limits, another of the major obstacles is lack of funding, then there needs to be a concomitant reconceptualization of the structure of government that integrates new partners but with new rules and explicit relationships. To integrate nonprofit organizations and volunteers in municipal affairs and to ensure accountability and transparency, it will be necessary to develop new forms of government and governance, new contracts, and new norms of expectations. This conceptual work has not been done.

Beyond the question of the implementation of green infrastructure by new forms of public-private collaborations, without new forms, the expectation that low-income communities should volunteer their participation to green their own environment can be problematic. Why volunteer for programs that have no obvious benefit and that—for some communities—are seen to create problems? Trees are perceived to provide shelter for criminals, and police departments do not like them. They can damage water and sewer pipes, harbor pests and birds that create a mess that must be cleaned, and, in southern California, they require water (Pincetl 2010a). In Los Angeles, in multiple-family neighborhoods, there is a negative relationship between property values and street trees, contradicting the values in the Forest Service tree valuation packages (Li and Saphores 2011). The Million Tree program in Los Angeles found resistance to planting street trees in the most disadvantaged neighborhoods. One could also ask whether there might not be other ways to achieve the same benefits but that pose less of a burden on residents, as mentioned above. For example, reducing the urban heat island could perhaps be better achieved through changing the albedo of streets and sidewalks, or installing shading structures, and relieving the necessity of residents themselves to maintain trees and the burden of additional water provision. More to the point, if one of the goals of tree planting is to reduce air pollution, perhaps a more effective strategy would be to reduce air pollution from polluting sources rather than to rely on trees to absorb the pollution.

Another of the benefits attributed to trees in much of the literature is their beneficial impact on property values (Payton et al. 2008; Mansfield et al. 2005; Anderson and Cordell 1988). As mentioned above, in Los Angeles, there is no evidence of a property value benefit to planting trees either in multiple-family neighborhoods where there is a negative correlation, or in single-family neighborhoods, where there is an insignificant correlation (Saphores and Li 2012; Li and Saphores 2011). Research in Los Angeles using hedonic valuation showed that in single-family neighborhoods, there was value in having lawns or nearby trees, but no statistically significant added property value to having a street tree in front of the house or on the property.

5.7 The Challenges of Shifting from a Sanitary City to a Sustainable City

Green infrastructure is treated as implicit to greater urban sustainability (see Beatley 2000; Benedict and McMahon 2006). Trees, bioswales to treat stormwater, green roofs, and other techniques using living machines, as John Todd dubbed them, are the current face of green infrastructure (Kollin 2006). Little serious consideration has been given to the challenges such infrastructure poses in the context of modernist cities as we know them. Governmental agencies and departments do not have the scientific knowledge to devise, deploy, and manage this different kind of infrastructure, especially given that the agencies are siloed and specialized to treat specific aspects of urban infrastructure: sewage sanitation, fresh water treatment, flood control, electricity provision, roads, and so forth, not ecosystem services that have multiple benefits. In Los Angeles, the city charter forbids the Department of Sanitation to consider water supply, making projects that encourage water reinfiltration, such as bioswales in streets, more difficult to justify as they are not responsible for enhancing water resources. Their role is to treat wastewater and stormwater to ensure it meets public health standards and is not a public threat.

The urban fabric itself is not built to accommodate natural processes—often planting widths are too narrow for trees, parking competes with stormwater infiltration, and potential local water supplies like local creeks are covered and shunted into storm drains, freeing more land for development. Financing a new infrastructure is expensive, especially when the benefits are either uncertain due to inadequate science, or marginal (like the CO_2 sequestration capacity of urban forests).

Additionally, it is not enough to plant trees, or build bioswales, and to then walk away assuming the job is done. They need tending. This can be potentially labor intensive and requires appropriate skill and knowledge. Neither is available in current cities as they face budget constraints. Nonprofit organizations, the US Forest Service, and EPA have rallied to encourage green infrastructure with small grants and programs. As in the Los Angeles case, cities across the United States have programs to plant trees and to experiment with bioswales and other techniques because they seem like commonsense good ideas. They may not be. In Los Angeles, the urban forest as it is presently being planted may end up adding 5% or more to water requirements (Pataki et al. 2011b). While the trees reduce the urban heat island (Pincetl et al. 2012), the power to pump the water into the basin is largely coal-based. What emissions are being generated to provide the cooling in the city? Further, while the urban heat island is cooled, there is no evidence that heating and cooling bills are any lower where there are trees.

5.8 Conclusion

Urban sustainability using green infrastructure to supplement conventional infrastructure will require new management structures, just like the sanitary city of twentieth century. It will require more and new science establishing the costs and benefits of this new infrastructure in a rigorous manner relevant to the city where it is to be implemented. Yet unlike the earlier progressive movement that ushered in the sanitary city, the urgency of green infrastructure for the better functioning of the city is not there. Sanitary city reforms saved lives; they removed the sources of disease such as cholera and diphtheria, yellow fever, and eventually polio. Sanitary city reforms paved streets, and established uniform codes based on engineering standards to make traffic flow more efficiently. They ensured buildings were well built. The reforms were good for business and good for residents. Green infrastructure does not have this appeal, nor the obvious benefits. While it could probably make an important contribution to make cities more livable, reduce pollution, and contribute to great local self-reliance, its attributes are more subtle and its implementation less straightforward in a period of budgetary austerity. Current approaches, as exemplified by tree planting, are opportunistic and not well factually based.

The Los Angeles Million Tree program is an example of such good intentions, the result of a campaign promise. The Mayor and his advisers were naïve about the difficulty of implementing such a program, and it has been fraught with difficulty. Money has been scraped together, and in the end, the program was entrusted to a political operative working out of the Mayor's office out of the limelight. There is little to no information on the program available, and its success in providing the attributes claimed for the urban forest is questionable. There is no accounting for water use by the trees planted, the size of the trees is not calibrated relative to their true eventual shade contribution, and their distribution is patchy. Yet the program has used the Forest Service claims about the benefits of the urban forest to continue to justify its importance.

For green infrastructure to truly contribute to making cities more sustainable, better science will be necessary about local conditions, as explained above, but there will also need to be well-thought out administrative structures to support this innovative change in how cities work. Indeed, it is one of the challenges of the twenty-first century.

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Chapter 6
Risky Business: Cap-and-Trade, Public Health, and Environmental Justice

Manuel Pastor, Rachel Morello-Frosch, James Sadd, and Justin Scoggins

Abstract At the global scale, the advent of a market-based, cap-and-trade approach to reduce greenhouse gas (GHG) emissions globally has been met with skepticism by some observers, who raise equity-based concerns over who will bear the costs of slowing climate change. Since California's passing of the Global Warming Solutions Act (AB32) in 2006, the "co-benefits" of climate policy – or health benefits that will accrue with a decline in the harmful pollutants that accompany GHGs ("co-pollutants") – and how they relate to current patterns of environmental disparity have been added to the debate. A key concern is that while GHGs may fall statewide, the decline may not be evenly distributed, and co-benefits could wind up eluding the low-income communities and communities of color who need them most. This chapter takes an empirical look at the relationship between GHG reductions, co-pollutants, and geographic inequality in California to better understand whether cap-and-trade could actually worsen the pattern of environmental disparity. We find that there is indeed a cause for concern and offer some policy suggestions to insure that environmental justice communities are better protected.

Keywords Climate justice • Greenhouse gas emissions • Cap-and-trade • Distributive equity • Public health

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_6,

6.1 Introduction

As the world attempts to tackle climate change, some observers have worried whether the medicine being proscribed to reduce the overall level of greenhouse gas (GHG) emissions could actually make one certain problem – environmental and social injustice – worse. Advocates rightly note that the developing countries that have contributed little to the current level of GHG emissions could wind up finding their development curtailed by a world suddenly eager to shave degrees even as low-income countries and individuals bear the brunt of higher energy costs (Barker et al. 2008). Others have argued that market-oriented remedies, particularly cap-and-trade, could lead, as does much of the market, to further inequality and a worsened situation for disadvantaged communities and less developed nations (Dorsey 2007; Lohmann 2008).

While the issue of climate justice has international dimensions, worries about environmental inequities and the propriety of market solutions have also preoccupied advocates and policy makers at a lower level of geography. In particular, California – which has been one of the globe's first movers on GHG reductions with its ambitious 2006 Global Warming Solutions Act (AB32) – has encountered many of the challenges and issues having to do with fairness and burden sharing. A path-breaking policy to reduce California's greenhouse gas (GHG) emissions to 1990 levels by the year 2020, AB 32 has garnered the enthusiasm of many mainstream environmentalists, partly because they are delighted to see progress being made on the climate front and partly because they suggest that the plan could reap significant "co-benefits" as we see declines in the harmful co-pollutants invariably accompany greenhouse gas emissions (Bailey et al. 2008).

For environmental justice advocates in California, however, the reception has been decidedly mixed (Environmental Justice Advisory Committee 2008; Sze et al. 2009). Despite the potential for decreased emissions in overburdened areas, one of the sore points for these advocates has been exactly the cap-and-trade program laid out in the California Air Resources Board's (ARB's) "Climate Change Scoping Plan." Among their concerns, while the program addresses GHG reductions across facilities included in the program at the state level, it does not ensure that those reductions (and consequent reductions in co-pollutants) would be evenly distributed geographically; thus, even though emissions may decline overall, the burden for already overly polluted communities could potentially get worse (or more likely not improve as much as the state average, thus worsening the inequality gradient). And the advocates have been remarkably successful in pressing their argument: when the state passed a Scoping Plan that included cap-and-trade, advocates sued and, in 2011, secured a court injunction that held up implementation of AB 32 until the distributional and other issues raised by the advocates were better addressed in planning documents.

How can this be? Doesn't cap-and-trade benefit all Californians, particularly those minority and low-income residents most vulnerable to climate change (Morello-Frosch et al. 2009; Shonkoff et al. 2009)? The crux of the issue is simple: while the "cap" part of cap-and-trade is inherently equal – everyone can benefit from a cap in GHG emissions no matter where you live – the "trade" part is not: because

GHG emissions come bundled with other pollutants, including particulates and toxics, the ability of a facility to exceed its permitted emissions levels in a given compliance period by purchasing allowances from other facilities means that localized health benefits from the reduction of co-pollutants will be foregone. Indeed, in the extreme case, co-pollutants could actually rise, worsening "hot spots" in a way that concerns activists and advocates.

To see the possibility concretely, consider a California example involving the La Paloma electrical power plant near rural Bakersfield and the ExxonMobil refinery in Torrance (within the Los Angeles metropolitan area). The La Paloma power plant sits about 35 miles west of the city of Bakersfield in an abandoned oil field just outside of the small town of McKittrick (population 160); there are fewer than 600 residents within a 6-mile radius and no other facilities in the immediate vicinity. The ExxonMobil refinery, on the other hand, is one of many facilities affecting nearly 800,000 people in its surrounding 6-mile area. These two facilities share one similarity – according to 2008 GHG emissions data from the California Air Resources Board, they both emit between 2.5 and 3 million tons of carbon dioxide each year. However, La Paloma releases 48.6 tons of asthma- and cancer-causing particulate matter per year, while ExxonMobil emits 352.2 tons. This staggering increase in risk to health is obviously important to Torrance's dense neighborhoods, although it is not accounted for in a cap-and-trade system that is focused on GHG emissions alone.

This chapter focuses specifically on the issue just described: the relationship between GHG reductions, co-pollutants, and geographic inequality in California. To investigate whether cap-and-trade could actually worsen the pattern of disparate pollution, we assemble a dataset of large GHG-releasing facilities in California, including power plants, cement kilns, and petroleum refineries. We then geo-code the facilities; attach publicly available emissions information on PM, NOx, and CO_2; and link in block group-level census data to carry out the kind of neighborhood-level environmental justice analysis that is common in the literature when considering point sources of pollution. Perhaps unsurprisingly, given both the national evidence (Ringquist 2005) and the state of the research for California (Pastor et al. 2004, 2005; Morello-Frosch et al. 2002), we find patterns of environmental inequity. To assess what this implies for a trading system, we identify which industries and facilities are driving the environmental inequity and use this to suggest the potential for problems of unequal benefits under cap-and-trade.

Our main point, one not heretofore made using an empirical rather than theoretical approach, is that there are indeed reasons to be concerned that cap-and-trade could exacerbate patterns of environmental injustice in terms of co-pollutant exposure. As a result, consideration of this effect should be part of climate change policy design. And while this research is on California – largely because we have data and experience at that level and because it is immediately relevant to ongoing policy debates about the implementation of AB 32 – we think the same issues are likely at play at the national and global levels. Thus, while we identify certain strategies policy makers could take into account to better protect environmental justice communities in lower-level geographies like California, we also consider the implications for climate change policy at higher levels of governance as well as the potential implications for future research.

6.2 Data and Methods

As noted, this chapter is a largely empirical effort – and this means that we must start with a description of the data and analytical approaches taken. To keep track as we provide the details, recall the top-line goal here: we want to link together facility-level data on both GHG and other emissions with neighborhood-level data to determine whether there are patterns of disparity in location, whether the disparity is worse when we consider the co-pollutants, and whether we can project the possibility of "bad" trades against which any system sensitive to environmental justice and health concern should create safeguards or compensation.

6.2.1 Preparing Facility Data

Following a method developed by the Natural Resources Defense Council (Bailey et al. 2008), we pulled together emissions data on industries that are known to emit large quantities of CO_2 – petroleum refineries, cement plants, and power plants.[1] Together, these sectors account for about 20% of California's GHG emissions and are slated to be the first group of industries to come under regulation in the state's cap-and-trade system. We extracted data on these facilities from two sources: the 2006 CARB emissions inventory for data on co-pollutants (NOx and PM_{10}) and 2008 GHG emissions from CARB's first annual release under the state's mandatory GHG Reporting Program.[2] The power plants considered in this dataset only include those oil and natural gas plants who reported to the California Energy Commission (CEC) in 2007 that they produced at least 50 online megawatts and all other plants that may not have met that criteria but were either coal fired or among the top 20 polluters of nitrous oxides (NOx), particulate matter (PM_{10}), or carbon dioxide equivalent (CO2e); this excludes a set of much smaller plants, such as most of the "peakers" that cycle only in times of high electrical demand, as less polluting plants (such as geothermal, solar, and nuclear), but it covers nearly 90% of the megawatt potential for the gas, oil, and coal plants in the CEC database. There are fewer petroleum refineries and cement plants and so we include data on all of them from the 2006 inventory. The resulting overall dataset includes 146 facilities (once restricted to those for which co-pollutant emissions information could be obtained).

Selecting down to a reasonable number that still covered the bulk of the sectors was important because of the challenge of spatially locating the facilities. Location is, of course, critical to any environmental justice analysis. However, this task proved to be challenging because the same facilities in different

[1] For a description of how the NRDC dataset was constructed, see "Appendix A: Co-Benefits Analysis Methods" at http://www.nrdc.org/globalWarming/boosting/boostinga.pdf.

[2] The CARB emissions inventory can be accessed at http://www.arb.ca.gov/ei/emissiondata.htm. The 2008 GHG emissions data can be accessed at http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-reports.htm.

databases often had slightly different coordinates and/or addresses.[3] Using mapping software, we cross-referenced the addresses given by the CARB emissions inventory with data from the GHG Reporting Program, the CEC power plants database, and a dataset of facility locations from the US Environmental Protection Agency (EPA) which provided geographic coordinates in addition to addresses. We then used aerial imagery in Google Earth to visually confirm that the resulting coordinates were correct, generally seeking, if possible to exactly locate the emissions stack. In cases where we had problems with locating a facility, we resorted to detailed web searches to locate the facility through a variety of sources including the parent-company's website, articles from web media sources, or permit application and review documents housed on the websites of regulatory agencies. In a few cases, we made calls to the relevant companies to ascertain locations and then check that information against Google Earth. The final results of that process are depicted in Fig. 6.1 in which we map the selected facilities against the state's demographics.

We linked the NOx and PM_{10} emissions to the facilities and used this to calculate the same health impacts index for each facility that was used in Bailey et al. (2008).[4] The health impacts index takes into account total facility-level emissions of the two co-pollutants and the air-basin-specific health endpoint factors for premature mortality for the air basin in which the facility is located.[5] The formula for the health impacts index is

$$HI_i = \left(\frac{NO_x}{HEP_{AB}}\right) + \left(\frac{PM_{2.5}}{HEP_{AB}}\right)$$

where HI_i equals the health impacts index, NOx equals emissions in 2006, $PM_{2.5}$ equals PM_{10} emissions in 2006 divided by the ratio of PM_{10} to $PM_{2.5}$ (from 2006 ARB emissions inventory for the particular source category (electric utilities, petroleum refining, or cement)),[6] and HEP_{AB} equals the air-basin-specific health endpoint factor for premature mortality. Because the health endpoint factors are derived at the broad geography of air basins, they are not appropriate for use at lower levels of geography (i.e., when considering populations immediately surrounding a facility as one does in an environmental analysis). Thus, in the analysis below, we use only proximity along with total NOx and PM emissions as indicators

[3] This was the EPA's Facility Registry System (FRS), and the shapefile was downloaded from http://www.epa.gov/enviro/geo_data.html.

[4] The only difference is that we used PM_{10} rather than total PM in the health impacts index calculation, which is considered more closely tied to health endpoints.

[5] Health endpoint factors are the estimated number of tons per year of a particular pollutant that can be associated with each case of a health endpoint (in this case premature mortality) in within a particular geographic area (in this case air basins). See www.arb.ca.gov/planning/gmerp/march21plan/docs/health_analysis_supplement.pdf for more information, including the health endpoint factors for each air basin.

[6] These ratios can be accessed at http://www.arb.ca.gov/app/emsinv/emssumcat.php.

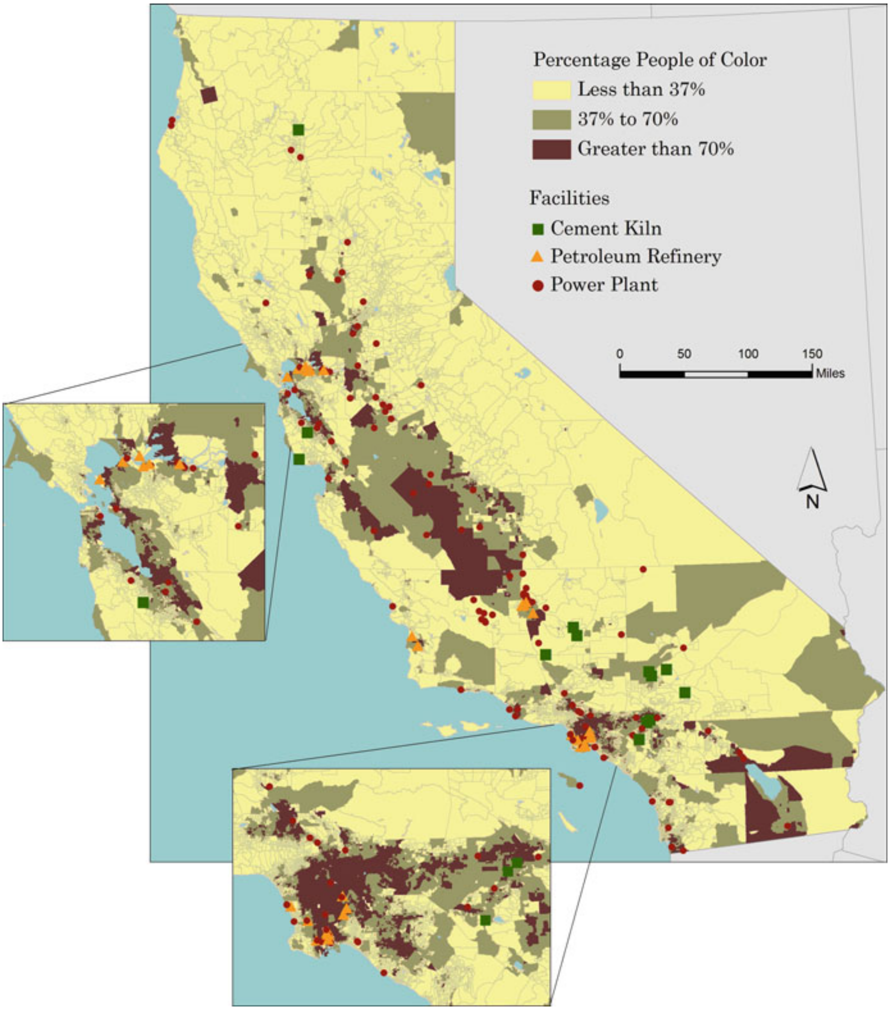

Fig. 6.1 Major GHG-emitting Facilities in California

of health risk, often using population weights to determine total effect. However, we occasionally refer to the health impacts index when we discuss which of our proximity measures is most consistent with this more standard measure.

6.2.2 Linking in Neighborhood Characteristics

To examine the issue of environmental inequity for the set of facilities considered, we utilize 2000 decennial US census data from summary files 1 and 3, observed at the block group, the lowest level of geography at which income information is available. Block groups are drawn to represent fairly homogenous populations in terms of demographic and economic characteristics, making them a good approximation of a neighborhood. They are more geographically detailed than census tracts (the next higher level of geographic aggregation in the census) which are often used by researchers to characterize "neighborhoods."

In any geographic analysis such as this – relating facilities, which are points in space, to census block groups, which are areal units – the methods by which the levels of geography are reconciled can be complex. In this case, to estimate the population exposed to a given facility's emissions, we assign any neighborhood to a facility following a variation of the distance-based approach recommended by Mohai and Saha (2006). We drew a circular buffer around each facility and counted as contained within the buffer any census block (the underlying components of block groups) whose centroid was within the buffer. We then tallied up the population of the captured blocks to estimate the total share of the block group's population that was within the buffer and used that number to appropriately "down weight" any association between a facility and block group that was only partially captured by a buffer; for example, if all blocks had equal population and half the blocks in a block group were in the buffer, then half the block group's population was assigned as being part of the proximate community.[7] The resulting flock group data on race and income was then attached to each facility; eventually, we went the other way as well, taking account of whether neighborhoods were affected by multiple facilities.

We drew multiple buffers of different radii (half mile, one mile, two and a half miles, five miles, and six miles, respectively) because of the large variation in the size of the facilities subject to analysis. While such facilities are represented as points with no dimension (only latitude and longitude coordinates) in our GIS environment, such a representation is grossly inaccurate for facilities that cover a large area and that may have multiple emission sources. In such instances, a half-mile buffer drawn from the point representing the facility may barely reach the real perimeter of the actual facility boundary. By running all analyses under multiple buffer distances, we have a way of testing the sensitivity of the results to the different buffer distances, and to the extent that the results under different lead to similar conclusions, we can discount the distorting effect that variation in facility size (or likely distance of effect) may have. The most generous of these radii (6 miles) is not standard in the environmental justice literature (see Pastor et al. 2004; Sadd et al. 1999), but it is the marker used by the California Energy Commission when it attempts to determine whether or not there are environmental justice communities located nearby any proposed location for a power plant; the other buffer distances have been used in the environmental justice literature, particularly when considering TRI facilities.

[7] We also calculated this share for and occupied housing units for use in appropriately weighting median household income for block groups by distance from a facility or multiple facilities.

6.3 Results

6.3.1 Existing Patterns of Environmental Inequity in Proximity to GHG Facilities

We begin our analysis by examining the difference in neighborhood characteristics by distance from a facility. This sort of analysis is common in environmental justice research to assess whether environmental disamenities are distributed evenly across groups defined by race/ethnicity, income, and other measures.

Table 6.1 offers a first view by looking at the composition of the neighborhoods within each of the distance buffers. The table shows that 62% of residents living with 6 miles of a facility in our dataset are people of color; beyond that buffer, communities are only 46% people of color. African Americans experience the most disproportionate burden: their share of the population living within half a mile of a facility is about twice their share of the population living outside of the 6-mile range. The Latino community share is highest at the two-and-a-half-mile range, where they make up about 40% of that proximate population, as compared to only 28% of those more

Table 6.1 Demographic and other characteristics of neighborhoods by proximity to large GHG-emitting facility in California

Average characteristics by distance from a facility						
	<0.5 mi.	<1 mi.	<2.5 mi.	<5 mi.	<6 mi.	>6 mi.
Total population	96,362	575,014	4,368,581	12,844,279	15,492,631	18,226,753
% California population	0.3%	1.7%	13.3%	38.8%	45.9%	54.1%
People/sq.mi.	1,002	1,325	1,841	1,802	1,779	125
Non-Hispanic white	42.6%	41.2%	37.4%	37.5%	38.0%	54.0%
People of color	57.4%	58.8%	62.6%	62.5%	62.0%	46.0%
African American	8.7%	8.2%	8.3%	8.5%	8.6%	4.6%
Latino	35.0%	38.1%	40.2%	38.6%	37.5%	28.1%
Asian/Pacific Islander	10.2%	8.9%	10.6%	12.0%	12.6%	9.7%
1980s and 1990s immigrants	19.1%	20.3%	20.9%	21.3%	21.4%	15.4%
People below poverty level	16.5%	16.3%	16.8%	16.9%	16.6%	12.2%
Children (under 18 years)	24.0%	26.8%	28.5%	28.1%	27.7%	27.0%
Renters	56.0%	52.8%	50.3%	49.6%	49.4%	37.8%
Per capita income (1999)	$21,399	$20,794	$20,043	$20,950	$21,186	$24,013
Relative median household income (CA median = 100)	87.7	87.7	90.4	93.5	94.0	105.0

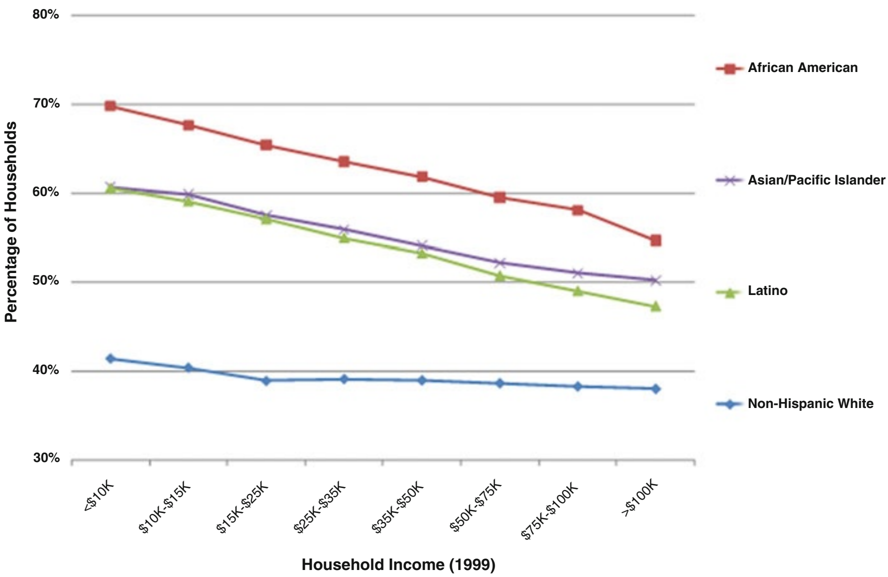

Fig. 6.2 Percentage households within 6 miles of any facility by income and race/ethnicity California

than 6 miles away. Asian Pacific Islanders are also overrepresented within 6 miles of a facility, with the disproportionality most marked at the greatest buffer distances. Recent immigrants are also overrepresented within the 6-mile range as are persons living in poverty.[8] As for other income measures, there are more renters, lower per capita incomes, and lower household incomes near the large GHG-emitting facilities considered in this exercise. The one variable that exhibits little difference, the percent of children living near facilities, is roughly the same as the percent of children at increasing distance from facilities.

When looking at these patterns, one question is whether the evident racial disparities are really just a function of the equally evident income disparities. Figure 6.2 thus presents the percent of households within the 6-mile distance buffer across income brackets by race – and it makes clear that while the likelihood of living near a facility declines as income rises for all groups (as does the racial disparity between groups), there remain differences by race at each and every level of income. While the results reported here are just for the 6-mile distance buffer, this pattern is the same at other distances.

[8] The figures we show are for persons living below 150% of the poverty line since some argue that this is a better measure of low income for a high-cost state like California.

6.3.2 *Environmental Inequity in Emissions Burdens from GHG Facilities*

Environmental justice advocates are increasingly concerned not just with whether a community is proximate to an emitting facility but also the level of burden associated with that facility and whether the community finds itself experiencing burdens from multiple facilities. To get at this issue of cumulative exposures, we now go beyond examining whether a neighborhood has any facility nearby and instead try to ascertain the local health burden from all facilities.

Ideally such information would be derived by modeling co-pollutant emissions from all facilities using a sophisticated fate and transport model to generate estimates of combined co-pollutant concentrations at the neighborhood level for all neighborhoods in California. However, such an in-depth analysis is beyond the scope of this work, so we instead take a simple "first cut" using the database we assembled.

We thus consider neighborhoods (block groups) within 6 miles of any facility as being "exposed" and characterize their degree of exposure by summing up the tons of co-pollutant emissions from all facilities within 6 miles. Such "exposed" neighborhoods are then classified into three categories of high to low exposure: high emissions (greater than one standard deviation above the mean across all such neighborhoods), middle range (within one standard deviation of the mean, plus, or minus), and low emissions (less than one standard deviation below the mean).[9] A fourth and lowest exposure category is then defined to include all remaining neighborhoods in the state for comparative purposes – those beyond 6 miles of any facility.

Using the above classification of neighborhoods, we report in Table 6.2 the same set of demographic and socioeconomic characteristics that were included in Table 6.1. We focus here on PM_{10} because it is a well-known co-pollutant with serious health effects including respiratory problems and premature death and on the 6-mile distance to be comparable with the information reported in Table 6.1.

As can be seen, African Americans are overrepresented in the high-emission group of neighborhoods, making up about 16% of the population – more than three times their share in either the low-emission group of neighborhoods or those neighborhoods outside of the 6-mile range of any facility. Latinos find their highest population representation in the middle range of emissions, and while Asians are overrepresented at each emissions level, their share is the highest in the places with lower emissions. As a group, there is a disparate pattern for all people of color: they make up about 46% of the population outside the 6-mile range, 57% of those in low-emission areas, and 66% of those in high-emission areas. Again, while we only show the results at the 6-mile range to conserve space, they are very similar at other distances, including the two-and-a-half-mile distance which becomes the focus of the analysis below.

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[9] Means and standard deviations discussed here are based on the natural log of the summed emissions across facilities within each of the distance ranges of a block group that were tested (in this case, 6 miles). This is a common transformation to normalize measures that exhibit a "long tail" or exponential distribution.

Table 6.2 Characteristics of neighborhoods in a cumulative exposure approach

	Average characteristics by PM_{10} emissions from facilities within 6 miles			
	High emissions	Middle range	Low emissions	No facilities within 6 miles
Total population	2,317,884	10,940,640	2,234,107	18,226,753
% California population	6.9%	32.4%	6.6%	54.1%
People/sq.mi.	2,638	1,746	1,425	125
Non-Hispanic white	34.4%	37.7%	43.5%	54.0%
People of color	65.6%	62.3%	56.5%	46.0%
African American	15.9%	7.8%	4.9%	4.6%
Latino	34.5%	38.8%	33.9%	28.1%
Asian/Pacific Islander	11.7%	12.5%	14.3%	9.7%
1980s and 1990s immigrants	18.7%	22.2%	20.2%	15.4%
People below poverty level	17.5%	16.3%	16.8%	12.2%
Children (under 18 years)	31.1%	30.5%	30.5%	29.4%
Renters	50.6%	49.6%	47.3%	37.8%
Per capita income (1999)	$20,986	$21,482	$19,945	$24,013
Relative median household income (CA median = 100)	90.8	95.8	88.4	105.0

6.3.3 Measuring the Gap in Emissions Burdens

Given the disparate pattern in which communities of color are the most proximate to and most affected by emitting facilities, one would suspect that such communities would have the most to gain from any attempt to reduce GHG, particularly to the extent that this also affects co-pollutants. Why then has there been opposition to the particular mechanism of cap-and-trade?

To understand this, it is critical to think about how a cap-and-trade system might affect the distribution of co-pollutant emissions across facilities and industrial sectors. This is no easy task, and the real answer will depend on the economic and financial characteristics of particular facilities, something that would require extensive research into industrial ecology, facility time horizons, and current operating costs. A simpler approach – and one we take here – involves examining the contributions of each sector and facility to the existing disparities in local co-pollutant emissions by race/ethnicity. We can then identify the sectors and facilities that are driving inequity and use this information to make a minimal case: not that cap-and-trade will worsen environmental inequality but simply that it might worsen environmental inequality, and thus we should consider clear safeguards as well as potential alternative strategies that have less risk of widening existing disparities.

To measure the contribution of each facility and sector to environmental disparities, we attempt to account for three dimensions: (1) how many residents are near in any particular facility, (2) the total tons of co-pollutant emissions from the facility as a gauge of relative health burden, and (3) the racial/ethnic composition of the impacted population.

Combining all the information is important. Suppose a facility is located in an area with a population that is 90% minority, but its emissions are dwarfed by a facility a county away that is only 50% minority; simply averaging the two population shares would make the disparity seem high when the health effects might be actually "fairly" shared or even disproportionate fall on whites. Or consider combining a highly polluting facility that is located in a sparsely populated area that is 90% white with a slightly less polluting facility in a densely populated area that is 70% minority; surely the size of the population affected should matter in calculating the overall environmental justice impacts.

We thus put all the information together into what we term an environmental justice "gap" index, with the actual formula described below. Again, the idea is to determine whether people of color are overrepresented in the community around a particular facility, the size of the population affected, and the level of emissions from the facility. We focus our calculations of the gap on PM_{10} emissions, partly because on the public health attention on PM but also because the results for NOx are similar.

Before looking at the results for the actual "gap" index, it is useful to understand a few general patterns in the data. First, power plants overall have the most people within each distance threshold, followed by refineries and cement plants; this is not surprising given there are many more power plants than there are refineries and many more refineries than there are cement kilns. However, if we adjust for the number of facilities, we find refineries are, on average, located in more heavily populated areas, followed by power plants and cement plants.

Meanwhile, cement plants have the highest average co-pollutant emissions, ranking above refineries which themselves rank well above power plants. Cement plants also have the highest minority (mostly Latino) populations nearby, but because they affect fewer people overall, they contribute less to overall environmental disparity than do refineries that have very high percentages of African Americans nearby.

Putting this all together in one metric, we approximate total local PM_{10} emissions burden to all facilities combined as the population-weighted sum of PM_{10} emissions across facilities (i.e., total person-pounds of PM_{10}), which can be calculated separately for each racial/ethnic group and expressed as average local exposure for each group by dividing by the group's statewide population.[10] The statewide difference, or the total "gap" in average local PM_{10} emissions burden between any two

[10] We would emphasize here that the approximation of "exposure" we use here is just that – an approximation. While use of the term "exposure" in the field typically implies modeling of emissions to determine concentration at the neighborhood level, taking into account distance from the facility, how emissions are released and local wind and atmospheric patterns, for the purposes of this preliminary work, we rely on the rough approximation described here based only on total emissions and distance of residents from the facility.

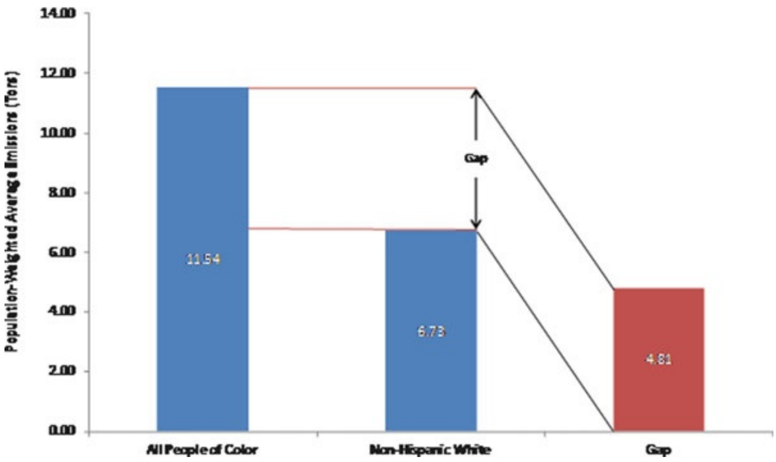

Fig. 6.3 Population-weighted average annual PM_{10} emissions burden (tons) by race/ethnicity for facilities within 2.5 miles

groups (in our case, people of color and non-Hispanic whites), is then used as the metric of disparity.

The overall results are presented in Fig. 6.3 for the two-and-a-half-mile distance threshold. We focus on the two-and-a-half-mile buffer because we think this is a reasonable distance for understanding emissions burdens – and it is also the case that the population-weighted emissions burden at two and a half miles is the most highly correlated among the buffer distances with the air-basin-wide health impacts index, a correlation that gave us some confidence in this choice of radius.

At this buffer distance, the burden faced by African Americans, Latinos, and Asians is very similar (and so we just present "people of color" as a single category) and about twice that of whites; at closer distances, Latino burdens are highest, and using longer-distance buffers, African American burdens are highest. However, the relative contribution of various sectors (cement kilns vs. power plants vs. refineries) to the environmental justice gap is not particularly sensitive to the buffers chosen, so focusing in on one illustrates the overall pattern while allowing for brevity in the presentation.

6.3.4 Which Sectors Are Driving the Pattern of Disparity?

Given the earlier evidence, finding a gap in relative burdens is not surprising – what we are really trying to do here is decompose the sources of the gap and understand whether trading between facilities and, more important, sectors could worsen the gap. To get at this, note that the overall California gap is actually derived as follows:

Total CA Gap$_{(POC\text{-}NHW)}$*d*=

[*average POC PM10 exposure*$_d$] – [*average NHW PM10 exposure*$_d$]

$$= \left[\frac{\sum_{i=1}^{n} POC_{i,d} \times PM10_{i,d}}{POC_{CA}}\right] - \left[\frac{\sum_{i=1}^{n} NHW_{i,d} \times PM10_{i,d}}{NHW_{CA}}\right]$$

$$= \sum_{i=1}^{n}\left[\frac{POC_{i,d} \times PM10_{i,d}}{POC_{CA}}\right] - \sum_{i=1}^{n}\left[\frac{NHW_{i,d} \times PM10_{i,d}}{NHW_{CA}}\right]$$

$$= \left[\frac{POC_{1,d} \times PM10_{1,d}}{POC_{CA}} + \frac{POC_{2,d} \times PM10_{2,d}}{POC_{CA}} + \ldots \frac{POC_{n,d} \times PM10_{n,d}}{POC_{CA}}\right]$$
$$- \left[\frac{NHW_{1,d} \times PM10_{1,d}}{NHW_{CA}} + \frac{NHW_{2,d} \times PM10_{2,d}}{NHW_{CA}} + \ldots \frac{NHW_{n,d} \times PM10_{n,d}}{NHW_{CA}}\right]$$
$$= \left[\frac{POC_{1,d} \times PM10_{1,d}}{POC_{CA}} + \frac{NHW_{1,d} \times PM10_{1,d}}{NHW_{CA}}\right] + \left[\frac{POC_{2,d} \times PM10_{2,d}}{POC_{CA}} - \frac{NHW_{2,d} \times PM10_{2,d}}{NHW_{CA}}\right]$$
$$+ \ldots \left[\frac{POC_{n,d} \times PM10_{n,d}}{POC_{CA}} - \frac{NHW_{n,d} \times PM10_{n,d}}{NHW_{CA}}\right]$$

Average local PM_{10} burden for each group at distance d is measured above as a simple population-weighted average of PM_{10} emissions across all facilities *i*, using the population within the distance *d* as weights, but with one modification: the sum of the weights (denominator) is set to the total California population for each group rather than the sum across facilities.[11] In the final line of the formula derivation above, each term represents the contribution (positive or negative) of each facility *i* to the overall statewide gap in local PM_{10} exposure at distance *d*. Thus, we can derive the positive or negative contribution to the statewide gap of each facility or sector, depending on how we group the terms.

Figure 6.4 does this first by sector. While refineries account for the majority of PM_{10} emissions for all people, they account for a much larger share (about 93%) of the gap in emissions between people of color and non-Hispanic whites. Figure 6.5 offers a view by facility; the ranking is determined by contribution to the state gap,

[11] This weighting scheme implicitly sets the PM_{10} exposure to zero for all people beyond distance *d* of any facility and is imposed so that disparities are figured relative to the statewide population rather than to the population within distance, *d*, of a facility. While this is not a realistic assumption – in reality PM_{10} and other emissions disperse and deconcentrate at varying rates by distance around a facility depending on a variety of factors – in lieu of a fate and transport modeling, our method is to test a variety of distances under the assumption that the PM_{10} concentration is constant within each buffer and zero outside of the buffer.

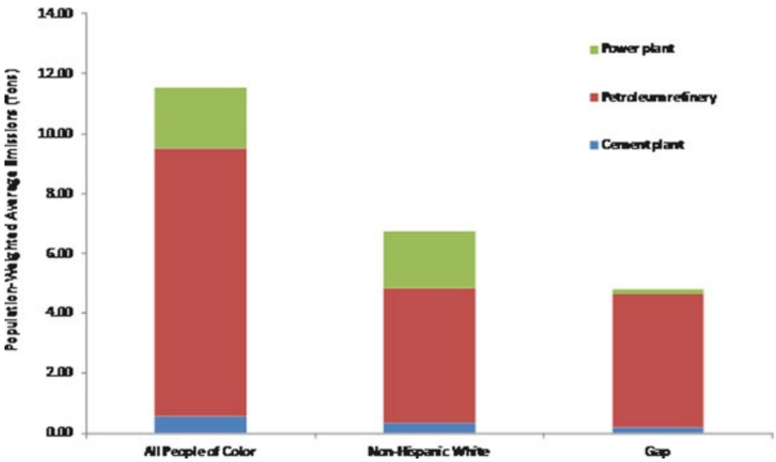

Fig. 6.4 Population-weighted average annual PM_{10} emissions burden (tons) by facility category and race/ethnicity for facilities within 2.5 miles

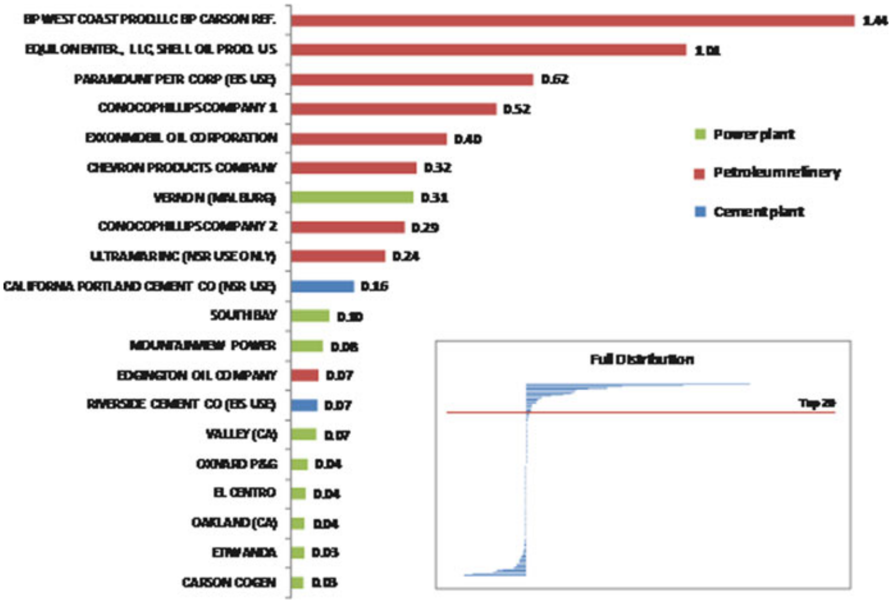

Fig. 6.5 Top 20 facilities in PM_{10} emissions disparity at 2.5 miles. Facility contribution

and it also points to refineries (which are eight of the top ten) as a key contributor to the environmental justice disparity. Moreover, the top eight facilities overall actually add up to the entire gap; if one considered all the facilities below that, there would be an even distribution of the PM_{10} emissions burden by race, since some facilities (displayed at the bottom of the full distribution in that figure) disproportionately burden whites. The full distribution also shows that vast majority of facilities have a score near zero. In short, a few facilities, mostly petroleum refineries, account for most of the observed inequities and are of most concern with regard to co-pollutant concerns in any sort of trading system.

6.4 Conclusion: Implications for Policy and Research

To consider the implications of these findings for policy and research, it is useful to stress three interrelated results. First, there are disparities in emissions burdens of large GHG-emitting facilities in California by race/ethnicity and income, and the extent of the disparity seems worse when we consider the quantity of co-pollutants emitted from the various facilities. Second, most of the observed disparities in co-pollutant emissions actually stems from petroleum refineries. And third, the disparity in co-pollutant emissions reflects the activities of relatively few facilities.

These patterns make clear, at least to us, that some carbon trades could worsen disparities in emissions burdens by race and ethnicity. Moreover, while there are legitimate worries about outcomes resulting from trades within a sector – such as when a power plant that impacts a large number of people in low-income communities of color eschews emissions reductions by buying credits from a power plant in a sparsely populated area – the real concern might be trade between sectors. Finally, the highly skewed nature of the emissions suggests that a carefully targeted approach – going after a few significant actors – might yield high health benefits.

Those who have dismissed the co-pollutant concerns have generally done so without doing any careful empirical analysis of the sort we have conducted. They do, however, tend to raise three theoretical objections that it is useful to address (see, e.g., Schatzki and Stavins 2009).

First, they suggest that it is unlikely that any trades could produce "hot spots" – that is, places where emissions of both GHG and co-pollutants actually increase.[12] We think that such "hot spots" are possible, particularly if some plants operating below current regulatory emission requirements for co-pollutants step up production (and emissions) because they believe they will eventually be sunsetted due to carbon caps (just as one might run an aging appliance past its prime knowing that it will soon be replaced). However, we think a more important fact is simply that we may miss an opportunity to achieve easily obtainable public health benefits from GHG reductions in the communities that need them the most. To some extent, the

[12] Such an outcome actually occurred in Southern California, for example, in a poorly designed system that allowed NOx emissions trading between mobile and stationary sources and led refineries to purchase and decommission "clunkers" rather than clean up near fenceline communities (see Drury et al. 1999).

insistence of environmental justice advocates on stressing “hot spot” potential has clouded the debate; the real focus should be on public health benefits left uncaptured.

Second, critics of the focus on co-pollutants worry that any remedies to address the issues would unnecessarily complicate the trading system. In our view, cap-and-trade for GHG reductions is a largely untried system that is trying to price a resource that has never been exchanged using mechanisms that are poorly developed and easily open to financial chicanery. If imposing a few extra restrictions – such as preventing trading out from highly impacted areas or imposing a surcharge on emitters with the highest health impacts – can break the system, such fragility is hardly a feature to recommend for the overall approach.

Third, and related to the above, some proponents of cap-and-trade believe that existing regulations are the most efficient way to deal with the co-pollutant burdens. This is not a convincing argument to many in environmental justice communities who cite as evidence the current pattern of disproportionate exposure by race and who further worry about the way in which current laws are either not enforced or do not take into account the cumulative exposures that affect vulnerable residents.

We therefore think there are reasonable grounds for concern. On the other hand, we would also note that the preferred strategy of many environmental justice proponents, a carbon surcharge or tax, also faces the same problem we outline above: a facility could decide to pay the charge rather than reduce emissions and, because the charge being set includes GHG emissions but not co-pollutants, there is no reason to believe that the differential landscape of reduction would be any different than under cap-and-trade (although the overall landscape might be, depending on whether a carbon charge is a more effective strategy overall, as many environmental justice advocates contend).

What might be a better policy? Since the risk of uneven reductions occurs in any market system, we believe that two sorts of approaches might be viable. The first involves setting up “no trading” zones (which in a fee system could be areas where simply paying the fine does not obviate the need to actually meet certain targets). In these areas, companies would not be allowed to trade; as can be seen from the work above, a fairly simple set of calculations would allow policy makers to determine which facilities are likely to cause the most damage if they do not reduce co-pollutants and so targeting along those lines would not be difficult.

Another approach, and one which has been gaining ground in California, involves taking the revenues generated by initial auctions or by carbon fees and differentially allocating at least some share of them to communities that are environmentally overexposed and socially disadvantaged. This may actually be a more efficient approach as the funds could go to communities that have even more need than those in the closest proximity to the polluter; in this case, a more general screening method that could identify those communities would be needed, but work in developing such methods is moving along in California and elsewhere.[13]

At the very least, this research suggests that there is enough of a potential problem that authorities in California – and anywhere else cap-and-trade is considered – should develop a mechanism for tracking the post-trade impacts on health and local communities. Just as many have insisted that offsets should be verified to make sure that they are actually reducing GHG emissions, at least the early phase of any trading system should be closely monitored to see if it is improving or worsening preexisting patterns of environmental disparity.

Globally, the issue of co-pollutants has not been comprehensively incorporated into the pushback around cap-and-trade. Other sorts of geographic disparities tend to come up in the global debate about climate – typically around the power held in the global North and with regard to ongoing environmental degradation from fossil fuel extraction in the global South.[14] But as the worldwide community considers (almost unilaterally) carbon trading, researchers would do well to consider the impacts of co-pollutants on disadvantaged communities – both in developing and developed nations (Rickenbacker and Faber 2009) – and in countries in the global South. The issues raised in the California case regarding co-pollutants are salient – particularly if one can calculate which facilities and sectors may be most leading to disparity at a global level.

This is one of the reasons why we believe that developing better models of facility-, firm-, and industry-level responses to market incentives, either under cap-and-trade or carbon charges, is critical. This would include better assessment of the cost to firms of reducing GHG emissions as well as better measures of carbon intensity per unit of output (e.g., megawatt hours of electricity). Performing this type of analysis worldwide will be difficult and would require that researchers devise methodologies to account for data that is likely incomplete and inconsistent.

The analysis here also suggests work that might be done around offsets. Certain schemes to, say, forgo cleaning up a refinery in urban Mexico by replanting trees in the Brazilian rain forest might have salutary impacts on global GHG but leave the health of thousands of local residents still at risk – surely, there must be a way to price that into considering whether an "offset" is an offset or loophole. And while one wants to devise a system that will not choke off the economic potential of developing countries, there would also seem to be an imperative to value the health of those in the global South at the same rate that we value the health of any other resident of the planet.

There is also a world of work to do on other aspects of climate justice, including the disparate enjoyment of the benefits of tree canopy in urban settings, the differential impacts of rising energy costs within and between nations, the disparate exposure to certain weather-related risks, and the differential access to air-conditioned facilities

[13] See Sadd et al. (2011) for a review of one approach for California; see also http://www.epa.gov/compliance/ej/resources/policy/ej-seat.html for an environmental justice screening approach developed by the US Environmental Protection Agency.

[14] Some even argue about inequality within the global South of the distribution of the benefits of the Kyoto Clean Development Mechanism (Galizzi et al. 2009).

and other mitigations by certain populations. Developing the science and analysis to demonstrate that there are real problems of justice will be essential to insuring that efforts to address climate change also address and close a global "climate gap" in a way that will ultimately benefit the planet and all its people.

Acknowledgments Aspects of this analysis were presented in more popular form in Pastor et al. (2010), which also provides more specific policy options for California. This research was supported by the William and Flora Hewlett Foundation; the conclusions and opinions are those of the researchers and do not necessarily reflect the views of the funder. We thank Diane Bailey of the Natural Resources Defense Council for kindly walking us through her earlier analysis of health impacts and Robert Vos for his assistance and comments on an earlier iteration of this work.

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Chapter 7
Urbanization, Environmental Justice, and Social-Environmental Vulnerability in Brazil

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Abstract This chapter presents four case studies (on the Brazilian metropolitan areas of Curitiba, Baixada Santista, São Paulo, and Rio de Janeiro) on the bidirectional interactions of urbanization and global environmental change through the frameworks of urban ecology and environmental justice. Very importantly, we utilize distinct concepts and methodologies for the identification and characterization of environmental risk. According to IPCC (2007), it is difficult to estimate all the impacts of climate change precisely, the intensity and frequency of extreme events, such as storms, heavy rain, heat waves, and vulnerability of populations in metropolitan areas increase significantly. The studies presented in this chapter were developed and have as a main focus the transformations in the landscape due to the urbanization process and the consequent environmental degradation in different regions of Brazil. Most of these studies involve the use of methods of analysis from techniques and geoprocessing tools for the integration of spatial data. Data from the physical and socioeconomic environment were collected, stored, and organized; those data were extracted from institutional sources and satellite images, which enabled the visualization and integration of information. In these case studies, risk is associated with society's susceptibility to environmental changes, seen not only as a result of a certain event but also as a consequence of a social process related to structural urban issues that are linked to political decisions and measures implemented in the course of history. Questions addressed in the chapter examine different dimensions and complementarities of territorial planning and the environmental changes caused by alterations in the dynamics of the local landscape.

Keywords Environmental justice • Vulnerability • Curitiba • Baixada Santista • São Paulo • Rio de Janeiro • Flooding • Sea level rise

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_7,

7.1 Introduction

While the environmental justice movement has gathered much attention from academics and activists, it seems odd that little has been written on what, exactly, is meant by *the justice* of environmental justice. For the most part, the concept has been used to illustrate the fact that low-income communities face more environmental risks than more well-off communities; this is linked, of course, to the other injustices in economic and social conditions that disempowered communities face (Schlosberg 2003). Environmental justice activists and academics call for less risk overall, but especially in communities already unduly burdened. But there is more to the concept of environmental justice than just this distributional aspect, and, in fact, a focus solely on distribution is problematic (Schlosberg 2003).

Environmental justice is a well-established field of social activism that draws attention to and seeks ways to ameliorate such risks and injustices (Boone 2010). Environmental justice activists have also called for *recognition* of communities as unfairly affected and insist on being seen and heard by both a mainstream environmental movement and a government that has, for the most part, ignored them. Further, the movement has insisted on changes in the way environmental policy is made in order to bring in community *participation* in both the design and ongoing oversight of environmental risks (Schlosberg 2003).

Boone (2010) argues that sustainability research and practice can benefit from a closer reading of environmental justice. At the same time, environmental justice can draw on sustainability principles of systems thinking, anticipatory action, and environmental stewardship to strengthen its methods and approaches while broadening its science. Furthermore, vulnerability science can provide an important bridge between the two spheres of environmental justice and sustainability while also benefitting from the convergence of ideas, principles, and practices from these fields of inquiry (Boone 2010).

So the concept of environmental *justice* in political practice deals with more than simply distribution. But, again oddly, there has been no thorough attempt to try to define exactly what the justice in environmental justice means. I attempt an initial foray into the issue, starting with an examination of the conceptions of justice as equity, recognition, and participation in the political scenario (Schlosberg 2003).

Fraser (2003) and Young (1990) illustrate the theoretical discussions of justice by contemporary politics through to an examination of the social justice movement. Their argument is that the movement embodies a number of different frameworks of justice, even if it is not always explicit about those differences. At various times, justice is defined as equitable distribution, recognition, and participation. The movement demonstrates the possibility of employing these different notions of justice simultaneously in a comprehensive political project (Schlosberg 2003). According to Freeden (2000), there is an interesting interface between political theory and environmental thought. It is common among recent political philosophers to argue that justice is the first virtue of the state, but it is rare for them to add that well-being is the first virtue of the community.

Considering this context, in 1997, the World Bank posed questions such as the following: What is the relationship between poverty and the environment? Does poverty lead to environment damage? If so, in what ways? Do environmental problems exacerbate poverty? Much has been written about the relationship between poverty and the environment. The poor are thought to be both victims and agents of environmental damage. Environmental damage tends to affect the poor particularly severely for several reasons. First, they tend to rely heavily on fragile natural resources for their livelihood. Poor people, almost by definition, have few assets and no access to decent housing. Generally, they live in places with many environmental risks (World Bank 2000). The relationship between poverty, environmental justice, and environmental damage is likely to vary considerably from case to case, especially since a host of other important factors, including government policies, institutional structures, and the specific characteristics of the environmental and natural resources, are involved (World Bank 2000).

This chapter presents the results of research undertaken in Brazil on a number of aspects of the relationship between environmental degradation, vulnerability, and environmental justice. It reports findings on four case studies conducted in the Brazilian metropolitan areas of Curitiba, Baixada Santista, São Paulo, and Rio de Janeiro.

7.2 Landscape Changes and Population Dynamic: A Spatial-Temporal Analysis of Curitiba Between 1986 and 2000 (Case 1)

Curitiba, the capital of the state of Parana, is located in southern Brazil, with total area of 435.01 km^2. It has a humid subtropical climate with an average altitude of 934.6 m (IPEA 2000). According IBGE, Curitiba had 1.586.848 inhabitants in 2000 and 1.746.896 in 2010. For this case study, we selected three areas of the city (Fig. 7.1) and conducted surveys on vegetation, urbanization, total population, number of households, average people per household, and income ranges of the heads of the family, utilizing data from the censuses of 1980, 1991, and 2000.

The main objective of this study was to analyze the changes in vegetation cover in the city of Curitiba in the period from 1986 to 2002 through the use of the normalized difference vegetation index (NDVI) and combining that information with demographic data from the census.[1] The three selected regions were compared in terms of changes in patterns of vegetation cover, urbanization, and population characteristics. Landsat TM and ETM+ were used in order to identify the areas with vegetation and impervious surfaces; NDVI was used as an indicator of the presence of vegetation.

Our comparative analysis of the regions in terms of vegetation mapping variations was calculated in hectares over time. By applying this technique, it was possible to

[1] IBGE (Brazilian Institute of Geography and Statistics) and IPPUC (Institute of Urban Planning and Research of Curitiba).

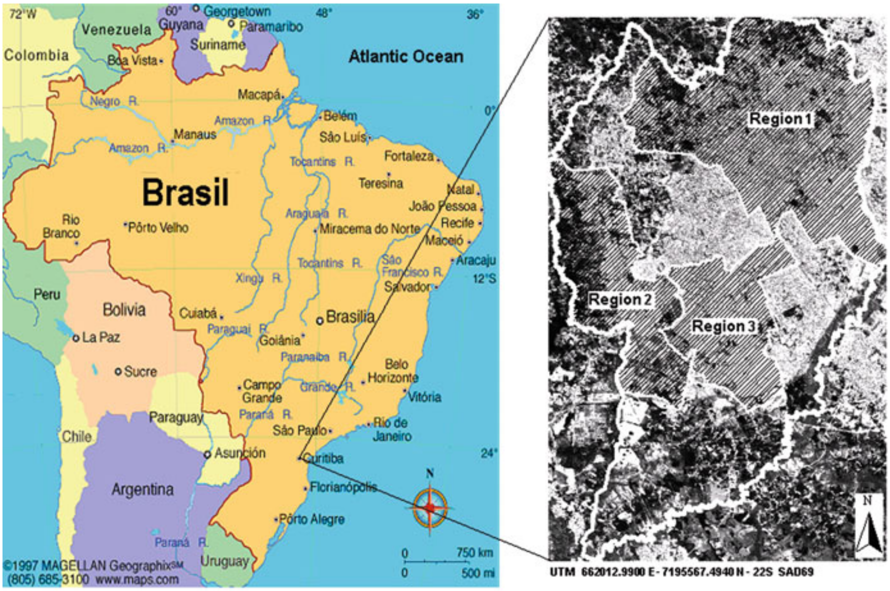

Fig. 7.1 Location of the city of Curitiba and the three regions studied

verify the importance of the size and distribution of vegetation areas in the characterization of urbanized and of semi-urbanized areas and to demonstrate how urban development and consequent population growth tend to compete with preexisting environmental conditions, such as areas of environmental protection and remaining forests.

The process involved changes in the composition, structure, and function of the landscape that occurred over a background of remaining natural spots altered by transformations of urban morphology. It is noteworthy that with the approval of the "Urban Plan"[2] of 1966, there was a fundamental change in the conformation of the city's growth, from a radial model to a linear model of urban expansion. Since then, the road transportation system and land use have been integrated and are utilized as instruments for urban planning (IPPUC 2002). From the 1980s, the urban space has been being shaped based on the structure designed by the "Urban Plan" through successive zoning, which gradually established the areas where the population density was appropriate due to the capacity of government power in providing necessary urban services, particularly appropriate public transportation (IPPUC 2002).

As a result of these urban policies, satellite imagery shows that between 1986 and 2002, there was an increase in urban concentration at about 68.33% and mainly along the structural city avenues. The series of urban measures discussed above, and implemented over the 1986–2002 period, led to an urbanization

[2] Urban Plan is a municipal law which establishes guidelines for the occupation of the city.

process of the city with a significant reduction of agricultural field and pasture areas and a significant increase of the physical urban area, about 4,138.42 ha. According to our surveys, during this period, there was an increase in vegetation areas, about 15.49%. This fact occurs as a result of urban policies such as the Municipal Law No. 6.819/86 of preservation and conservation of green areas in Curitiba (de Oliveira 2001). Other uses observed such as bare soil, mixed urbanization, exotic vegetation, and flood plain areas are in decline, primarily due to the urban growth process.

All regions experience a significant increase in urban area. In Region 1, we record an increase of 38.86% in the period analyzed, whereas in Region 2, this increase was only of 11.23%. Region 3 experienced an increase of 119.30% between 1986 and 1999 and 37.47% during 1999 and 2002, totaling an increase of about 156.77% between 1986 and 2002.

Region 1 has extremely diverse characteristics in terms of land use. However, it is interesting to note that these areas are integrated so that switching between different uses is smoothed by the presence of vegetation and lakes in the landscape. Region 2 is formed by industrial, transitional, services, and residential zones (environmental protection area of Passaúna); mixed-use zones; and some differentiated special sectors. Region 3 has peculiar characteristics such as lack of vegetation and areas without presence of water, such as reservoirs and lakes. This region is a combination of residential, services (larger), structural sectors and transition zones, including the "Linhão do Emprego",[3] and finally a small portion of the industrial zone.

Analyzing the design of the urban environment, we notice significant differences between the three regions with respect to spatial configuration and urban density. In terms of population, Region 2 had the largest increase (around 6.46% per year for 20 years). The other regions, 1 and 3, had lower growth rates – 1.14% per year and 2.57% per year for the period under study, respectively. In Region 1, there was a decrease in the population growth rate in the period between 1991 and 2000 (1.38–0.85% per year); as for the Region 3, there was an increase in the rate from 2.35% per year in the first period of 1980–1991 to 2.84% per year in the following period of 1991–2000. In absolute terms, the most populated region was Region 1, followed by Region 3 and Region 2. Furthermore, there was an increase in the number of households in all regions and a decrease in the average number of inhabitants per household over the years.

Regions also differ when compared through the lenses of vegetation and the NDVI images. In Region 1, for example, increases were registered in both the number of households and areas of vegetation. In Region 2, there was a growing rise of the urban area and of the number of households, and the vegetation areas decreased by −1.01% between 1999 and 2002. In Region 3, in turn, there was an increase of the number of households and a decrease in vegetation areas, coinciding with the expansion of the urban area.

[3] "Linhão do Emprego" sector (incentive program to generate employment and income in Curitiba).

We also associate income distribution for household heads with variation in urban growth and the vegetation areas. The data show that there has been an increase in incomes in the three regions for the number of household heads in the income range between 2 and 5 times the minimum wage (m.w.). In Region 1, the household heads in the income range of 2–5 minimum wages (m.w) increased substantially, followed by the growth in the number of household heads in the income ranges from 5 to 10 m.w., 10 to 20 m.w., and more than 20 m.w., respectively. The remaining ranges – between intervals of up to half a m.w., half m.w., and 1–2 m.w. suffered decreases, a fact revealing a more even distribution of income of the population of this region. At the same time, this increase in income was accompanied by the expansion of the urban area and by a significant increase in vegetation areas. Incentive policies put in place to encourage preservation of green areas were implemented, and a considerable number of urban parks were created, with a result of attracting population with higher income levels.

Region 2 had a significant increase in the number of household heads in the income range from 2 to 5 m.w. between 1991 and 2000. This increase was followed by the number of household heads with income ranges from 5 to 10 m.w. and 1–2 m.w., respectively. There was also a significant increase in the number of household heads with no income (27.39%). Thus, for Region 2, we find larger populations of lower income level, particularly compared with Region 1. Region 3 is very similar to Region 1 in terms of income range. The increase in number of household heads in the income range of 2 to 5 m.w. is followed by the increase in the ranges of 5 to 10 m.w., 10 to 20 m.w., and more than 20 m.w., respectively. It also observed an increase in the number of heads of family with no income in 2000, about 30.09% compared to the number observed in 1991. This increase in income was accompanied by the expansion of the urban area and by a decline in vegetation areas. Therefore, it is noted that during the consolidating process of the urban area, with the expansion of commercial and service areas, there has been an increase in the income level of this region, but at the expense of vegetation areas.

7.3 Socio-Environmental Vulnerability in Baixada Santista Metropolitan Region (Case 2)

The Baixada Santista Metropolitan Region, located on the southern coast of São Paulo (Fig. 7.2), was established in 1996 and comprises nine municipalities, Santos, São Vicente, Cubatão, Guarujá, Praia Grande, Mongaguá, Itanhaém, Peruíbe, and Bertioga, with a population of 1,713,581 people, according to 2008 estimates of the SEADE Foundation. The aim of our research was to identify spaces of socio-environmental vulnerability of population residing near environmentally protected areas. For this reason, we selected five cities within the region (Santos, São Vicente, Cubatão, Guarujá, and Praia Grande), focusing on their social and environmental vulnerability characteristics. The analysis of the socio-environmental

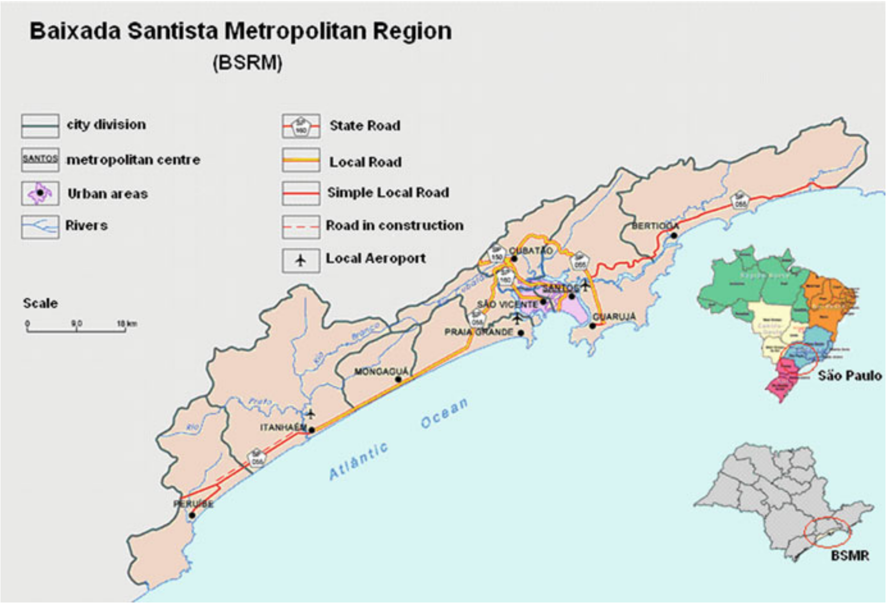

Fig. 7.2 Location of the Baixada Santista Metropolitan Region (Source: Cartography and Geographic Institute 2000)

vulnerability considered the social deprivation[4] and the environmental risks in these cities. Our objective was to further the understanding of the urbanization process and its consequences for environmental protection areas.

Social deprivation considerations imply the recognition that "new" forms of urban poverty involve an increasing spatial segregation and fewer opportunities of social mobility. In other words, the existing opportunity structures (offered by the state, the market, or the society in general) of certain areas are so limited that they often act as negative stimuli, promulgating mechanisms of social exclusion. It is noteworthy that this study deals with the social and environmental vulnerability of the region's specific areas, and such vulnerability is perceived as a sum of situations of social and environmental precariousness besides the poor socioeconomic conditions.

We explored the social and environmental vulnerability through social deprivation related to the lack of infrastructure (self-construction, street paving, supply, and sewerage conduits), basic services (continuous water and electricity supply and garbage collection), and the median household income per capita. On the environmental

[4] Besides the numerous disagreements referring to the definitions of urban poverty and the best ways to deal with this problem, the identification of the different demands that involve the poor populations in certain contexts is very complex as these populations are not always spatially concentrated within predetermined areas and rarely face the same deprivations. In addition, certain areas are susceptible to different social and environmental risks as a result of the historical legacy of several mistaken decisions.

vulnerability front, we considered risks including floods, landslides, contamination by waterborne diseases, and highway bushfires.

The expansion process of the region has been dynamic and diverse. Expansion has been driven by different motivations (industrial development, trade, and tourism among others). When an enterprise is directed and situated in a specific locality, often determined by governmental and regional economic interests, the poorest of the population seeking jobs follow in their location decisions in the surroundings of the businesses which are typically located close to highways, railroads, waterways, etc. As this population has no land access (for the purchase and the financing with the government's aid and support), many (state or municipal) government lands become illegally occupied. In general, this type of land occupation, lacking any spatial and ecological criteria, generates environmental degradation and endangers the poor population itself.

We investigate the population located in these (illegally occupied) risk areas in order to classify their vulnerability to risks. We integrated specific information provided by public agencies in the region, aiming at elaborating a diagnosis. Three topics were used for the analysis: (1) socioeconomic and landscape characteristics, (2) urbanization and spatial segregation, and (3) socio-environmental vulnerability.

The first topic links the economic, social, and environmental dynamics of the region. The second connects the access of specific population segments to facilities and services, the land availability for housing, and the profile of the illegal occupations in environmentally protected areas, within the context of public policy. The last topic has the objective to qualitatively detect the degree of social and environmental vulnerability of specific population groups that settled illegally in environmental protection areas within the metropolitan area. This integrated analysis enabled the identification of social and environmental vulnerability[5] by assigning classes (e.g., very high, high, medium, and low) with attributes that were differentially susceptible to specific risks across time.

The results showed that the demographic growth of the region beginning in Santos (a central node in the region) is based on a spatial logic that produces a dispersed land occupation through the incorporation of areas which are not yet urbanized, located beyond the Imigrantes, Pedro Taques, and Padre Manoel da Nobrega highways, absorbing progressively portions of neighboring municipalities, mainly toward the south. This dynamic occurs partly because of factors of population attraction[6] due to dispersion of productive activities of complex technology; Baixada Santista stands out in its participation in the state production through the

[5] The qualitative analysis of environmental susceptibility was based on surveys carried out based on PRIMAC (2005) and PRIMADH (2006) reports provided by AGEM (Metropolitan Agency from Baixada Santista), while qualitative analysis of the susceptibility of households was based on the analysis developed by Jakob and Cunha in 2007 – Jakob and Cunha published the "Atlas de vulnerabilidade da Baixada Santista: diversidades socioespaciais" http://www.nepo.unicamp.br/vulnerabilidade/atlas/atlas_santos/Atlas_Final/index.htm

[6] Thus, it is noteworthy to point out the importance of the economic dynamic and the labor market in Baixada Santista, which can be considered as an attractive factor for people who are looking for better life and work conditions. The surrounding municipalities fulfill an important role in the economic production of the region, despite not being exactly the population of the municipality that, in fact, occupies the jobs offered in their respective territories.

increasing deployment of metallurgical and petrochemical industries, port activities, and advanced tertiary sector of specialized and sophisticated services.

According to the city hall, the slums have been a major problem in Cubatão. Approximately 64,000 people (60% of the total population) lived in the slums in 2000. The land and rent prices of Cubatão drove a portion of their labor force employed in construction companies, as well as those with lower wages, to the cheaper land of Vicente de Carvalho (Guarujá), the continental zone of São Vicente, and Praia Grande. Housing interventions (single-family units and apartments) have provided an alternative for confronting the growing housing shortage. Several enterprises of this kind were established, like the Santos Housing Company, the Popular Home Foundation of the BNH, and the COHAB of Santos (AGEM 2006).

The lack of effort for conservation of natural areas in the production of urban space is visible in the region and can be found through the processes of environmental degradation and the several types of impacts related to urban activities. Wetlands and estuary water areas are contaminated by effluents from heavy industries located in Cubatão, and toxic gases released by these industries trigger the erosion in mountainous hillsides. In many areas, the deforestation of hills, plains, and wetlands for the expansion of the urban area is still visible (AGEM 2006).

One of the main motivations behind this process was the market economy that substituted the subsistence economy incorporating areas of the coastal zone for economic and social development. At the regional scale, the Baixada Santista has come to play roles which are complementary to the metropolis of São Paulo. The evolution of this process resulted in the worsening of predatory environmental practices causing problems related to deforestation, erosion, floods, landslides, and air and water pollution, affecting the whole region and the areas occupied by low-income population[7] in particular, with significant losses for the proper functioning of the entire metropolis.

According to the report of FINEP (2009), the proportion of the poor in Baixada Santista has increased in the 1990s from 10.0 to 13.7%. In 2000, the proportion of the poor in Baixada Santista was one of the highest (13.7%), very similar to the state of São Paulo (13.6%) and the São Paulo Metropolitan Region (13.4%). Social inequality, as measured by the Gini coefficient, was elevated in Baixada Santista (0.549) in 2000. Baixada Santista ranks similarly relatively to the state (0.593) and the other two metropolitan regions – São Paulo (0.544) and Campinas (0.523). But the ratio between the average incomes of the richest 10% and the poorest 40% (4.09) was less than that of the metropolitan regions of São Paulo (5.41) and Campinas (4.19) and also of the state of São Paulo (5.57). From the standpoint of

[7] The metropolitan area of Baixada Santista, with a population that concentrates 5.6% of the population of São Paulo state, was responsible for 3% of the state GDP (R$ 727 billion) in 2005. In 2000, Baixada Santista had a household income per capita (535.2) just below the one of the state and lower than those of the other two cities of São Paulo state, São Paulo (623.8) and Campinas (569, 89). Concerning the income concentration, the richest 20% of Baixada Santista concentrated 58.3% of income in 2000.

Table 7.1 Poverty, concentration and dissimilarity of the household income within Baixada Santista (1991–2000)

	% of poor (poverty)		Income concentration (of 20% richer)		Relation between average incomes of the richest 10% and the poorer 40%	
	1991	2000	1991	2000	1991	2000
Baixada Santista Metropolitan Region	11.9	13.6	55.8	64.9	3.5	4.1
Santos	5.3	5.5	68.9	58.8	8.6	13.3
Praia Grande	15.4	15.6	39.4	66.7	1.4	2.7
Bertioga		11.5		63.8		2.0
São Vicente	11.8	15.6	46.3	64.2	2.1	1.9
Peruibe	20.9	22.8	48.9	67.1	2.0	2.1
Guaruja	17.7	16.3	38.2	66.9	1.2	1.7
Monguagua	23.1	24.1	33.9	67.4	1.0	1.8
Itanhaém	20	22.3	44.5	70.5	1.4	1.4
Cubatão	16	16.7	33.6	69.8	0.8	0.9

Source: Censo Demográfico (1991, 2000). Microdados. Elaboração: Projeto Regiões Metropolitanas e Pólos Economicos do Estado de São Paulo NEPP/NEPO/FINEP

the municipalities of Baixada Santista, poverty, income concentration, and rich-to-poor ratios are reported in Table 7.1.

There exists a less obvious correlation between income and concentration. That is, those municipalities that have a higher per capita income are not necessarily those with the highest income concentration. Between 1991 and 2000, the income concentration has increased significantly in most cities. The income concentration among the richest 20% was only reduced in the city of Santos. The dissimilarity measured by the ratio between the average income of the richest 10% and the poorest 40% reveals that in 2000, the richest 10% had an average income which was equivalent to four average incomes of the poorest 40%. This ratio was exceeded only by the city of Santos.

In the 1990s, there was a slight increase in per capita household income in Baixada Santista, covering all nine municipalities. The concentration and dissimilarity increased significantly, and the proportion of poor people did not increase in the city of Guarujá only. The city of Santos deserves attention because it has the highest per capita income, above the average of the metropolis, but a negative growth rate of its population. The municipality exhibits the lowest proportion of poor people, but the greatest dissimilarity. The municipalities of Praia Grande, Peruíbe Mongaguá, and Itanhaém experienced simultaneously income and population growth. All these cities presented, however, an increase of its proportion of poor people, inequality, and income concentration.

In 2000, were observed that the poorest people still suffer from the lack of access to basic services, leading to a better quality of life. Concerning access to sanitation, the share of poorest 10% of the population is still experiencing unfavorable conditions. It seems evident when comparing the poorest 10% to the richer 10%, showing that the about 47% of the poor people have access to sanitation, while the richer people present values of over 90%, thus indicating a significant disparity between the income classes.

The city that shows better access conditions is Santos, which on average attains values of serving 94% of the population. The municipalities of Mongaguá, Itanhaém, Peruíbe, and Bertioga presented conditions of access to the very precarious general sewage network; a coordinated and planned action of the state and local governments is needed so that this population is granted access to a range of services, especially the general sewage networks, whose importance to the improvement of living conditions is essential. Moreover, according to the data of the SEADE Foundation (2003), the number of houses which are located in slums was quite significant in the cities of Cubatão, São Vicente, Guarujá, and Santos, precisely in those municipalities where the proportion of poor people was not that elevated compared with the municipalities of Mongaguá, Itanhaém, and Peruíbe. Most of the developed and apparently wealthier regions attract people who end up focusing on such settlements.[8]

The construction made by the dwellers themselves in lots purchased on the black market and divided among relatives and friends was propagated, and this phenomenon that might seem at first a temporary alternative was the generalized form of urban configuration. This market is considered illegal because it is a product of the transgression of housing lot makers operating in contradiction with the legal provisions of the land division. But these are exactly the contingencies of this "illegal city" that define the terms of a devastating urbanization pattern, which continues to advance. In general, they are public areas (protection) along railroads, roads, floodplain, riverbanks, streams (areas subject to floods), and steep slopes (subject to landslide risk).

The analysis showed that the environmental risks are primarily related to the location of the population (on hillsides, wetlands, etc.), while the precarious conditions are linked to situation of households (illegality), average per capita income, local infrastructure, and access to social services. The social susceptibility is more stressed exactly in cases where the risks are related to poor housing conditions. It is observed that in the case of São Vicente, households in poor conditions that are located in areas with a higher degree of environmental susceptibility had a higher socio-environmental vulnerability.

It occurs because only 88.7% of households have continuous supply of water, only 10% of the garbage is collected daily, 56.2% of the streets have no paved roads, and only 54.2% of sewage is connected to the general collection service. About 72.1% of households have no regular documentation of the property, most of them are located in public areas of government (illegal occupation), and the average per capita income is very low (less than a minimum wage).

[8] The periphery of the metropolitan area of Baixada Santista was built very poorly through the division of rural and environmental protection areas. Illegal urban lots marked the urban landscape and shaped the region's growth, especially toward the west (hillsides) and the south (coastal plains) of Baixada Santista (AGEM 2006).

In the city of Guarujá, the situation is similar, the permanent protection areas and wetlands were occupied, and the population is under risk of floods and contamination by waterborne diseases. The hillsides of Guarujá are another serious problem, since many households were settled in areas of uneven terrain and present characteristics of precarious and semi-precarious households. These households are located in public areas (illegally occupied), and due to terrain characteristics, deforestation (for occupancy) and households in precarious conditions, and to the place where they were settled, they are subject to the risk of landslides. The majority of people in Guarujá, who are in this situation, are also very poor, with average per capita income less than the minimum wage. Approximately 82% of households in these conditions have high socio-environmental vulnerability.

In the city of Praia Grande, the degree of socio-environmental vulnerability of the population located in the slums is very high. Despite the significantly lower volume of people in these conditions, when compared to other municipalities in the region, most of the 17,000 inhabitants (approximately 98%) were located in areas of permanent protection and wetlands and are subject to risks of floods and waterborne diseases. The rest, about 2% of the population, is under risk of landslides. Most areas had been illegally occupied, and the situation of households is precarious. Only the population living in the hillsides presents average per capita income of higher than the minimum wage.

In the city of Santos, the situation is somewhat different; many poor households have the basic infrastructure already installed (approximately 66%), significantly reducing the social susceptibility since this population has access conditions, public services, and supply (water, energy, etc.) more frequently. In addition, approximately 3% of households have no susceptibility to environmental risks. However, over 90% of households show a very high environmental susceptibility since most of them are located in protected areas, roads, and areas of wetlands, mainly subject to risks of floods, and about 4.5% of households are subject to risks of landslides (located in hill areas). Thus, the socio-environmental vulnerability in Santos is very high in households in precarious conditions, as shown in other districts of the region, but at the same time, there are some households in a less serious situation, whose socio-environmental vulnerability was considered low because they were not in any of these conditions.

The city of Cubatão has the worst conditions in the region. There are illegal occupations in areas of the conservation unit of Serra do Mar, environmental protection areas, and areas of highways, railroads, wetlands, and hillsides. The degree of environmental susceptibility is quite high with risks of landslides and floods in other areas, without mentioning the risks of contamination by waterborne diseases in the wetlands and fires near the roads, many accidents caused by truckloads linked to activity of the petrochemical center of Cubatão. Most poor households have precarious and semi-precarious conditions, and the average per capita income is less than a minimum wage; therefore, the socio-environmental vulnerability is quite high due to the high degree of social and environmental susceptibility.

7.4 Vulnerability to Floods in São Paulo Metropolitan Region: Human Dimensions, Conflicts, and Urban Landscape Changes (Case 3)

The aim of this study was to identify areas vulnerable to floods in the metropolitan area of São Paulo, composed of 39 municipalities with a population of 19.697.337 inhabitants (IBGE 2007). The city of São Paulo, regional center and capital of the state of São Paulo, has 10.886.518 inhabitants (IBGE 2007) and is one of the most affected.

In order to develop this study, a database containing information on the physical environment, land use, and urban expansion was organized. In this case, the information available is based on analysis performed by the application of remote sensing techniques and GIS (geographic information system). From the integration of these, information maps were generated concerning the identification of areas of vulnerability.

The metropolitan structure of São Paulo can be characterized by three basic principles – (a) accessibility: continuous urbanization, connected by highways from a radial and concentric spatial distribution called radio-concentric structure; (b) polarization: the presence of areas characterized as development poles, where over time the city of São Paulo (main pole of São Paulo Metropolitan Region) and the industrial hub of ABC region (smaller cities bordering on São Paulo) led to the merger of urban areas in its vicinity acting as a polarizer in a spatial process economically tied to secondary and tertiary activities; and (c) extensive urbanization: linked to a process of urban expansion and social differentiation with the proliferation of condominiums (closed high standard residential centers) distant from the center. Another dimension of this growth is the concentration of the low-income population in irregular settlements. In most cases, they occupy illegally in inappropriate areas, keeping themselves in precarious conditions and away from the downtown.

The spatial configuration of São Paulo Metropolitan Region had as one of the main factors the transport and road system. This system has always been very tied to the installation and deployment of industrial activity.[9] The establishment of major industries in the ABC and the high population growth of their municipalities have changed the dynamics of the urban region so that access to and communication with the capital have become essential for the development of economic activities (Francisconi 2004).

In 1950, the city of São Paulo achieved an urbanization rate of 88%. Since then, its growth has spread to neighboring municipalities, which have begun to grow rapidly,

[9] The industrial plants of the 1950s, notably the automobile ones, were settled on the banks of the highways. Old factories, located near the railways or in the central cities of São Paulo, were gradually transferred to new industrial areas along with road infrastructure (RODRIGUES 2004).

beginning the periphery process of the population toward locations more distant from the capital (SEABRA 2004). The Metropolitan Region of São Paulo has serious problems of social, political, and economic inequality. The precarious conditions of the metropolitan population gathers a group of closely related characteristics: lack of water supply, of sewerage, and street paving; illegal occupations; and insalubrities of several houses, among others. These characteristics are concentrated in the most popular areas, suburbs, and slums.

The urbanization process that occurred intensively from the 1960s has resulted in soil sealing, the removal of vegetation, disintegration of the soil's surface layers, and pollution of waterways and air, that is, the entire natural system has been altered. Added to this problem is the practice of piping of rivers and streams, often radically, altering the behavior and the natural regime of rivers and increasing floods. It has not solved the problem, since the region continued to grow without planning, demanding more measures to discipline and to contain the waters (Ross 2004).

Floods have caused devastation and economic losses, mainly in the rainy season – December to March – is invaluable when all socioeconomic interfaces involved are considered. Cutting the metropolis, the Tiete River is one of the most affected, causing to the region floods provoked by the overflowing of the river, which occurs during heavy rains. The mapping of areas susceptible to floods in São Paulo Metropolitan Region reveals more clearly the situation of the Alto Tiete basin (Fig. 7.1). The darker the areas (gray scale), the lower the degree of flooding risk. Therefore, the higher risk is located in the white areas, and the red points refer to flash flood spots. For the identification of these areas, data on land use, protected areas, hydrographic network, soil suitability, road system, and topography (digital terrain model) were incorporated, providing the identification of the most vulnerable areas, that is, those areas subject to damage from these events.

Over the years, the vegetation cover was giving space to an extensive urban area, chaotically implemented, occupying bottom areas of valleys of the main streams, as Tietê, Tamanduateí, and Pinheiros rivers, and more recently several smaller tributaries as Aricanduva, Cabuçu de Cima e de Baixo, Pirajuçara, and others (RIBEIRO 2004).

To further aggravate the environmental conditions of the basin, many of these streams begin to serve as a manner of dilution of domestic and industrial effluents. This fact, coupled with inadequate provision of urban solid waste, has brought serious consequences during the flood events (ROSS 2004).

According to DAEE,[10] the stretch of the Tietê River which crosses the city of São Paulo had alterations in its leakage conditions. In its natural condition, the river and its important tributaries, such as Pinheiros and Tamanduateí, showed morphology characterized by meanders, which indicated the low declivities of its thalwegs and

[10] Plano Diretor de Macrodrenagem da bacia do Alto Tietê [Master Plano of Macrodrainage of the Tietê River Basin] (DAEE 2009).

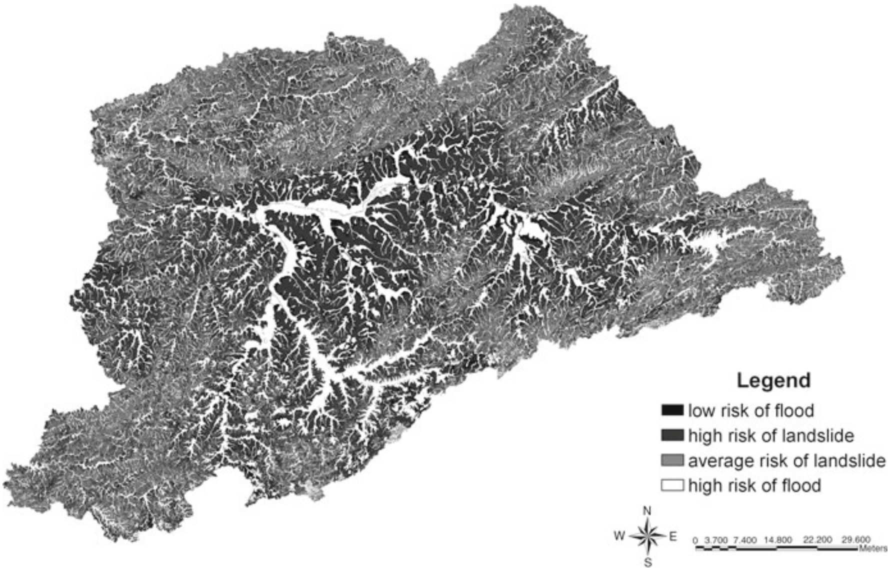

Fig. 7.3 Mapping of areas susceptible to floods in the São Paulo Metropolitan Region

therefore difficulty for the leakage of flood seasons, creating large areas of flood (Fig. 7.3), called larger margins.

The region where these changes are felt most intensely, with a remarkable index of urban occupation, superior to 80%, corresponds to the stretch of the Tietê river basin between the dams of Penha and Edgard de Souza. However, the process of urbanization is already disfiguring the rest of the basin[11] as well, advancing toward the tributaries and also occupying its headwaters and hillsides.

Successive adjustments and plumbing were done for confinement, restriction, and partitioning of the rivers' course. It enabled urbanization to be even closer to the river channels. The urbanization invaded, through bordering constructions as the roads and buildings, the so-called the largest river margins, space that should have been preserved for seasonal floods (DAEE 2009).

Its main tributaries, while encompassed by urban expansion, also suffered this type of change, mainly due to works carried out in their margins. The increasing urbanization of the basin made the project flows of the channel of the Tietê River, and the problems have spread in the basins of Tamanduateí, Aricanduva, Ribeirão dos Meninos, and Pirajussara, among others.

[11] The areas classified as unoccupied refer to the location of parks, protected areas, watershed areas, reservoirs, anthropic fields, and agricultural and rural areas. Such areas may be subject to processes of occupation in the future due to the illegal market of land or even to changes in the master plans of cities (the transformation of rural areas into urban areas).

7.5 The Impacts of Sea Level Rise Associated with Heavy Rains in the Plains and Hillsides of Rio de Janeiro City (Case 4)

Preceded only by São Paulo in the hierarchy of Brazilian metropolis, Rio de Janeiro is one of the largest and most complex urban agglomerations of the Brazilian coastal zone, with an estimated population of 11.812.482 inhabitants. The city of Rio de Janeiro, hub of the metropolitan area, has about 6.093.472 inhabitants (PNAD 2008). The aim of this study was to identify vulnerable areas related to the increase in sea level associated with heavy rainfall events. In this case, the information available relies on the analysis performed through the application of remote sensing techniques on Landsat satellite imagery and GIS.

According to Netto (2007), "the landscape of Rio de Janeiro of the 21st century depicts the historical process of city growth at a site marked by mountain massifs surrounded by the fluvial-marine plains, sandbanks and coastal lagoons." From the mid-twentieth century, the city underwent a process of accelerated growth, "expanding its formal and informal constructions in the lowlands and on hillsides replacing the ecosystems of the Atlantic Forest." The advance of forest degradation "has resulted in increasing instability of the hillsides, providing an increase in frequency and magnitude of landslides that converge to the drainage channels, natural or artificial." According to the researcher, "the increase of sediment supply during and after heavy rainfall has been responsible for the increased frequency and magnitude of floods, enhancing the socio-environmental disasters during the rainy season, i.e., summer."

In general, urban areas in the municipality of Rio de Janeiro have expanded intensively in areas poorly suited for urban use, such as wetlands, steep hillsides, outcrops and rocky shores, and estuarine channels, rivers, and forest remnants. The interventions are developed on time, appropriating the environmental units in an isolated manner, ignoring the concept of system (MACEDO 2007). The main natural threats triggered by atmospheric phenomena in Rio de Janeiro are floods and mass movements (landslides). These processes occur in the rainy season and are more frequent and severe as the triggering events are stronger and prolonged. Through a survey using satellite images (Landsat 5 and Landsat 7 ETM +), it was possible to observe the process of urban expansion in the city of Rio de Janeiro between 2001 and 2009. One may observe an edge effect around the majority of consolidated urban areas in 2001 and the confirmation of the trend of expansion to the west of the city in 2009.

According to Muehe and Neves (2008), a series of impacts caused by climate change[12] can affect the city of Rio de Janeiro, being manifested in "changes in morphology and dynamics of beaches, water quality in lagoons, bays and estuaries,

[12] According to Muehe and Neves (2008), initially one must consider that "the main causes of sea level rise are thermal expansion of ocean water (eustatic rise) and the melting of continental glaciers." Then, it is necessary to emphasize that "the level of oceans varies from year to year, in cycles of about 20–30 years, with variations from 10 to 50 cm in width, depending on location and time."

balance of the hillsides, and in the survival of mangroves and other plant species. The land use in the past, under other environmental conditions, may not respond adequately to new meteorological and oceanographic conditions."

For purposes of urban planning and decision-making processes, more important than a gradual increase is the occurrence of variations associated with meteorological tide. On the values of the meteorological tide, says Muehe (2010), there are the "astronomical tides," which "can reach amplitude of about 1.30 m, ranging in magnitude for different points of Guanabara Bay, Sepetiba Bay and ocean beaches. In the open sea the tidal wave would be little affected by climate changes or by a rise of the average level of about 30 cm to 1 m. In the inner parts of bays and of the estuaries that flow into those bays, however, the rise in sea level would make a tidal wave hit higher points reversals in the direction of rivers leakage."

Rosman et al. (2007) mention that despite attempts, the simulation of the sea level rise is very questionable, precisely because it is a dynamic system that varies according to the astronomical tides and mainly to meteorological ones. Moreover, Mendonça and Silva (2008) point out that "the coastal geomorphology of the Rio de Janeiro is diversified and extremely modified by many factors of natural origin and human interventions. The coastal areas have dynamic characteristics and own specificities that will certainly respond in different ways to the sea level rise."

Through the digital terrain model generated from interpolation methods, we have identified the lower areas of the municipality that would be more susceptible to the sea level rise (associated to heavy rain) (Fig. 7.4). The orange areas correspond to the sea level rise considering the meteorological tide. The red areas represent the increase in sea level considering the meteorological and astronomical tides (assuming the most critical situation). The areas in red and orange are the most affected and basically correspond to locations in the east, part of the south, and of the west of the city. The most affected portions of the east would be the harbor and Governor's Island. In the south, which is constituted by a vast area that spreads from Jacarepagua Lagoon to Barra da Tijuca, the Aterro do Flamengo appears as the most affected area. It is observed that there is in these regions the Galeão and Santos Dumont Airports and Marina da Gloria, as well as the whole cove (small bay) of Flamengo and Botafogo. The west part of the city brings together the regions of Bangu, Campo Grande, Santa Cruz, and Guaratiba (in Sepetiba Bay).

In population terms, the total number of people affected (located at an average altitude of up to 1.50 m) would be about 60,320, or more specifically, in the west, this number would remain around 5,412, in the south would be 35,557, and in the east around 20,000. In the average altitude of up to 3 m, there are 402,849 people. The low areas of lagoons and inlets grounded, as well as terraces or fluvial marine plains, already represent areas at flood risk due to proximity of groundwater, to the outcrop of groundwater, and to the consequent difficulty of drainage.

Due to geomorphologic, geological, and hydrological characteristics present in Rio de Janeiro City and to human interventions on their water courses and to the diversity of use and occupation of their land, there may be a variety of risks related to flood events. The urban occupation interferes in this process in that it leads to their aggravation and that its occurrence shall constitute a risk to the population,

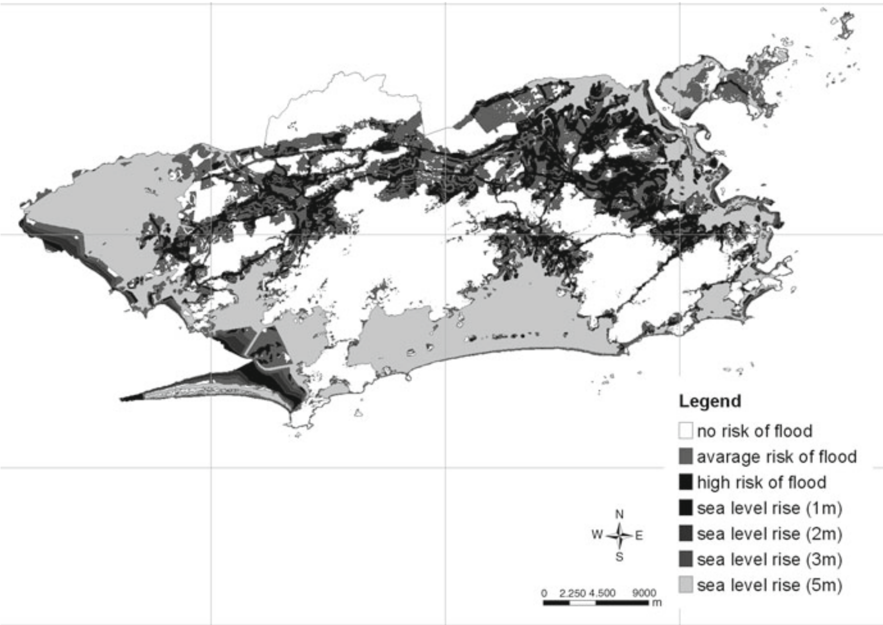

Fig. 7.4 Identification of areas affected by sea level rise associated to heavy rain

their improvements, and economic activities. There is some consensus among scientists about the possibility of heavy rainfall and floods to become more frequent (Marengo et al. 2009), unpredictable, and of magnitude more severe with climate changes (Egler 2008). The origin of the floods is related to heavy rains. Shortly, when the rain reaches the surface, a portion of the rain infiltrates the soil and the other portion is drained into natural lines and strands of the terrain (relief), flowing into the lower areas and ultimately to the sea.

According to Azevedo (2007), urban drainage system of the city of Rio de Janeiro has not been able to prevent floods due to some failures arising from faulty design, lack of maintenance, obsolescence of equipment, and rapid urban growth. Urbanization can cause damage to the drainage system in various ways. Moreover, the removal of vegetation (for urbanization) has made possible the increase of surface leakage and maximum output volume, increasing the leakage velocity, increasing the vulnerability of land to erosive processes, and leading to the silting of canals and galleries.[13]

As noted, urban growth is a factor that contributes substantially to the occurrence of problems related to floods, since one of its consequences is the expansion of impervious[14] areas. Most of the occupation of the city of Rio de Janeiro focuses on

[13] The increase of the degree of sealing of land has generated an increase in surface leakage and maximum output volume, decrease of retention, and increase of surface leakage velocity. The implantation of artificial drainage network provides a significant increase in velocity of leakage and peaks of flood leakage, and the occupation of riverside areas make the population exposed to periodic inundations in areas naturally flooded (floodplain).

coastal plains situated between sea and mountains. This relief configuration gives rise to a huge amount of micro and small hydrographic basins subject to flood by convective (more commonly) and front rainfall, also observing a strong influence of orographic rainfall[15] in the areas near hillsides. The regular and irregular occupation (by poor people) of the coastal plain was gradually being consolidated, significantly increasing the population periodically affected by floods and impeding even the performance of cleanup actions, dredging, and maintenance of gutter and of channelizing work.

The construction of drainage networks, widely adopted solution in general as a solution to drainage problems, also contributes to the aggravation of floods in lower areas when transferring the volumes of upstream to downstream in a speed faster than the natural leakage. The accumulation of solid waste in rivers, besides the release of untreated sewage, also contributes to the aggravation of floods, causing siltation of the plumbing and clogging of the hydraulic elements that are part of the drainage system. Moreover, these factors deteriorate the water quality of rivers and can cause contamination of the local population with waterborne diseases (e.g., leptospirosis).

Besides the occupation of marginal areas of water courses, the process of urbanization in Rio de Janeiro was also unable to prevent the occupation of their hillsides. Currently, a considerable area of the hillsides of Rio is occupied by slums or low vegetation, replacing the Atlantic Forest that occupied most of this area in the past. With that, the rain that now falls on the slums downs quickly, like a flash flood, and accumulates in the lower areas of the city affected more intensely. The vulnerability of the hillsides of Rio de Janeiro tends to increase once relevant factor in control of the stability of hillsides is threatened by deforestation (i.e., forest cover in advanced stage of succession). The current state of vulnerability of the domain of the hillsides and the growing instability of the soil will increase the velocity of leakage during periods of heavy rainfall and consequently the frequency and magnitude of floods in lowland areas adjacent to uplands. The hillside field is cut by numerous drainage basins, which attach to coastal massifs a pattern of channels of significant relevance.

7.6 Discussion

The case of Curitiba has illustrated how policies can potentially open up spaces for environmental injustice. Despite the effort to integrate the activities of conservation and preservation with the demands for expansion of the city, urban areas are still advancing on remaining vegetation areas. This occupation reflects two processes: the search for lower-cost land without any environmental amenity by a low-income population (as noted for Regions 2 and 3) and the search for areas with more appropriate environmental amenity and safety conditions by social groups with

[14] The increase of the degree of waterproofing, according to studies conducted by Leopold et al. (1964), shows that the flow of flood peak in urbanized basin can become six times larger than the peak of this same basin under natural conditions.

[15] It occurs when a mass of moisture-laden air rises when finding an elevation of the relief, like a mountain, causing rain.

higher income, as noted in the case of Region 1. It demonstrates that the principles of equity and procedural justice can be severely compromised at the local level, once it is necessary to give emphasis on strategies of community consultation, empowerment, and activity within a framework of sustainable resource use and development. Urban planning without a participatory process can be less effective in terms of protecting both people and nature areas.

In short, the analysis performed on the socio-environmental vulnerability of Baixada Santista indicated a scenario quite varied from the point of illegal settlements in the cities studied. It was possible to identify sites with more services and public facilities, as in the case of Santos, and others where access to these services and equipment is sparse or completely inadequate to cover basic needs, especially in the case of Praia Grande and, in a lesser extent, in other cities. This set of elements reinforced the importance of looking closely to the situations of socio-environmental vulnerability in urban areas, insofar as the context may have negative or positive impact on the situations of socioeconomic fragility in existing households. Accumulation of environmental risk situations in certain areas, for example, is an aspect that may contribute to the reproduction cycle of poverty, the aggravation of conditions of privation, and environmental injustice.

Another limitation of environmental justice can be verified in São Paulo Metropolitan Region and Rio de Janeiro where the importance of the biophysical environment has neglected or underplayed as part of the urban dynamic that lead to injustice. The flooding risks in both cases show that the environmental justice has been constrained by a focus on reaction rather than proactive decisions. In Rio de Janeiro, this situation is aggravated by sea level rise. This reflects the historical trajectory of urbanization process that has resulted in soil sealing, the removal of vegetation, disintegration of the soil's surface layers, pollution of waterways, and between other landscape degradation forms. The majority of vulnerable areas are concentrated in the illegal settlements (in poor suburbs and slums), and the environmental injustice can be identified through the lack of urban infrastructure and ecosystem service benefits to the poorest population.

Despite concerns of reducing harm to vulnerable populations, justice is rarely considered next to the discussions of urban planning, adaptive capacity, or resilience. An expanded notion of vulnerability, however, can incorporate principles and practices of ecological urban design and environmental justice. Similarly, a systemic approach to understanding the relationship between people and the environment can be considered. It means that there are thresholds of harm that can be avoided with a proper understanding of exposure, sensitivity, and adaptive capacity of both social and biophysical systems in order to promote environmental justice.

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Chapter 8
Environmental Inequality in São Paulo City: An Analysis of Differential Exposure of Social Groups to Situations of Environmental Risk

Humberto P.F. Alves and Ricardo Ojima

Abstract This chapter aims to operationalize the concept of environmental inequality, measuring the association between disadvantaged socioeconomic conditions and greater exposure to environmental risks through the use of geoprocessing methodologies. We offer a case study of the city of São Paulo, Brazil, analyzing situations of environmental inequality, based on the level of risk exposure of different social groups. Our methodology is based on the construction of a geographical information system through which the digital layers of environmental risk areas are overlapped with the digital meshes of the census sectors of the 1991 and 2000 IBGE demographic censuses. The results show that people living in risky areas are in a much worse socioeconomic condition than those living outside them. Moreover, in recent years there has been an increase in the level of environmental inequality in the city of São Paulo.

Keywords Environmental injustice • São Paulo City • Geographic information system • Risk

8.1 Introduction

One important dimension of *environmental injustice* is the differential exposure of individuals and social groups to environmental security and risk. This implies that individuals are unequal from the perspective of (a) amenities, defined as the access

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_8,

to environmental benefits such as clean air, green areas (parks, open space, etc.), and clean water, and (b) security, primarily the exposure to environmental risks such as floods, landslides, and pollution. In this way, factors as residential location, dwelling quality, and means of transportation available can limit the access to environm ental benefits and increase the exposure to environmental risks (Torres 1997; Pastor et al. 2001).

The argument of environmental inequality emerges from the hypothesis that a number of social groups such as minorities and low-income groups are more sensitive and vulnerable to certain types of environmental risks (floods, landslides, etc.). The environmental risk areas (close to landfills or subjected to floods and collapses) are very often the only places accessible (or affordable) to low-income populations. In turn, they end up building their dwellings in hazardous conditions while simultaneously tackling other environmental, sanitation, and health problems (Torres 2000; Jacobi 1995).

The expressions "*environmental inequality*" and "*environmental (in)justice*" are often used interchangeably, which clearly propounds the closeness of these two concepts. We broadly define *environmental injustice* as an iniquity resulting from the uneven distribution of environmental externalities which have a disproportionate effect on minority communities and low-income groups. Consequently, *environmental justice* (or environmental equity) can be described as the reduction or "correction" of environmental injustices (Most et al. 2004; Holifield 2001).

The concept of environmental justice was born of social movements in the United States of America in the late 1970s prompted by Blacks, Natives, Latinos, and low-income populations living close to landfills, radioactive dumps, and highly polluting industries. In that country, the scope of research concerning environmental justice is very extensive and has shown increasing scrutiny of a variety of issues in the past 30 years. This field of study has had a positive influence on current environmental policies in North America (Bullard 1990; Cutter 1995).

In view of these elements, the general objective of this chapter is to make the concept of *environmental inequality* operational so as to identify and characterize its recent incidence in the metropolis of São Paulo, Brazil. To achieve this, social and environmental indicators and geoprocessing methodologies were utilized to pinpoint and measure the existence of a link between disadvantaged socioeconomic conditions and greater exposure to environmental risk. Further, an attempt was made to verify whether the current trend of environmental inequality is increasing in São Paulo City.

To accomplish this objective, we have analyzed the exposure level of different social groups to situations of environmental risk in São Paulo City, doing a comparative study of the demographic and socioeconomic dynamics between the populations living in areas of environmental risk and those living elsewhere. Our main hypothesis was that environmental risks are unevenly distributed among different social groups. Thus, our empirical research shows that a quantitative spatially explicit approach should be an important part of the endeavor to advance the research on the themes of environmental inequality and environmental justice (Acselrad et al. 2004).

8.2 Urban Sprawl, Environmental Inequality, and Vulnerability to Climate Change in São Paulo Metropolis: A Brief Review of the Literature

The second half of the twentieth century marked the acceleration of urbanization process in Brazil. Among the consequences of this process, the following can be highlighted: the formation of metropolitan areas, the vertical growth and densification of already-urbanized areas, and urban sprawl to peripheral and peri-urban areas (Reis and Tanaka 2007). Brazilian urban sprawl is different from medium- and high-income urban sprawl processes that take place in developed countries such as the United States of America. In Brazil, the suburbs are considered the place of residence of low-income families. In the Brazilian literature, they are usually called the "periphery" (*periferia*), which represents both the location of those areas and the social condition of the population living there. Therefore, the peripheral urban growth pattern typical of Brazilian urban agglomerations and metropolitan areas has been formed by the continuous production of residential land developments directed toward the low-income sectors of the population. The outcome of this process has been the creation of enormous extensions of urban peripheries – incomplete urbanized areas without basic urban infrastructure, social services, and public amenities. This peripheral urban growth pattern has serious environmental consequences in terms of transportation and pollution as well. On the one hand, peri-urban housing means longer journeys and an increase in air pollution; on the other, poor peripheral and peri-urban areas are also characterized by lack of sanitation and the consequent pollution of rivers and streams (Bonduki and Rolnik 1982; Torres 2002, 2005; Costa and Monte-Mor 2002).

In fact, a significant part of the literature on urbanization in Brazil shows that this urban sprawl to the periphery is related to the demand for housing in places with low land prices, which results in a greater number of precarious settlements such as slums and shantytowns in areas without any urban infrastructure and exposed to environmental degradation and risks. Thus, in Brazilian metropolitan areas, the dynamics of urbanization in the peripheral regions, through predatory and illegal occupation of urban land, mean that most urban areas of risk and environmental protection such as the margin banks of watercourses are threatened by poor use of low-income housing due to a total lack of housing alternatives, either through the private market or through social policies. There is, therefore, a tendency for lower-income groups to reside in areas with poor sanitation and in situations of risk and environmental degradation (e.g., near watercourses, landfills, or steep slopes) (Smolka 1993; Maricato 1996, 2003).

In the metropolitan region of São Paulo, a strong process of urban sprawl to peripheral areas has occurred since the 1970s, with the incorporation of a vast area to the urban perimeter of the metropolis. In this sense, a considerable population growth and horizontal expansion of the most distant peripheral and peri-urban areas of São Paulo metropolis have increased the poverty and the social and environmental vulnerability and inequality within these peripheries. Indeed, the level of social and environmental problems in certain peripheral areas of São Paulo is appalling, the lowest socioeconomic indicators overlapping spatially (and socially) with the risk of floods and landslides, a heavily polluted environment, and highly inefficient public services. In some parts of the periphery of São Paulo, there is, therefore, a high concentration of negative indicators which indicate the presence of "hot spots" of socio-environmental vulnerability and inequality, revealing the existence of a form of periphery on the periphery (Marcondes 1999; Meyer et al. 2004; Torres and Marques 2001; Marques and Torres 2005).

It should be noted that these major processes of urban transformation that peripheral areas of the metropolis of São Paulo have undergone in the last decades have made it clear that there is growing interweavement and overlap between social and environmental problems. This overlap or accumulation of socioeconomic and environmental risks and problems in certain places represents a challenge to public policies as they are in most cases compartmentalized according to fields of sector intervention. Thus, the great number of situations in which appalling social and health conditions and environmental risks and conflicts overlap requires analytical approaches that address the relationships and interactions between the social and environmental dimensions of urbanization (Alves 2006; Alves and Torres 2006).

A concept that could be used to analyze these relationships is that of *environmental inequality*, which can be defined as the differential exposure of individuals and social groups to amenities and environmental risks. Another way to conceive of environmental inequality is to relate it to other forms of inequality present in society such as those between races, sexes, and income groups. In this case, individuals are environmentally unequal *because* they are dissimilar in other ways. From this perspective, the notion of environmental inequality conveys the sense of overlapping or simultaneous exposure to more than one form of inequality in addition to the environmental one, such as social inequality, economic inequality, residential inequality, and race inequality (Torres 1997).

Taschner (2000) develops systematic reflections on what she has identified as "slums in situations of environmental risk." It is a formulation very close to environmental inequality since it refers to certain particularly marginalized population groups (slum dwellers) also affected by environmental risks. In this regard, it is worth mentioning that in the last decades, there have been a strong expansion and peripherization of the slums in São Paulo City, which usually occupy public areas, often located in valley bottoms and edges of streams, at risk of flooding, or on hillsides with steep slopes, highly prone to erosion, generating situations of environmental inequality and risk (Torres and Marques 2001, 2002) (see Fig. 8.1).

In the context of climate change, in the beginning of this century and in the coming decades, with scenarios of increasing intensity and frequency of extreme events such as storms, hurricanes, floods, and droughts, situations of vulnerability and environmental inequality will rise dramatically in cities and metropolitan areas like São Paulo (Huq et al. 2007; Ojima and Alves 2007). The Brazilian report *Megacity Vulnerability to Climate Change: the Metropolitan Region of São Paulo* has made projections which indicate that the urban stain in 2030 will be approximately 38% higher than the current one if the pattern of expansion of this metropolis keeps pace with historical

Fig. 8.1 Example of a shantytown in São Paulo City located in valley bottom at the edge of stream, at risk of flooding (Photo by Luciana Travassos)

records, with floods and landslides posing greater risks to the population as a whole, especially to the poorest groups. According to the report, if this process of urban growth takes place, more than 20% of the projected urban area of São Paulo metropolis for 2030 will be susceptible to flooding. And about 11% of this projected metropolitan area for 2030 may be at risk of landslides (Nobre et al. 2010).

Social groups of greater socioeconomic vulnerability are often more vulnerable to events such as floods, landslides, droughts, and lack of water availability. These events are being intensified with the arrival of climate change and tend to be more frequent and intense as those changes are more profound. Thus, the vulnerability of disadvantaged groups in relation to the impacts of climate change is also present in the debate on environmental justice. Under the name of *climate justice*, this concept is used to refer to disparities in terms of the impacts suffered and responsibilities for the causes and effects of climate change. The growing perception about the inequality of impacts with regard to those of climate change has acted as a catalyst for the international movement for climate justice. This movement assumes that those who are the least responsible for emissions of greenhouse gases (GHGs) are the ones who will suffer the most from the impacts of climate change. To minimize these problems, they propose the use of initiatives and policies that deal with the ethical dimensions of human rights concerning climate change so as to reduce the vulnerability of social groups disproportionately affected by climate change (Milanez and Fonseca 2011; Roberts and Parks 2009; Shepard and Corbin-Mark 2009).

Thus, in São Paulo metropolis, the projection models of urban expansion estimated for 2030 show that the risk scenarios and their vulnerability to floods, storms, and landslides will worsen in the context of climate change. These estimates are also based on the supposition that a growing number of people will be living in precarious settlements on lands within the floodplains and drainage trenches with steep hills on the outskirts of the city. However, if floods and landslides are expected to affect the metropolitan population as a whole, it will affect with greater intensity and severity the poorest and most vulnerable families, who will be living in precarious settlements in areas of higher environmental risk, particularly the slum and shantytown population. That is why environmental (and climate) justice issues will be an important part of the urban dynamics of the metropolis of São Paulo in the coming years and decades (Nobre et al. 2010; Milanez and Fonseca 2011).

8.3 Methodology

The methodology is based on the construction of a geographical information system (GIS), through which the digital cartographies (layers) of the environmental risk areas (near watercourses and with high declivities) are overlapped with a digital mesh of the census sectors of the 1991 and 2000 IBGE (Brazilian Institute of Geography and Statistics) demographic censuses of São Paulo City.

We began by selecting the environmental risk areas – places very close to watercourses (less than 50 m) and/or with steep slopes (more than 30%) as these features make them vulnerable to floods and mudflows. The choice of the proximity of less than 50 m from watercourses as a parameter to define a high environmental risk was based on two main criteria. Firstly, we intended to identify the people actually living in areas close to watercourses, who are in fact at risk of flooding and direct contact with waterborne diseases. According to the literature on the subject, this situation is typical of most of the slums of São Paulo as they occupy the floodplains of rivers and streams (valley bottoms), which are unsuitable for settlement due to geotechnical or environmental reasons (Taschner 2000; Alves 2006). Secondly, we used the regulation on areas of permanent preservation (APP) of the Brazilian Forest Code as our point of reference, which establishes environmental protection strips along rivers and any watercourse.[1] Taking into account that terrains with the predominance of slopes higher than 30% are quite susceptible to processes of destabilization and mudslides (Ogura et al. 2004; Lopes et al. 2007), for the purposes of this study, we also considered areas with slopes higher than 30% in the municipality of São Paulo as environmental risk areas.

The city of São Paulo was then stratified according to three main types of regions which correspond to the three large social groups living in the city. "Poor regions"

[1] Under the Brazilian Forest Code, human settlements are not allowed along any watercourses, on bank strips whose width is (1) 30 m for streams less than 10 m wide or (2) 50 m for streams that are 10–50 m wide. Since the vast majority of watercourses in the municipality of São Paulo are less than 50 m wide, we consider that the proximity of 50 m is adequate to represent the areas with environmental restrictions on their occupation.

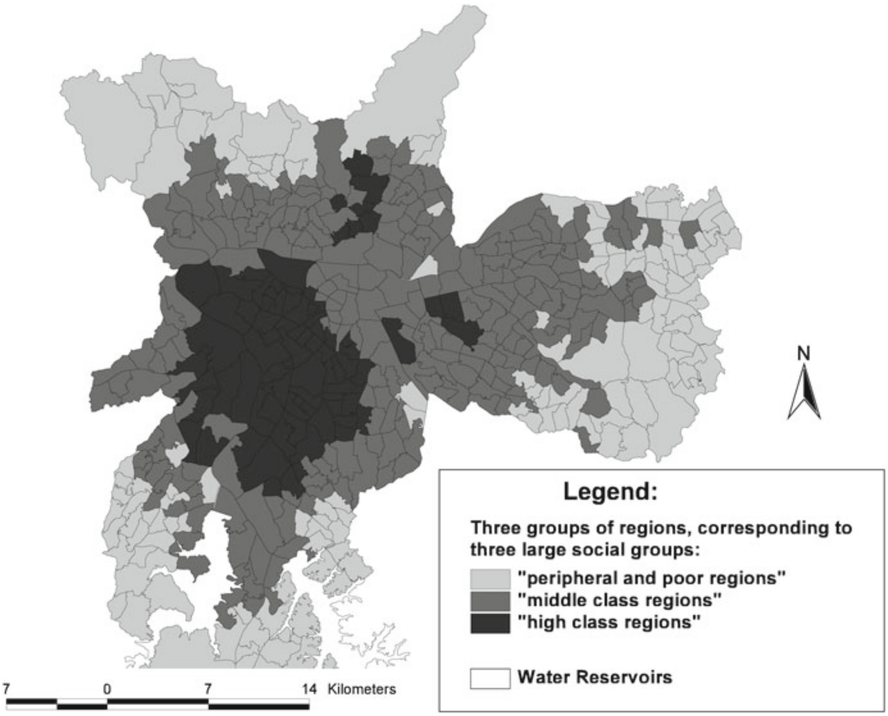

Fig. 8.2 Three groups of regions corresponding to three social groups living in São Paulo City (Sources: IBGE demographic census of 2000; Marques 2005)

consist of areas with predominant low-income population, "middle-class regions" have a predominantly middle-income population, and "high-class regions," with a predominance of high-income population (see Fig. 8.2). The three regions were defined by Marques (2005), based on factorial and cluster multivariate analyses from a broad set of socioeconomic and demographic variables of the 2000 IBGE demographic census.

Finally, the population size, the demographic growth, and the socioeconomic characteristics of the residents *inside* and *outside* the environmental risk areas were assessed, for both census dates (1991 and 2000). These estimates were done for the city as a whole and for each region delimited by the spatial distribution of the social groups of São Paulo City (poor, middle class, and high class). Our findings are the result of an overlaying geoprocessing operation. An estimate of the resident population in 1991 and 2000 living in areas of environmental risk can be attained by superimposing (and imputing) the demographic and socioeconomic data of the census sectors in proportion to their participation in the territories of the risky areas.[2]

[2] Therefore, more than just a tool to visualize the cartographic overlapping, the overlaying operation helps to estimate for the environmental risk areas (in this case, those near to watercourses and/or with high slope) information such as the population and the number of residences that [before] were accounted for by the census sectors. When using the *overlay*, we assume that the distribution of the population is homogeneous along the area concerning the population information, in this case the census sector.

8.4 Increase in Environmental Inequality for São Paulo: Differential Population Growvth of the Social Groups Exposed to Situations of Environmental Risk

We started by analyzing the evolution of the population living in areas of environmental risk between 1991 and 2000 in order to verify whether environmental inequality has increased in recent times within São Paulo City. To do that, the population living in areas of environmental risk, that is, very close to watercourses (less than 50 m) and/or with high slope (more than 30%), in 1991 and 2000 was assessed using the "*overlay*" approach.

The estimates obtained for 1991 show a population of 1.6 million living in areas of environmental risk in São Paulo, corresponding to 16.5% of the total population of the city – 9.6 million people that year. In 2000, while the population of the city reached 10.4 million, the number of people living in areas of environmental risk raised to almost 2 million, accounting for 19.1% of its inhabitants (Table 8.1). Thus, one out of five inhabitants of São Paulo City lives in areas posing environmental risks, that is, in localities in close proximity to watercourses (risk of floods and exposure to illnesses transmitted through the water) and/or in those with high slope (risk of mudflow).

The increase in the proportion of people in areas of environmental risk within the total population results from the fact that while these areas of risk had a population growth rate of 2.5% a year, in the remaining areas it barely attained 0.5% a year, between 1991 and 2000 (Table 8.2). However, it is important to note that most of the environmental risk areas are concentrated in the poor and peripheral regions of the city. Therefore, by observing the population growth in the set of risky areas, it is not possible to discern whether that is a direct result of the environmental characteristics of these areas or from the fact that this type of area is concentrated in poor and peripheral regions of the city.

Taking this into consideration and in order to avoid the effect of peripheral population growth on population increase data in areas of environmental risk [aggregated for the city as a whole], comparative analyses between areas of risk and non-risk were performed for each of the three groups of regions: "poor regions," with a predominant low-income population; "middle-class regions," with a predominant middle-income population; and "high-class regions," with a predominant high-income population (Marques 2005). For each region, population size estimates within the areas of risk and non-risk in both census dates (1991 and 2000) were assessed. Afterward, the population growth rates for 1991 and 2000 were measured (Tables 8.1 and 8.2). Figure 8.3 shows the spatial distribution of the environmental risk areas (near to watercourses and with high declivities) and of the three groups of regions (poor, middle class, and high class) for São Paulo City.

In the set of "poor regions" (where low-income population predominates), the proportion of people living in environmental risk areas reaches an impressive 28.3% for 2000, which represents a population contingent of 1.1 million people living in areas with cumulative overlapping of poverty and environmental risk. As for the "middle-class

Table 8.1 Size and participation of the population, by regions, in relation to areas of environmental risk and non-risk

		1991				2000		
Areas	Total of the city	Poor regions	Middle-class regions	High-class regions	Total of the city	Poor regions	Middle-class regions	High-class regions
Population								
Total	9,644,122	2,799,606	5,198,973	1,644,240	10,434,252	3,873,362	5,074,262	1,486,628
Areas of risk	1,593,591	717,645	712,089	163,855	1,991,716	1,095,621	749,052	147,043
Non-risk areas	8,050,531	2,081,961	4,486,884	1,480,385	8,442,536	2,777,741	4,325,210	1,339,585
Participation (%)								
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Areas of risk	16.52	25.63	13.70	9.97	19.09	28.29	14.76	9.89
Non-risk areas	83.48	74.37	86.30	90.03	80.91	71.71	85.24	90.11

Sources: IBGE demographic censuses of 1991 and 2000; CEM-Cebrap, cartographies of environmental risk areas; and Marques (2005)
City of São Paulo – 1991–2000

Table 8.2 Geometrical rates of annual population growth, by regions, in relation to areas of environmental risk and non-risk

Areas	Total of the city (%)	Poor regions	Middle-class regions	High-class regions
Areas of environmental risk	2.51	4.81	0.56	−1.20
Areas of environmental non-risk	0.53	3.26	−0.41	−1.10
Total	0.88	3.67	−0.27	−1.11

Sources: IBGE demographic censuses of 1991 and 2000; CEM-Cebrap, cartographies of environmental risk areas; and Marques (2005)
City of São Paulo – 1991/2000

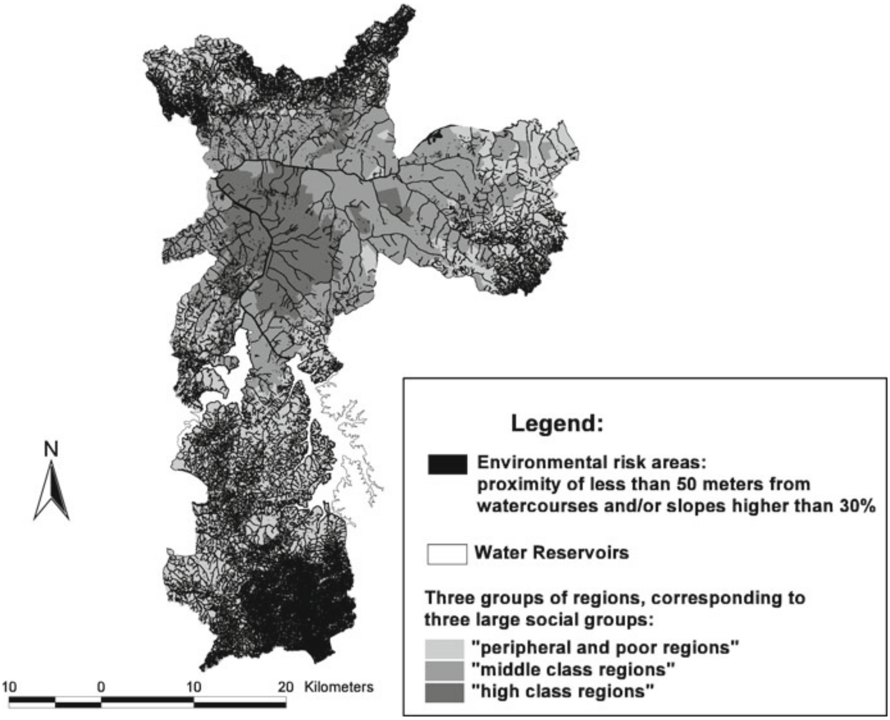

Fig. 8.3 Spatial distribution of the environmental risk areas (near to watercourses and with high slopes) and of the three groups of regions (poor, middle class, and high class) in the city of São Paulo (Sources: IBGE demographic census of 2000; CEM-Cebrap, cartographies of environmental risk areas; Marques 2005)

regions" and "high-class regions," the proportions of population living in environmental risk areas are much lower, 14.8 and 9.9%, respectively (Table 8.1).

The results also show that for the three groups of regions, the population grew more rapidly in the areas of environmental risk (near to watercourses and/or with high declivities), between 1991 and 2000. Likewise, in the peripheral and poor regions, the population in areas of risk grew 4.8% a year, while the population outside these areas recorded a much lower rate (3.3% a year). In the middle-class regions, the number of residents in areas of environmental risk increased 0.6% a year, while in the non-risk areas the population decreased 0.4% a year in the 1991–2000 period. In the high-class regions, the population decreased at very similar rates in the areas of risk and non-risk (Table 8.2). As the high-class regions (risk areas included) had negative population growth and the environmental risk areas in the middle-class regions increased nearly 0.6% a year, the largest part of the population rise in the environmental risk areas of São Paulo occurred in peripheral and poor regions.

Therefore, while the population of the poor and peripheral regions grows at a moderate to high pace, the population increases dramatically in the environmental risk areas within these suburbs. What is more, the environmental risk areas in the suburbs and peripheries are in general less urbanized than the areas of risk located in central and wealthy regions. In other words, the peripheral localities close to watercourses and/or with high slopes, very often situated in less urbanized areas (and consequently more prone to environmental risks) showed explosive growth rates in São Paulo City during the 1990s.

8.5 Association Between Disadvantaged Socioeconomic Condition and Environmental Risk in São Paulo

Now that we have established the rise in environmental inequality for São Paulo City,[3] we can continue to explore the hypothesis about the existence of a positive association between disadvantaged socioeconomic conditions and greater exposure to environmental risk. As previously mentioned, one of the hypotheses on environmental inequality infers that environmental risks are unevenly distributed as are income and access to public services. To test the hypothesis that there is a positive association between disadvantaged socioeconomic conditions and larger exposure to environmental risk, we present below a comparative analysis of the socioeconomic and demographic indicators between the areas of environmental risk and non-risk for the city of São Paulo.

First we compared the indicators of sanitation in the areas of environmental risk and non-risk for the city of São Paulo in 2000. With regard to the coverage of the water supply network and of garbage collection we show, in Table 8.3, that the differences of coverage between the areas of environmental risk (near to watercourses and/or with high declivities) and those of non-risk (distant from watercourses and with low declivities) are small. These small differences between the areas of environmental risk and non-risk are due to the fact that the water supply and garbage collection coverage are provided nearly everywhere in the city of São Paulo, even in the poor and peripheral areas. However, the same cannot be said in regard to

[3] As observed, the increase in environmental inequality was demonstrated by verifying that the areas where the population of São Paulo is growing more significantly are simultaneously areas of environmental risk, as well as peripheral and poor areas.

Table 8.3 Comparison of the socioeconomic and demographic indicators, by area of environmental risk and non-risk

Indicators	Areas of environmental risk	Areas of environmental non-risk	Total of the city
Water network coverage (%)	96.90	99.00	98.62
Sewage network coverage (%)	71.94	90.58	87.23
Garbage collection (%)	97.76	99.51	99.20
Illiterate heads of household (%)	8.95	5.19	5.86
Low schooling heads of household (until 3 years in school, including the ones without) (%)	24.09	16.41	17.78
Heads of household with college degree (%)	10.03	19.25	17.60
Average number of years of schooling of the heads of household	6.44	7.94	7.67
0–3 minimum wages heads of household income (%)	51.84	37.48	40.06
More than 5 minimum wages heads of household income (%)	17.08	21.80	20.95
Average income of heads of household (in reais)	888.24	1421.05	1325.43
Average income of heads of household (in minimum wages)	5.88	9.41	8.78
0–4-year-old population (%)	10.31	7.98	8.43
0–14-year-old population (%)	29.23	23.81	24.84
More than 65-year-old population (%)	4.10	6.97	6.42
Population living in subnormal sectors (%)	21.60	5.68	8.72

Sources: IBGE demographic census of 2000 and CEM-Cebrap, cartographies of environmental risk areas
City of São Paulo – 2000

sewer coverage, showing huge inequalities between the two types of area. In the non-risk areas (distant from watercourses and with low declivities), 90.6% of the domiciles were connected to the sewer system, while for those in environmental risk areas (near to watercourses and/or with high declivities), the proportion was close to 71.9%, indicating minute sewer coverage in many areas next to watercourses and/or with high slope (Table 8.3).[4]

The indicators of income are also very dissimilar between the areas of environmental risk and non-risk in the city of São Paulo. In Table 8.3, one can verify that the monthly average income for the heads of household living in environmental risk areas corresponds to 888 *reais* (5.9 Brazilian minimum wage) in 2000, compared with those in areas of non-risk who earned 1,421 *reais* (9.4 Brazilian

[4] In reality, the sewer coverage percentage is lower in the areas close to watercourses than in those with high declivities, with 70.7 and 73.1%, respectively.

minimum wage). Also, the proportion of heads of household with a low income (lower than three minimum wages, including the ones without incomes) was around 37.5% for the group in the non-risk areas, compared with 51.8% for those in environmental risk areas.

Levels of education can also be seen in Table 8.3. In 2000, the proportion of heads of household with low schooling (includes those with 3 years of schooling or less) reached 24.1% in the areas of environmental risk versus 16.4% for those living in environmental non-risk areas. By the same token, the heads of household with college degrees corresponded to 19.3% in non-risk areas versus 10% in the environmental risk area. In light of this, the average number of completed school years by the heads of household varied from 6.4 years to 7.9 years, for risk and non-risk areas, respectively.

Concerning the age structure of the population, it is observed that the areas of environmental risk (near watercourses and/or with high declivities) had, in 2000, a significantly superior concentration of children and youths than those of non-risk areas. Thus, while the non-risk areas barely recorded an 8% proportion of 0–4-year-olds, the areas of environmental risk achieved 10.3%. The 0–14-year-old group corresponded to 23.8 and 29.2% in non-risk and risk areas, respectively. The proportion of elders (65 years old or more) also varied significantly between the areas of environmental risk (4.1%) and non-risk (7.0%). It should be noted that 0–4-year-old children are the most prone to waterborne diseases, which reinforces the state of vulnerability and environmental inequality in risky areas at the edge of watercourses.

By comparing the percentage of inhabitants living in subnormal sectors (shantytown areas, according to IBGE definition), it can be seen that in the areas of non-risk, only 5.7% of the population lived in subnormal sectors, while in the environmental risk areas, the percentage of population living in shantytowns was much higher, reaching a whopping 21.6% (Table 8.3).

In brief, the results for São Paulo City show that the residents in areas of environmental risk possess inferior socioeconomic conditions and that there is a greater concentration of children and youths. Therefore, these results validate the hypothesis about the existence of a positive connection between disadvantaged socioeconomic conditions and greater exposure to environmental risk.

8.6 Discussion of the Results

In this chapter, we attempted to build an empirically operational concept of environmental inequality by means of geoprocessing methodologies for identification and characterization of environmental inequality situations in the city of São Paulo. The hypothesis was that environmental risks are unevenly distributed among different social groups. Hence, the objective was to test for the existence of an association between disadvantaged socioeconomic conditions and greater exposure to environmental risks. Moreover, it was the goal of this chapter to assess whether environmental inequality has increased within the city in recent times.

The results show that the areas where the population of São Paulo grew significantly, between 1991 and 2000, were both areas of environmental risk and peripheral and poor areas. This phenomenon indicates an increase in environmental inequality in the city in recent years. Subsequently, we reflect on some decisive factors that may account for the high growth rate of the population living in areas of environmental risk (near watercourses and/or with high declivities) in São Paulo, particularly for peripheral and poor regions.

The first factor that explains the growth of the city and of the metropolitan region of São Paulo continues to be its horizontal expansion and urban sprawl. The suburbs and peripheries of the city and metropolitan region, especially in south, east, and north extremes, encompass a very dense watercourse network due to the topographical and hydrological emplacement of its river basins. Furthermore, the peripheral areas also cover mountainous regions, such as the Cantareira mountain range, in the north of the city. This basically means that higher population growth rates in these areas translate into a larger population increase in areas of environmental risk (Torres et al. 2007).

The second aspect is connected with the dynamics of urban land occupation. As the urban mesh of the city, including the more consolidated peripheral regions, is already occupied to a great extent, it is reasonable to assume that the continuity of the horizontal growth implies the occupation of less appropriate areas for human settlements, such as the ones near watercourses and those with high declivities. These areas of environmental risk are very frequently the only ones accessible to the low-income population because they are public and/or preserved areas (invaded) or very devaluated in the market due to the risk and lack of urban infrastructure (Alves 2006).

A third factor is related to the significant growth of the population living in slums and shantytowns. The association between shantytowns and areas of environmental risk, not only those places at the edge of watercourses but also the ones with high declivities, is evident in the literature on the subject (Taschner 2000).

In summary, the natural conditions of the areas where population growth has occurred, the exhaustion of areas available for horizontal urban growth, and the increase in shantytown populations are major factors in the substantial increase in the population in areas of environmental risk seen recently in the city of São Paulo (see Figs. 8.4 and 8.5).

Moreover, the results also suggest that the socioeconomic conditions of the population living in environmental risk areas (near watercourses and with high declivities) are much worse compared with populations in non-risk areas. All the indicators that were considered pointed toward worst socioeconomic conditions in areas of environmental risk. Among these indicators, there are significant differences for access to public sanitation and percentage of people residing in shantytowns.

Two key factors may explain the association between exposure to environmental risk and precarious socioeconomic conditions. The first reason for that is related to the fact that the areas of environmental risk are often the only places accessible to people of lower income as they are highly devalued in the land markets due to their characteristics of risk and lack of urban infrastructure. The second reason is that these areas are considered unsuitable for urban settlements by the city's planning department and environmental laws due to environmental risks or because they are

Fig. 8.4 Example of urban sprawl to peripheral environmental risk areas in São Paulo City: precarious settlements at the edge of Guarapiranga Water Reservoir (Photo by Luciana Travassos)

Fig. 8.5 Shantytown located at environmental risk area (edge of watercourse) in the city of São Paulo (Photo by Luciana Travassos)

Fig. 8.6 Slum area located at the edge of watercourse: example of association between exposure to environmental risk and precarious socioeconomic conditions in São Paulo City (Photo by Luciana Travassos)

areas of environment preservation. In most cases, these public or private areas are usually invaded by precarious settlements, which turn into shantytowns and slum areas (see Figs. 8.6 and 8.7).

Therefore, the results of the analyses confirm the hypothesis that a positive correlation exists between greater exposure to environmental risk and disadvantaged socioeconomic conditions. In addition to the validation of this hypothesis, this analysis allowed us to evaluate the environmental inequality phenomenon in São Paulo both in quantitative and spatial terms by identifying the most exposed social groups (to environmental risk), their location, and the number of people involved.

8.7 Concluding Remarks

We conclude that the high concentration of social and environmental problems in the risky and in the poor and peripheral areas of São Paulo metropolis makes them totally inappropriate to new urban settlements, particularly the poor and precarious ones such as slums and shantytowns, which ironically insist on going to those areas. However, the low-income families and immigrants, who reside or move into these areas, are not to blame. In fact, these poor families are the first ones to be affected

Fig. 8.7 Slum area located on hillside with steep slope: another example of association between exposure to environmental risk and precarious socioeconomic conditions in São Paulo City (Photo by Luciana Travassos)

by the degradation of the environment, not only through their exposure to environmental risks and hazards but also because their places of residence are less protected in terms of infrastructure and/or construction patterns that could avoid such hazards, which reinforces the high degree of socio-environmental vulnerability and inequality of these families (Torres et al. 2007).

A key question raised by the results of this work is, therefore, how to change these processes of socio-environmental vulnerability and inequality triggered by uncontrolled urban sprawl to peripheral and peri-urban areas. Although we do not have a complete answer, we believe that only a significant change in the dynamics of land and housing markets and public policies on land use and housing would allow a more sustainable pattern of land use and occupation in São Paulo metropolis.

In this sense, the detection of some specific patterns of spatial coexistence and overlapping of poverty and environmental risk situations present in metropolitan areas like the city of São Paulo require the development of detailed analyses such as those allowed by the geographical information systems, using extremely disaggregated spatial units of analysis such as the demographic census sectors. Therefore, this work could possibly provide an insight into situations of environmental inequality in São Paulo City and other metropolitan areas, hence yielding subsidies for the planning of social and environmental public policies such as housing and sanitation.

Finally, this study intends to contribute to the development of methodologies and quantitative analysis for empirical studies on the issue of inequality and vulnerability to climate change. We believe that the development of these methodologies should be an important part of the research agenda around the theme of human dimensions of global environmental change. In this sense, there is a series of methodological, empirical, and conceptual challenges for the construction of a research agenda on environmental justice and vulnerability to climate change.

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Chapter 9
Climate Change Adaptation and Socio-ecological Justice in Chile's Metropolitan Areas: The Role of Spatial Planning Instruments

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Abstract Chile has increased its institutional response to climate change adaptation in recent years. However, the focus remains on partial or fragmented responses based on "productivist-infrastructural" principles. This chapter argues that there are fundamental issues relating to socio-ecological justice that have to be addressed in order to move toward more effective adaptation planning. An important link is also made to existing spatial planning instruments and their role in reducing risks, by confronting situations of social vulnerability. This orientation is essential in order to increase resilience to climate change or "climate proofing." This chapter uses the cases of Antofagasta, Valparaiso metropolitan area, and Greater Concepción to examine these underlying issues in terms of different climate change impacts.

Keywords Social vulnerability • Socio-ecological justice • Climate proofing • Climate-adaptation planning • Clean Development Mechanism

9.1 Introduction: Adaptation as a Socio-ecological Challenge

The 2006 CONAMA and University of Chile study of expected climate change impacts in Chile, based on the PRECIS methodology (Universidad de Chile 2006), has generated responses by consecutive governments and private sector organizations. The responses have been focused principally on the threats to the export sector, agribusiness in particular, as can be seen in the National Climate Change Strategy of 2006 and the National Action Plan of 2008 (Gobierno de Chile 2006; CONAMA

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Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_9,

2008). However, with over 80% of the population living in urban areas in Chile, there are only two urban-oriented objectives in the plan: coastal zone protection and incorporation of adaptation themes in regulatory plans. Currently, these are framed in vague terms, and the goal is that they will be fleshed out by 2012 when the plan should be fully operationalized.

This chapter focuses on the latter of these objectives, the role of regulatory plans, and other planning instruments in the process of building urban resilience to climate change. In particular, two lines of argument will be pursued. The first is that vulnerability to climate change is currently insufficiently understood in terms of the planning process. Responses are principally short-term programmatic initiatives that do not take a longer-term perspective on climate change. The second is that socio-ecological justice is central to the discussion of climate change, its impacts, and potential responses. This point is important to make since the reaction to date, in the Chilean context, has been a concern primarily of the risks to the export-driven economy. While this economic focus, with issues such as water availability for mining and impacts on agriculture due to water stress and temperature changes, is relevant for the Chilean response and clearly involves social vulnerability issues, the focus on the social dimensions of climate change impacts has been weak. As such, factors of vulnerability that in many cases relate back to structural development issues remain unexplored. This chapter will draw out this discussion by referring to the processes of climate change adaptation as a socio-ecological justice challenge. The argument is that metropolitan vulnerability to climate change is sustained by unresolved, pre-existing distribution and equity issues and that a re-centering of the climate change agenda is required to confront these structural obstacles to effective adaptation.

Although there is an instrumental orientation to this chapter, focusing on the existing and potential roles of spatial planning instruments, the argument is based on a political ecology perspective that questions the prioritization of different themes on the national climate change agenda. The consequent focus is on the vulnerability of different social groups to climate change and how this vulnerability is expressed in regulatory plans and other instruments and in regulated and unregulated localization and resource use decisions.

Political ecology, as a framework for analysis, focuses on the sociopolitical dimensions of environmental change rather than the objects of nature themselves (see Forsyth 2003; Robbins 2004). The focus is therefore on the actors involved and their motivations, as opposed to the biophysical processes or ecosystems per se. Consequently, it is an understanding of political action, with associated discourses and scientific constructions, that is imperative for understanding ecological change and the production of nature. The multi-scalar implications (panarchy) associated with this political action are also critical from a political ecology perspective, hence the relevance to climate change.

This chapter is organized in four sections, followed by a return to the main argument of the need for a re-centering of the agenda. The first section provides an introduction to the recent development of a climate change agenda in Chile and the relevance for urban areas. The second section highlights the need to understand climate change adaptation and vulnerability issues as a socio-ecological justice challenge, understanding resilience building as part and parcel of a wider development agenda as opposed to a "silo approach" to climate change. The third section focuses on the role of spatial planning instruments and how these are critical to mainstreaming climate change adaptation into existing governmental structures, as opposed to the addition of climate-specific programs in isolation. In the case of climate change adaptation, it is argued that the most effective way of dealing with socio-ecological justice issues is through the same instruments that guide housing development, green space development, transport networks, services provision, and local strategic visioning. In this sense, climate change adaptation becomes part of the sustainable urban development agenda in all its complexity (Campbell 1996; Barton 2006), rather than merely an "add-on." The fourth section deals with specific cases of socio-ecological justice in terms of vulnerability to climate change that are evident in each of the cities mentioned. The cases of Antofagasta, the Valparaiso metropolitan area, and Greater Concepción provide the experiences that reveal the complexity of urban vulnerability to climate change in the country and the socio-ecological roots that account for this complexity. The conclusions are made in terms of a critical appraisal of the central argument of this chapter: That resilience to climate change (effectively the capacity to maintain systems and livelihoods in the face of climate change effects) equates to a reduction of social vulnerability that in turn is a reflection of structural constraints to socio-ecological justice. The effective use of spatial planning instruments offers a path to reducing some of these constraints.

9.2 The Economic Imperative: The Chilean Response to Climate Change

The Chilean response to climate change was slow to emerge despite the creation of a National Climate Change Committee in 1996. It was not until 2006 that a national strategy was developed, giving rise to a National Action Plan presented at COP 14 in Poznan (December 2008). For most of this time, the logic associated with climate change was the fulfillment of obligations within international circles, on the one hand, and the opportunities generated by the Clean Development Mechanism, on the other. The development of a national emissions inventory, and the encouragement of projects to be certified as CDM, took precedence over other issues. The fact that the Foreign Affairs Ministry took the lead in climate change affairs during this time was emblematic of this social construction of climate change issues in the country.

The constitution of different national-level bodies charged with climate change management also indicated the particular concerns relating to these issues. With physical scientists, meteorologists, the navy, and other technical personnel, climate change was presented as a global rather than local affair, with mitigation being the principal concern (Barton 2009). Factors relating to adaptation were not present, although vulnerability issues were presented from an early point in response to climate change reporting instruments. In one of the first reports, Chile met 7 of 9 vulnerability conditions of Article 4.8 of the Framework Convention (CONAMA 2008). However, the particular vulnerability focus was on risks to the productive sectors, agriculture in particular.

It has only been during the 2008–2011 period that there has been a slow increase in discussion on two key themes of climate change adaptation: social vulnerability and urban transformations. Nevertheless, the nascent interest in these themes still reveals that there is a lack of research and orientation from the principal authorities, in particular the Ministry of Environment (established in 2010 and now the lead agency on climate change). The economic imperative associated with likely changes in productive sectors has been the principal concern of national actors involved in climate change affairs (see Vicuña et al. 2009). The agricultural sector has been particularly proactive along these lines, setting up its own advisory committee on climate change (in May 2009) and commissioning diverse studies on potential impacts in different river basins and particular crop varieties (through the National Institute for Agricultural Research – INIA) (AGRIMED, Universidad de Chile 2008). While these transformations in agricultural production, also water availability for mining and forestry, are indirectly vital for social welfare, there are other issues that have remained relatively hidden on the climate change agenda to date.

The urban population of Chile is almost 90 % of the national total. This urban population is concentrated in the Santiago metropolitan area in particular (approximately 40 % of the national total), also in other large cities such as Antofagasta, and conurbations such as the Valparaiso metropolitan area and Greater Concepción. Although the rate of urban growth declined during the later twentieth century, these hubs of national development are central for understanding not only mitigation (associated with transport and energy demand) but also adaptation. It is in these centers that impacts relating to energy restrictions and pricing, water stress, heat stress, extreme events, and costs of basic goods and services, e.g., food security, will be experienced most intensely. However, there has been a relative absence of baseline information relating to potential urban experiences of climate change and resilience building for adaptation and in particular how different social groups will be affected in different ways according to location, income, and other variables.

It is not only the focus on urban areas, the largest in particular due to the concentrations of population in centers further up the urban hierarchy, that is important but also the fact that these centers house large numbers of low-income residents who will be subject to different physical stresses and price stresses associated with climate change (Satterthwaite 2006; Satterthwaite et al. 2007). While it is important not to diminish the impacts on rural inhabitants, with their close links to the agricultural, forestry, and fisheries sectors, in total numbers, the urban population outweighs them considerably in the Chilean context. It is also important to differentiate between the stresses that will be faced by these different populations due to their local settings. Given the focus to date on the agricultural sector and potential impacts, the rural population is being taken into account to some extent (indirectly and implicitly), more so than the urban majority.

The lack of consideration of urban populations, compounded by a relative lack of social vulnerability analysis (beyond the economic vulnerability signaled in earlier national submissions), has persisted to some extent into the National Action Plan. The plan can be characterized as having a strong focus on mitigation and the productive sectors, organized as it is in terms of productive silos: agriculture, forestry, mining, and fisheries, as well as the more transversal themes such as energy, water, biodiversity, and health. Since the plan merely prioritizes certain key issues that should be developed fully and operationalized in 2012, there is little detail and the particular mechanisms to be used are unclear. Nevertheless, the ways in which urban areas and social vulnerability are incorporated into the plan are limited.

Of particular interest is the attention paid to the incorporation of climate change considerations into regulatory plans, also the need for better coordination between urban planning instruments and information generated by other services in coastal areas and along rivers (CONAMA 2008). Factors such as landslides and other physical risks are brought out in the focus on the health sector, where other issues such as the potential increase in new and old diseases, e.g., the increase in hanta virus cases or the reintroduction of yellow fever, dengue, and malaria. This category of environmental health is where the plan comes closest to engaging with social vulnerability issues within urban settings. What is interesting however is how the principal government services charged with managing social vulnerability and planning issues, such as the Ministry of Housing and Urbanism, and municipal and regional governments are not identified as lead institutions in adaptation design and implementation; apart from the Ministry of Environment, it is other sectoral institutions that are designated this role, e.g., Ministries of Agriculture, Public Works and Health, and the Undersecretariat of Fisheries. As a consequence, the focus and prioritization of issues on the national climate change agenda is also a product of a particular construction of impacts and sectors, defined by the set of actors who have been most influential to date. This has given rise to a strong productivist-infrastructural orientation to potential measures (effectively a concern for commercial impacts associated with infrastructural responses, e.g., sea defenses, increased irrigation reservoir capacity), obscuring many other structural challenges that climate change impacts expose. Perhaps the most important of these is how different social groups will be affected by these impacts and how vulnerability can be reduced.

9.3 Old Wine, New Bottles: Climate Change Vulnerability as Socio-ecological Justice

While the climate change debate unfurled and possible approaches were considered in Chile, it was evident that the opportunities from the Clean Development Mechanism (CDM) were prioritized. The means for the private sector to reduce costs on certain projects, e.g., landfill, appeared as a highly attractive option; 76 projects were approved between July 2003 and January 2011 (MMA 2011). This focus on Kyoto mitigation benefits was then complemented by highlighting appropriate adaptation for productive sectors, with considerable public support for addressing potential impacts in these sectors. Vulnerability to climate change was cloaked in the same language as vulnerability for the export-oriented economy. What was notably absent was a prioritization of social issues and how the population at large would be influenced by climate change. This in turn produced a very low public consciousness of climate change issues, with no real awareness of how these would influence livelihoods at local levels in terms of heat stress, water stress, disease risk and other environmental health issues.

Rather than the technical approach that characterized the dominant productivist-infrastructural view of the impacts and responses, what has been missing is an engagement with the social dimensions, from equity considerations to education and local preparedness. While the former approach is based on "hard" responses from coastal defense infrastructure to irrigation reservoirs, the latter requires "soft" planning considerations based on the human dimensions of these changes and evident interactions with other local development issues; this same situation is also common in other natural hazard responses (Barton 2010).

Within the National Adaptation Plan, it is only in the health sector that adaptation considerations have made some headway in this respect. Risks of landslides, of flooding, of heat stress, of disease exposure, and particularly of changing prices for basic goods (e.g., basic foodstuffs) and services (e.g., energy and services) are not universal risks in the sense that not all people are subject to them to an equal degree. This is due to the dimension of vulnerability of the group that is exposed and the resilience of that group in terms of its ability to militate against the scale of the impact and recover swiftly. Nevertheless, the objectives for the action plan in these fields are not sufficiently clear. The principal areas outlined for capacity building are as follows: identification of vulnerable zones and their inhabitants, monitoring of environmental health variables, the interactions with other sectors to understand better the health impacts of climate change, the incorporation of risk management in issues of climate-related health impacts, and adapting monitoring systems and contingency plans.

What further work in any of these lines of inquiry exposes is that they tend to return to conventional development considerations relating to socioeconomic groups, their levels of vulnerability in a broad sense (including access to work and incomes, goods, and services), their localization, and the quality of their homes and immediate surroundings. In other words, the debate returns to more established considerations relating to socio-ecological justice: the old bottles. These are the same considerations highlighted by Jane Jacobs (1961) in the centers of US cities in the postwar period, by David Harvey (1973) in Baltimore in the 1970s, and by other authors and institutions such as UN Habitat in subsequent decades (e.g., Habitat 2008). Consequently, climate change impacts are bound up with political ecology, whereby environmental changes across different geographical scales have to be understood in terms of the political context in which they are raised, addressed, and responded to.

While climate change is a relatively new issue in the field of national public policy, development considerations relating to the distribution of income, opportunities, and access (to infrastructure and services) have been part and parcel of Chilean polity for considerably longer. These social justice lacunae are also closely related to ecological justice issues, hence the term socio-ecological justice. Socio-ecological justice stands at the interface of how people engage with one another and simultaneously with their environment. In the urban context, the lack of green space in low-income neighborhoods, the security of those neighborhoods, the costs of water, energy and transport in proportional terms, and exposure to risks from flooding and extreme temperatures, exacerbate the social divisions that characterize Chilean society. This is the lived experience of socio-ecological injustice that not only impacts negatively on the quality of life in households with low incomes in particular but also affects life chances through ill health and lack of access and opportunities.

While absolute and relative poverty rates reduced considerably from the early 1990s, it is the issue of equality and the distribution of the benefits of the Chilean development model that are central to Chilean politics in the twenty-first century. Meller Commission on Work and Equality, created by President Michelle Bachelet to confront this challenge, published its findings in August 2008 (Comité Asesor Presidencial Trabajo y Equidad 2008). One of the five reasons provided as to why inequalities should be reduced is that social fragmentation is produced, and this reduces dialogue between different groups: "Briefly, to be a developed country it is not enough to have high per capita income: a higher level of equality is required" (xiv). The report noted that Chile was ranked 12 among 100 countries documented in terms of inequality in 2000. This social fragmentation is evident in Chile's metropolitan areas and larger cities and poses an additional challenge for effective climate change adaptation.

It is these inequalities in Chilean society that shape the landscape of vulnerability. This includes vulnerability in terms of personal security, employment security, quality of health and education for personal advancement, and vulnerability associated with expected climate change impacts (those noted above). To confront the vulnerability that underpins the risks from climate change requires an engagement with these wider development issues that are structural in nature and go beyond a "silo" approach to climate change issues understood in isolation and contextualized most often in terms of carbon, carbon equivalents, and carbon costs.

Given that risk is often short-term and sporadic in nature (e.g., in terms of extreme events) and that carbon-specific instruments closely tied only to climate change in terms of mitigation and specific adaptation are unlikely to generate the necessary longer-term structural changes, the argument advocated here is that climate change adaptation should be mainstreamed. This mainstreaming should be undertaken with existing instruments, strengthening them in the process. In the case of urban planning, spatial planning instruments have a tremendously influential role to play.

9.4 From Silos to Systems: Prioritizing the Role of Existing Spatial Planning Instruments

In the Chilean context, spatial planning instruments refer to a toolbox of instruments that are used by local and regional governments to organize geographical space and to orient the development processes that take place in those spaces. These instruments are embodied within the General Law on Urbanism and Construction and have, as principal goals, the optimization of the use of space, the regulation of buildings in urban areas, and the preservation of areas for urban expansion. To achieve these objectives, the instruments define where specific land uses can be established, they define the location of public spaces and infrastructure, and they establish the conditions for new construction and urbanization. Since these instruments are the principal measures for organizing the use of urban space, they are critical in terms of the distribution of urban "goods" and "bads" and the localization of different urban activities, including residential use across different social groups.

The instruments that comprise this toolkit include the following: inter-municipal and municipal regulatory plans, highly localized modifications to regulatory plans known as sectional plans, the definition of urban boundaries (urban limits), municipal development plans (PLADECOs by their Chilean acronym), and regional urban development plans. From regional development and administration legislation, a further relevant instrument is the Regional Development Strategy (EDRs), while a new instrument that has yet to take root in the planning toolkit is the Regional Spatial Development Plan (PROT).

Although it is the case that multiple short-term initiatives relating to different sectoral policies, programs, and plans have a tremendously important role in urban and regional development, it is these instruments noted above that attempt to coordinate and guide activities within a spatial context. They are the relevant instruments in order to begin to "climate proof" not only the physical urban fabric of cities but also the more important social fabric. Since they are instruments that, on the whole, are of medium-term duration or longer (at least 4 years in the case of development plans and strategies and much longer for the regulatory plans), they have the potential to ground initiatives relating to climate change adaptation into city plans over the longer term in contrast with more sporadic programs subject to annual budgetary approval and that are vulnerable to more immediate pressures: The 27 February 2010 earthquake in Chile and the costs of rebuilding for the state purse is a case in point.

Climate change adaptation is not a sprint but a marathon. It requires long-term, embedded changes in how we organize society, how we produce, and how we respond to diverse extreme events and *longue durée* patterns. The instruments that are used to pursue adaptation have to be embedded in how the state, the private sector, and civil society operate: in practices, in physical infrastructure and building design and use, and in how artificial spaces are connected with natural spaces and, most importantly, with people.

Spatial planning instruments are influential for several reasons, although two principal ones stand out. The first is that they regulate locational decisions for different activities, also the ways in which these activities are connected through diverse transport and services infrastructure. In this sense, they define the morphology of the city and the forms and directions of its expansion (both horizontal and vertical). The second is that they should incorporate considerations of risk and reduce these risks in the process of shaping urban development.

The incorporation of risk criteria is especially relevant in the case of regulatory plans. Article 2.1.17 of the General Ordinance on planning defines risks in broad terms as hazards such as flooding, avalanches, landslides, volcanic lava and volcanic faults, and potentially hazardous infrastructure. While flooding, avalanches, and landslides fall within the pantheon of climate change impacts, there is no specific determination of climate change risks to date. Generally speaking, the notion of risk is embedded in traditional conceptualizations rather than a more expansive use of the term following the work of Ulrich Beck (1992) and others whereby risk is not only a natural hazard but also part of the modernization process – manufactured risk – in which new risks are created and old ones may be reduced or exacerbated. A more systemic notion of risk within socio-ecological systems is useful for linking the hazards with the vulnerability of certain groups (and therefore, the construction of the risks to be faced), e.g., if the hazard is high but the vulnerability is low, risk is also limited.

Climate change is complex both in terms of understanding of the phenomenon and its systemic repercussions. It is also uncertain given the nonlinear aspects of its evolution, so associated risk also needs to be understood as a complex phenomenon. Incorporating climate change into planning instruments thus needs to go beyond the identification and zoning of land for controlling certain uses to constructing instruments capable of climate proofing urban areas over the longer term. This climate-proofing process is as much a social challenge as a physical one. It involves the integration of considerations of social vulnerability and how socioeconomic processes and dynamics manufacture this vulnerability and the incorporation of these considerations into the instruments.

The silo thinking associated with viewing climate change science, and mitigation and adaptation responses, as being new phenomena limits appropriate responses. Climate change impacts are part and parcel of human development over time (one of a small number of key variables in societal longevity noted by Diamond 2005). The intensity of those impacts and the particular trends that are evident require appropriate measures. However, a hard planning response that seeks to reduce these impacts via, first and foremost, infrastructure is limited by the social factors that underpin those responses. A soft planning response that engages with the social and cultural dimensions of understandings of change – perceived and real – and engages with the concepts of vulnerability and risk (hazard x vulnerability) in an integral way, as opposed to one based on a reductionist, monocausal logic, is a vital complement to the harder options; in fact, it is a *sine qua non*.

Some of the issues involved in shifting to this softer planning approach, in which the social fabric is considered alongside the physical fabric of urban areas as a socio-ecological system, are explored in the following section. Chile's larger cities, some designated as metropolitan areas, are likely to concentrate the lion's share of direct risks to people involved with climate change impacts. This is due to total numbers of inhabitants, also the additional risks in urban areas such as heat stress associated with the heat island effect. Indirect effects associated with lost earnings from the export sector will affect both rural (lost income and rising food prices) and urban populations (rising food prices) alike.

Table 9.1 Expected climate change impacts in major Chilean cities (A2 scenario)

City	2010–2039	2040–2069	2070–2099
Antofagasta precip.	−5 to −10	−10 to −20	−5 to −10
Antofagasta temp.	0.5–1	1.5–2	3.5–4
Valparaiso precip.	−5 to +5	−20 to −30	−20 to −30
Valparaiso temp.	0.5–1	1.5–2	3–3.5
Santiago precip.	−5 to +5	−10 to −20	−20 to −30
Santiago temp.	0.5–1	1.5–2	3–3.5
Concepción precip.	−10 to −20	−10 to −20	−20 to −30
Concepción temp.	0.5–1	1–1.5	2–2.5

Source: Universidad de Chile (2006) and Vicuña et al. (2009)
Precipitation values are percentage change relative to historical baseline. Temperature values are changes in degrees C relative to historical baseline

The cities that have been selected to review the socio-ecological challenges relating to planning instrument design are the largest in the country (excluding Santiago) and span different latitudes, from Antofagasta at latitude 23°38′ S in the north to Concepción at latitude 36°49′ S in the south. According to the University of Chile (2006) report on climate change impacts in the country during the twenty-first century, undertaken for the National Environment Commission (now the Ministry of Environment), Chile will experience considerable variations in impacts from north to south, as well as the local-level variations associated with the topographical effects associated with the east–west geography of the country, defined by the profile from Andes peaks to sea level (Table 9.1).

9.5 Metropolitan Experiences of Localized Adaptation for Vulnerability Reduction

Table 9.1 above masks the considerable uncertainty to be faced once climate modeling is scaled down to smaller polygons in which we can find cities and their immediate peripheries. Meta-analyses, which generate estimates of climate change based on multiple existing models, may provide this level of detail. However, to date, it is only in Santiago that there has been a downscaling calculation for the city-region (conducted within the auspices of the German-funded Climate-Adaptation-Santiago research project in early 2011). Despite the variations that can be expected, particularly with altitude and vegetation types, this type of downscaling provides more specific data as well as revealing the need to continue working within ranges of uncertainty that are broad, especially over time spans of several decades, e.g., to 2050, to 2070, and to the end of the century, and according to different global scenarios, as defined by the IPCC (A1, A2, B1, B2). In view of the absence of similar experiences in the other Chilean cities, we are faced with high levels of uncertainty. Nevertheless, certain patterns are “more likely” (to use the IPCC terminology), and it is these that provide the available inputs to date.

The experiences that are noted below provide a range of key climate change impact issues that can be expected to intensify during this century according to PRECIS A2 estimates for the country (Universidad de Chile 2006). For the case of Antofagasta, the key issue in this arid environment is the availability and management of water. In the case of the Valparaiso metropolitan area, the issue relates to the precarious nature of some housing that can be found in the ravines that surround the city itself. Finally, the case of Concepción relates to the expected increases in the intensity of precipitation events and the risks of flooding that are likely to ensue. In all of these cases, there are strong socio-ecological justice issues that have yet to be brought into public debates relating to climate change policy and planning.

Planning instruments are designed to identify risks and also to promote more equitable development opportunities through the organization of urban and peri-urban spaces. In the case of Chile's major cities, despite the overall reductions in poverty levels since the early 1990s, problems of inequality remain and are evident in the spatial organization of these settlements. These situations of inequality are more marked in those cities where there are also more numerous concentrations of high-income groups, and they can be observed in situations of socio-spatial segregation. In Chile, the lowest-income settlements are known as *poblaciones* (settlements). Previously, there were also a large number of *campamentos* (squatter settlements), but these have all but been eradicated over the past two decades with their populations relocated to new social housing projects, mostly on the outskirts of the cities.

9.5.1 Antofagasta: Distributing the Costs of the Water Deficit

One of the general objectives of the Regional Development Strategy for the Antofagasta region (2009–2020) is to "protect the water resource via efficient administration, in line with the regional conditions of extreme aridity and the pressures on its limited and little known supply" (p.75). The limited water supply in the Antofagasta region is well known to all actors involved, from residential users to the large copper-mining firms, e.g., Codelco and BHP Billiton, that dominate the regional economy and are the motors of the national export economy. As the copper-mining sector has flourished, its water demand has followed suit, leading to the purchasing of water rights from other user groups, such as the few remaining agricultural associations. Since 2003, when the state water companies were dissolved and the utilities were privatized, regional water supply has been managed by Aguas de Antofagasta S.A. (ADASA); ADASA is part of the Antofagasta PLC group that also owns one of the largest mining companies in the country, Antofagasta Minerals S.A.

As water has become scarcer, different options have become possible due to the changing price curve. More recently, a shift into desalinization plants on the coast and long pipelines into the interior of the region has been the response of these firms to the deficit crisis. Given the limited surface water flow through the arid region, aquifers provide an important share of water needs (approximately a third of the terrestrial water resource). However, during the past decade, sectors of two of the major aquifers (Sierra Gorda and Aguas Blancas) on which the city depends have been declared "Restriction Zones" (DGA 2010), meaning that no new water extraction rights may be granted. The limitations on water have led to increasing residential demand also being met by desalinization. ADASA has introduced two inverse osmosis desalinization plants in recent years (La Chimba in Antofagasta, and Taltal); approximately 50% of water provision in Antofagasta is now generated by desalinization (Antofagasta PLC 2008). While this measure for producing drinking water serves to militate against the problems associated with the lack of water within the region and for the towns in particular, there are further risks associated with the dependence on this new infrastructure, compared with a more diversified supply network. In March 2011, detection of microalgae at La Chimba desalinization plant led to water being cut off to 120.000 users for 3 days (El Mercurio de Antofagasta, 3 March 2011).

The rising production associated with the mining in the region, also the rising population of Antofagasta (increasing 30% in the 1992–2002 intercensal period), means that there is increasing pressure on water resources. However, climate change is expected to reduce the volume of the resource, given reduced glacier melt over time and rising temperatures. The CEPAL (2009) report on climate change in Chile indicates that there will be strong warming in the interior and higher latitude areas of the region between 2040 and 2100, precisely in the zones where the principal riverheads of the region are to be found and where aquifers will be replenished. While the A2 scenario for the final decades of the century points to a possible rise in precipitation (which is generally very low except at high altitudes), for the decades to 2070, the trend is toward a reduction in the already scarce rainfall (1.7 mm per annum in the city itself).

According to the tariffs as of 31 March 2011 (published by the sanitation superintendency, SISS 2011), the cost per m^3 of drinking water (nonpeak) varies among the largest cities from 282,15 pesos (Aguas Andinas, Santiago) to 340,70 (ESSBIO, Concepción), 575,36 (ESVAL, Valparaiso), and 1.164,60 in Antofagasta (ADASA). These additional costs in Antofagasta are due to the alternative technologies that are now required in order to produce drinking water. However, this situation is not a product of a lack of water per se but rather the way in which it is distributed and the demands that have been created; in this case, it involves an accumulation of water rights by the mining operations, leaving domestic consumers with the need to consume 'manufactured water' via their natural monopoly utility provider (part of a mining conglomerate), at a price that reflects the additional technological factors associated with its production.

The 1980 Water Code created a water rights market. Over time, the mining firms have concentrated these rights as water has become increasingly scarce. This situation has led to the need to find alternative water generation methods, i.e., desalinization, which in turn leads to high water costs. These are clearly felt more by the lowest-income groups within the city. The lack of low-cost water also influences the quality of green spaces since municipal irrigation costs are high and may become prohibitive over time. As more water has to be generated by more costly methods and available rights are held by fewer actors, principally mining firms, the socio-ecological justice of access to water at a "just price" will become a paramount issue. Consequently, it is evident that high levels of demand for water in this arid environment, combined with concentration of rights in the productive sector, and rising prices per unit will be exacerbated over time by climate change impacts. The regressive impacts of this situation will be felt largely by the lower-income sectors of urban society, despite the availability of water subsidies for those families registered as "in need" by the national social protection system (Ficha CAS).

As a strategic issue in planning local and regional development, the fact that the water crisis is not addressed in the Regional Development Strategy as perhaps the key limitation to future development in the region is problematic. Desalinization is a high-cost response to absolute scarcity, but scarcity is also a product of the limitations of the Water Code in distributing water at prices that respond to the needs of different groups and interests across society. As climate change impacts increase these water stress issues across the river basins of the country, the weaknesses of this instrument will become increasingly apparent.

9.5.2 Valparaiso: A History of Precarious Settlement and Landslide Risk

The Valparaiso metropolitan area brings together the traditional port city of Valparaiso and its wealthy city neighbor of Viña del Mar, as well as a large surrounding area that encompasses the coastal zone of the Valparaiso region. As the center of national development when wheat was exported north to fuel the Gold Rush in California and as the commercial entrepôt and home of the country's mercantilist elites, the city's development was conditioned by its port heritage. Even the impact of the 1906 earthquake was overcome to reestablish this vital trading hub. However, in recent decades, a lot of port traffic has gravitated to the port of San Antonio (further south within the same region) due to better facilities for deep-water vessels and container trade. The urban decline of Valparaiso has mirrored this loss of economic vitality. While higher education establishments and tourism provide important local income, the city has large pockets of low-income settlement. Traditionally, given the limited flat land in the city (known as the plan) which served for the docks, commercial and naval buildings, and a small city center, expansion was either to the north along the coast, e.g., to Viña del Mar and Reñaca, or up into the hills that envelope the city.

The ravines that characterize these hillsides are the sites of potential risks from landslides in terms of climate change impacts. With increased intensity of precipitation events expected, the likelihood of landslides rises. For the most part, construction within these ravines is based on complex wooden pillar systems that are precarious given their largely informal assembly. Although these types of assembly are historically commonplace, this does not mean that risks have been reduced over time.

Each year, there are cases of landslips within these ravines, with loss of property and occasionally loss of life. Given the precarious nature of this topography and the housing that is built there, it is principally low-income groups that settle in these zones. Much of this informal housing does not meet with the current regulatory plan since it exists from previous periods. There are also issues that complicate the relocation of low-income groups since new social housing projects are sited beyond an main city center (given the lack of available land), often far from city services and employment opportunities. They are thus less attractive to these inhabitants, who have also learned to live, precariously, with their vulnerable conditions.

Rauld and Fernández (2002) document a series of landslides in the Valparaiso and Viña del Mar area in 1982, 1986, 1987, 1992, 2001, and 2002; further cases have been generated since, such as in August 2008 when 40 people were made homeless (Cooperativa.cl, 2 August 2008), but the phenomenon should be understood as an annual occurrence. Rauld and Fernádez note the highly erodible nature of the soil type and the gradients that are common in the area. However, they emphasize that there are important anthropogenic factors that also contribute to this vulnerability such as the cutting and filling of hillsides for access routes and housing (artificial terracing), also informal wastewater pipes that flow directly onto these slopes and contribute to their saturation. There is also the factor of additional construction and other waste materials that lie over the soil and vegetation and that contribute to the load that moves once the soil creeps, also the blocking of natural drainage systems with waste.

In a recent susceptibility mapping exercise for mudflows and rockfalls in the city's ravines, undertaken for the Inter-American Development Bank, Puglisi and Indirli (2008) identify the widespread risks that are faced across the area and the particular risks posed during the May–August period when 20–80 mm of rain falls in the 5-day period preceding the event or when 40 mm falls in 1 day (based on registered events 1961–2006; at least one event was observed in each year). Bearing in mind that these baseline conditions are likely to rise with climate change impacts, the need to address the vulnerability of groups inhabiting these ravine landscapes becomes increasingly urgent.

Paragraph 11, Article 3.19, of the ordinance of the Valparaiso Metropolitan Regulatory Plan (PREMVAL, to come into force in 2011 and replace the previous instrument of 1965) states clearly that any construction on hillsides requires a technical report that confirms that the stability of the land will not be affected, also that storm water drainage is provided for, and also underground water in areas where it may rise to the surface. Gradients over 70% are zoned as "restricted" due to risks of natural origin, whereas gradients between 40 and 70% can be built on subject to restrictions. In the zoning of both of these categories (ZRN-P), the regulatory plan reveals that most of the land in the Valparaiso municipal area is one or the other.

The principal problem to be faced is that earlier constructions were not evaluated with such rigor and are informal in most cases. These are precisely the houses that face most risk from intense rainfall events over coming decades if there is not sufficient investment in improving storm water drainage systems, maintaining them, and securing the frameworks that attach these houses to the ravines. This is the legacy of the city's development and reveals the structural issues that have to be confronted in climate proofing the city over the coming decades. This legacy is also one of historical socio-spatial segregation and the perpetuation of the vulnerability of lower-income groups who chose to occupy the ravines as a response to the lack of formal housing on the plan. The 2002 PLADECO diagnosis report (CGP 2002, 24) notes the situation as follows: "In the case of housing, those affected have no planning permission and are in precarious conditions, having been constructed in the ravines of the hills seeking protection from the wind (self-built)." Further, it states that "between 1969 and 2000, the urban physiognomy of Valparaiso is chaotic, influenced by the natural spatial organization that conditions the structuring of the city. Most of the population is from sectors with few economic resources and have moved to the higher sectors, over 450 m above sea level" (p. 48).

The failure to effectively regulate land use and building security over recent decades does not bode well for the coming decades when the baseline conditions associated with landslides are expected to increase. In this sense, the climate change adaptation agenda is not novel. The experience of landslide risk and associated vulnerability has evolved with the growth of the city and its precarious sprawl over the surrounding topography. What current research, such as that for the IDB, points to is not only the physical hazard but also the socio-ecological injustice of housing and segregation over a long period of time. This injustice links the physical hazard to social vulnerability and highlights the fact that the outcome has been manufactured risk.

9.5.3 Greater Concepción: Creating Flood Risk Through Urban Expansion

In July 2006, large swathes of the Greater Concepción area were underwater following the river Andalién breaking its banks. Across the region, about 3,000 people had to seek refuge in temporary accommodation, as their homes were flooded. The explanations for this dramatic event that caused widespread damage and high cleanup costs were focused on three particular factors. The first involved a questioning of the releasing of water higher in the Bío-Bío catchment that has several hydroelectric dams. In order to avoid damage to the dams, water was released (the Pangue plant), increasing flow intensity downstream. The second involved a debate over the forestry and agricultural industries and their practices of removing vegetation in the catchment, which would otherwise have slowed overland flow and reduced the peak of the storm event. The last focused on the regularity of these types of intense precipitation events and the likelihood of similar ones in the future due to climate change. However, a fourth played a significant role. It relates to the extensive building of new settlements in wetlands and floodplains over recent decades, changing the natural drainage systems in the process, due to increasing artificial imperviousness associated with urbanization and consequent increased surface runoff (Stone 2004; Vidal and Romero 2010).

It is most probable that the extent and intensity of the flooding were a combination of all four. It is also likely that similar events will take place in the coming century due to the expectation that temperatures will increase, and although rainfall will decrease, more intense rainfall events will also increase. Adaptation to this scenario will require widespread coordination and the effective use of planning instruments in order to shape the city's development to minimize the disruption (and loss of life) and cleanup costs that will be incurred. The risk of flooding has been increased over time by the expansion of the city of Concepción, also other towns in the metropolitan area; the province of Concepción has experienced high levels of population increase accompanied by the gradual urbanization of this population (see Rebolledo 2000). The Greater Concepción urban area increased by 6.000 ha in the period 1955–2007, with the urban area in the Andalién catchment to the north of the city increasing 700%; the corresponding decrease of wetland surface area was 84% in the same period (Vidal and Romero 2010). This new housing has been situated in areas of risk, often wetlands that characterize much of this part of the region. By "building-in" risk in this way to resolve socioeconomic problems associated with housing deficits, planning mechanisms have generated new problems associated with the security of these areas. Given the gravity and cost of the 2006 event, the response has been one of major infrastructure work (approved in 2008).

The population that is affected by potential flooding in the Andalién catchment numbers at least 11,500. These people are predominantly from socioeconomic groups C3 and D (the lowest-income segments), although some new housing for slightly higher-income groups has been installed more recently (C2) (Ministerio de Obras Públicas/EIC Ingenieros Consultores 2008). The movement of lower-income groups onto land that is susceptible to flooding has been a common flaw in land use planning, not only in Chile. It is a product of previous regulatory plans rather than a residual of earlier decades when there were none. One of the problems associated with planning has been that areas beyond the urban limit were not considered by the "urban" regulatory plan. Residential developments in these areas then become incorporated into the city as the city envelopes these rural spaces. A further limitation was the fact that the incorporation of risk assessment in regulatory plans only came into force through a modification of the General Ordinance on Construction and Urbanization in 1993. In 2001, Mardones and Vidal wrote that the high densities and high urban population growth rates during the 1982–1992 period (a 20% increase) had led to expansion (p.99), "…into areas with great difficulties in terms of management and exposed to high indices of natural dangers; increasing the probability of catastrophes. To this can be added the vulnerability of housing and infrastructure that do not have the capacity to resist efficaciously the effects of nature."

Given that climate change impacts suggest that these types of events are likely to increase rather than diminish and bearing in mind the problems of retroactive planning (effectively changing zoning from residential to other uses and moving people from these settlements), the already high costs associated with major infrastructural work are likely to rise over time (approximately US$ 70 million at the present time; Ministerio de Obras Públicas/EIC Ingenieros Consultores 2008). Ríos (2010) presents a critique of this "hydraulic technique as the only solution" approach and how this "disaster-risk space production" functions. He notes that land is valorized through defenses but displaces risks elsewhere in the catchment and also gives residents a false sense of security.

This scenario is in tune with the Stern report (2007) predications for the rising costs over time if adaptation measures are delayed; however, it also reveals the high costs of adaptation measures where major infrastructure work is adopted in order to counteract poorly formulated earlier planning instruments. These instruments enhanced the vulnerability of principally low-income communities on the urban periphery by settling them on wetlands and flood plains. As much as a problem of flooding, it is one of waterlogging of this land due to the permeability of the soil, the proximity of the underground water level, and artificial or natural obstructions to the river courses (Mardones and Vidal 2001; Ferrando 2006).

While infrastructure works since the 1960s have reduced the flooding risk along the principal river, the River Bío-Bío, to protect the center of the city, the problems of waterlogging to the north of the city are now the priority. Mardones and Vidal (2001) cite historical work based on events reported in the local newspaper Diario El Sur that reveals the tendency noted above: In the period 1885–1920, there were 35 episodes of waterlogging and 53 of flooding in the municipality of Concepción; in the 1960–1990 period, this rose to 132 in the case of waterlogging and decreased to 33 for flooding. As more housing has been built on this land over time, this waterlogging has been converted from a problem of agricultural productivity losses to one of considerable social upheaval. It is likely that the high rainfall intensity events will increase with climate change (rainfall over 140 mm in 72 h which detonate flooding and waterlogging, according to Mardones and Vidal 2001). Consequently, the ways in which public policy and public instruments, such as planning controls, increase the vulnerability of the lowest-income groups must be reviewed with greater attention and the situation reverted.

Five years before the severe event of 2006, Mardones and Vidal (2001) correctly noted the high probability of its occurrence (p.118): "The areas exposed to flood risk are limited in the city of Concepción; they are more likely in the vicinity of the river Andalién (University of Bío-Bío), riverbanks of the Estero Nonguén and the riverbank of the Bio-Bio to the east of the Old Bridge (the lower Pedro de Valdivia sector)." It is precisely in these areas that, a decade later, major infrastructure works are being implemented. A more long-term proposition is currently in Congress. The local senator, Alejandro Navarro, has proposed a motion to change the law governing planning instruments to ensure that geological formations that shape the dynamism of the river systems are considered as an obligation and not as an option by the Ministry of Housing and Urbanism. This, he expects, will reduce the events such as July 2006 when higher flows through the catchment led to the overwhelming of the natural channels that had been subject to new earthworks for more settlements, impeding the natural drainage system; Vidal and Romero (2010) calculated that the Andalién river system had lost 64% of its density and length over the 1955–2007 period. The motion (Bulletin 6912–14), proposed in April 2010, remains under consideration in Congress.

Although this modification of the law is minor in principle, it follows the argument that urban and regional planning should follow river basin logic rather than urban land use demand logic. This is in line with the main principal of the Declaration of Concepción based on the first Latin American Congress on River Basin Management held in the city in 1990 (Ferrando 2003). Urban expansion onto areas where risk is higher and vulnerability increases for the lower-income groups (who are encouraged onto this lower-value land, i.e., lower housing unit cost) exposes a flaw in the logic utilized by the Ministry of Housing and Urbanism. This situation reveals its inadequate grasp of the dynamics of the socio-ecological system within which urbanization takes place. Vidal and Romero (2010, 9) are explicit in their long-term analysis of the changes in the catchment most affected by the 2006 event: "In synthesis, urban expansion has led to the occupation of flood plains, altering the routes, geometry and density of the hydrological networks as well as increasing barriers that impede normal river flow. This all translates into an intensification of flooding processes."

9.6 Conclusion: The "Re-centering" of Metropolitan Climate Change Adaptation in Chile

Political ecology, as a lens for engaging with issues relating to the orientation and management of socio-ecological systems, emphasizes the need to focus on the decision-making elements that shape the development of these systems. Rather than purely a focus on the ecological objects themselves that may give rise to the need to control them, such as channeling a river course, a political ecology perspective poses the question as to why hydraulic infrastructure needs to be put in place, at what cost, and for the benefit of whom. In the three city cases noted above, it is evident that what lies at the heart of climate change adaptation is a highlighting of socio-ecological injustices that are both structural and historically embedded. While the climate change modeling tells us that certain scenarios are more probable during this century, in terms of temperature, precipitation, and other factors, a political ecology perspective indicates that responses to these tendencies are fraught with sociopolitical and socioeconomic implications.

It is these implications that constitute the socio-ecological justice agenda. A "re-centering" of climate change adaptation in Chile requires that this agenda be put at the forefront of policies, plans, programs, and related investments. It is insufficient to highlight the risks to the economy without reflecting on the justice considerations that are related to these changes. This process of agenda reorientation must highlight who will be impacted in which ways and not only what will be impacted (economic sectors and branches, infrastructure and physical resources) in a more abstract, neutral, and objective manner. The "who" relates to different social groups that inhabit diverse urban and rural landscapes, with contrasting incomes and other resources that they can mobilize (their vulnerability profiles). A shift from a dominant economic orientation to a more socially sensitive climate change adaptation agenda may lead to a better identification of the ways in which climate change impacts will affect these different social groups in their different locations.

Part of this process involves the highlighting of two complementary themes. The first of these is that the impacts of climate change are not "to be expected" or current. In the cases of Chilean metropolitan areas, there is a long history of change during the twentieth century, with evidence of climate change impacts, vulnerability to these impacts, and coherent responses in some cases (mainly technical and mostly devoid of explicit socio-ecological justice considerations). What can be expected is an exacerbation of these trends, with rising potential risks if vulnerability is not reduced explicitly over time. This vulnerability should be understood as complex and multidimensional, relating not only to household incomes but also location, housing quality, and other variables. Responses therefore should also be multidimensional and should engage with the structural roots of social vulnerability. Climate change adaptation is unlikely to be effective if these structural issues are sidelined or minimized in the generation of new "add-on" climate change responses. Adaptation is a development challenge, and failures to engage with this challenge can be observed in different events that have taken place in Chilean cities over recent decades.

The second theme relates to "how" climate change adaptation in metropolitan areas should be engaged with principally the use of spatial planning instruments. This chapter has highlighted the need to avoid the invention of new instruments and programs without addressing those that already exist and which are likely to be more appropriate, better known, and more legitimate (given their legal basis). Strategic instruments such as regional development strategies and municipal development plans must prioritize adaptation themes as a way of raising consciousness and ensuring that investments across different sectors are coherent with these longer-term challenges of climate change impacts.

It is these instruments that will determine the nature and form of future urban consolidation and expansion. Past negligence has led to a displacement of risks and costs: of risks to low-income groups in the case of urban periphery expansion of Concepción and ravine-side construction in Valparaiso; and costs to these same households, as well as to the Public Works Ministry with the large infrastructure investments that are now required to control impacts and reduce these risks. There is also the lingering concern that these investments are shaped by political interests and short-term responses to specific crises. Demand for defensive infrastructure outweighs supply since there are demands in multiple locations to respond to "planned-in risk" associated with previous instruments and "unplanned risk" associated with locational decision-making prior to instruments regulating land use, as in the case of rural areas on the urban periphery or urban densification and loss of green spaces without due consideration of the consequent heat island impacts.

The next steps in the operationalization of the National Action Plan in Chile involve putting the flesh on a range of issues across several themes. The theme of urban development is one of these, but it remains underdeveloped given the prioritization of the economic concerns around water availability and crop and variety selection in different catchment areas. Indirectly, through GDP, labor requirements, and resource distribution criteria, these economic changes will have a significant impact on urban populations. However, there are also issues or impacts that will have a direct effect, particularly those relating to extreme events (flooding, waterlogging, and heat waves). These direct effects, and their inequitable distribution across locations and socioeconomic groups, will also require priority consideration if the process of climate change adaptation is to ensure that climate change impacts are not suffered disproportionately by the most vulnerable groups in society, thus exacerbating preexisting socio-ecological injustices.

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Chapter 10
Double Exposure in the Sunbelt: The Sociospatial Distribution of Vulnerability in Phoenix, Arizona

Bob Bolin, Juan Declet Barreto, Michelle Hegmon, Lisa Meierotto, and Abigail York

Abstract The Phoenix, Arizona, metropolitan area's relentless pursuit of urban growth for more than a century has produced a durable racialized landscape, with minorities concentrated in an environmentally degraded urban core and a largely white and relatively privileged population in the expanding zone of peripheral suburbs. As suburbanization has marched outward, new and different forms of environmental insecurity are appearing. While vulnerable people in the central city are exposed to a concentration of industrial hazards and victimized by the construction of transportation infrastructure, some peripheral populations face an emergent double exposure to both an imminent water resource shortfall as a result of regional climate change and localized effects of the crisis of finance capital and resultant foreclosures and plunging home values. We explore how historic sociospatial and political economic processes produced the current landscape of environmental injustice in the urban core and led to suburban expansion and the foreclosure crisis and how predicted climate change in the West has begun to reconfigure existing patterns of environmental risk and security due to its effects on water resource availability. Through an integration of these domains, we analyze the shifting patterns of sociospatial vulnerability and extend the conception of environmental injustice.

Keywords Urban growth • Phoenix • Hazards • Environmental injustice • Risk • Security

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3_10,

Perpetual change and an ever-shifting mosaic of environmentally and socio-culturally distinct urban ecologies—varying from the manufactured landscaped gardens of gated communities and high technology campuses to the ecological war zones of depressed neighborhoods with lead-painted walls and asbestos covered ceilings, waste dumps and pollutant infested areas—shape the process of a capitalist urbanization. (M. Kaika 2005:22)

10.1 Introduction

The Phoenix, Arizona, metropolitan area has pursued a space-consuming pattern of growth almost since its founding more than a century ago. From its incorporation as an agricultural outpost in the Arizona Territories in 1870, it has expanded to a conurbation of four million people housed in more than two dozen municipalities sprawling over thousands of square kilometers of former desert and farmland.

The region's growth has been promoted and enabled by an ever-expanding transportation infrastructure, an increasingly elaborate system of securing and allocating scarce water resources supported by large federal expenditures, a pro-growth *laissez faire* political culture, antiunion workplace laws, and cheap, readily available land (Sheridan 1995; Wiley and Gottlieb 1985). The historical process of spatial expansion, infrastructure development, and the politics of white privilege have produced a durable racialized landscape, with minority populations concentrated in an environmentally degraded urban core and predominantly white and advantaged populations in the expanding zone of peripheral suburbs. In this chapter, we look at the shifting patterns of environmental justice and environmental risk in the Phoenix metropolitan area.

We find a trend toward a broader distribution of risk: on the one hand, there is persistent concentration of contamination and pollution in the predominately minority urban core. The central city neighborhoods represent documented examples of environmental injustice, in which mostly low-income minority populations are exposed to a variety of industrial hazards (Grineski et al. 2007). However, as suburbanization pushed populations outward, new and different forms of environmental insecurity have appeared. Currently, the predominately white and relatively more affluent populations at the outer reaches of the urban expanse are facing an increasing risk of water insecurity. Once the epicenter of Phoenix's real estate building boom, the large planned suburban developments are increasingly facing water shortages resulting from the effects of climate change (Bolin et al. 2010; Gober et al. 2010), as well as economic distress with very high foreclosure rates resulting from the collapse of the housing bubble and the financial crisis that began in 2007. Thus, although spared exposure to some industrial hazards faced in the urban core, the suburbs are differentially exposed to other vulnerabilities exacerbated by global scale processes and are emerging as a new region of what O'Brien and Leichenko call "double exposure" (O'Brian and Leichenko 2000).

The situation we describe is an emergent core-periphery geography of vulnerability, with a degraded landscape of chronic environmental injustice near the central city and an emergent region of resource insecurity and neighborhood decline variably affecting outlying suburbs. Our comparison of the developing double exposure on the urban fringe and persistent environmental hazards in the urban core extends traditional environmental justice analysis through incorporation of emerging, although typically overlooked, environmental vulnerabilities. In the first section of this chapter, we review the sociospatial and political economic processes that produced the degraded and mostly minority urban core. This is a classic case of environmental injustice, (see United Church of Christ 1987) in which a variety of discriminatory processes, including residential segregation and official neglect, caused minority populations to be differentially exposed to industrial hazards. Second, as a direct sociospatial corollary, we discuss how the spatial expansion of Anglo Phoenix away from the urban core reinforced this racialized landscape. In this section, we draw on Laura Pulido's concept of "white privilege," a more subtle but equally pernicious form of environmental racism than intentional discrimination (Pulido 2000). We trace how the racial privilege of whiteness – and the class privilege historically attached to it – has shaped urban land uses and development patterns through zoning, taxation, and strict land-use management strategies, protecting Anglo middle-class neighborhoods from unwanted land uses (see Bolin et al. 2005). We also examine how periphery suburbs are especially vulnerable to the growing economic vulnerability from collapse of home values through a disproportionate number of household foreclosures resulting from the global economic crisis. Third, we discuss growing water insecurity on the urban fringe, as more subdivisions are built with water supplies that are legally tied to Arizona's Colorado River water allocation through the Groundwater Management Act's Assured Water Supply Rules and the creation of the Groundwater Replenishment Districts (Bolin et al. 2010). Then we draw comparisons across these three domains and discuss the relevance of these findings, particularly with regard to the conceptualization of environmental injustice.

10.2 Constructing Environmental Injustice in the Urban Core

Studies in environmental justice examine correlations between race and class and the equitable distribution of environmental risk as well as access to environmental amenities. A number of studies have established the distributional and procedural environmental injustice in Phoenix (Bolin et al. 2002; Grineski et al. 2007, 2010; Sicotte 2008; Sobotta 2002). Fundamental to these studies is the concentration of minorities, industrial hazards, and ambient air pollution in a region of the city known locally as South Phoenix (Fig. 10.1). While the region abuts the glossy skyline of the central business district (CBD), it has been a historic zone of racial segregation, bank redlining, toxic pollution, transportation corridors, and disinvestment for much of the twentieth century (Bolin et al. 2005).

Unlike other southwestern US cities such as Los Angeles, Tucson, El Paso, and Albuquerque, Phoenix had no preexisting Mexican settlements (Sheridan 1995). Phoenix began as a self-identified "Anglo city," and municipal boosters aggressively

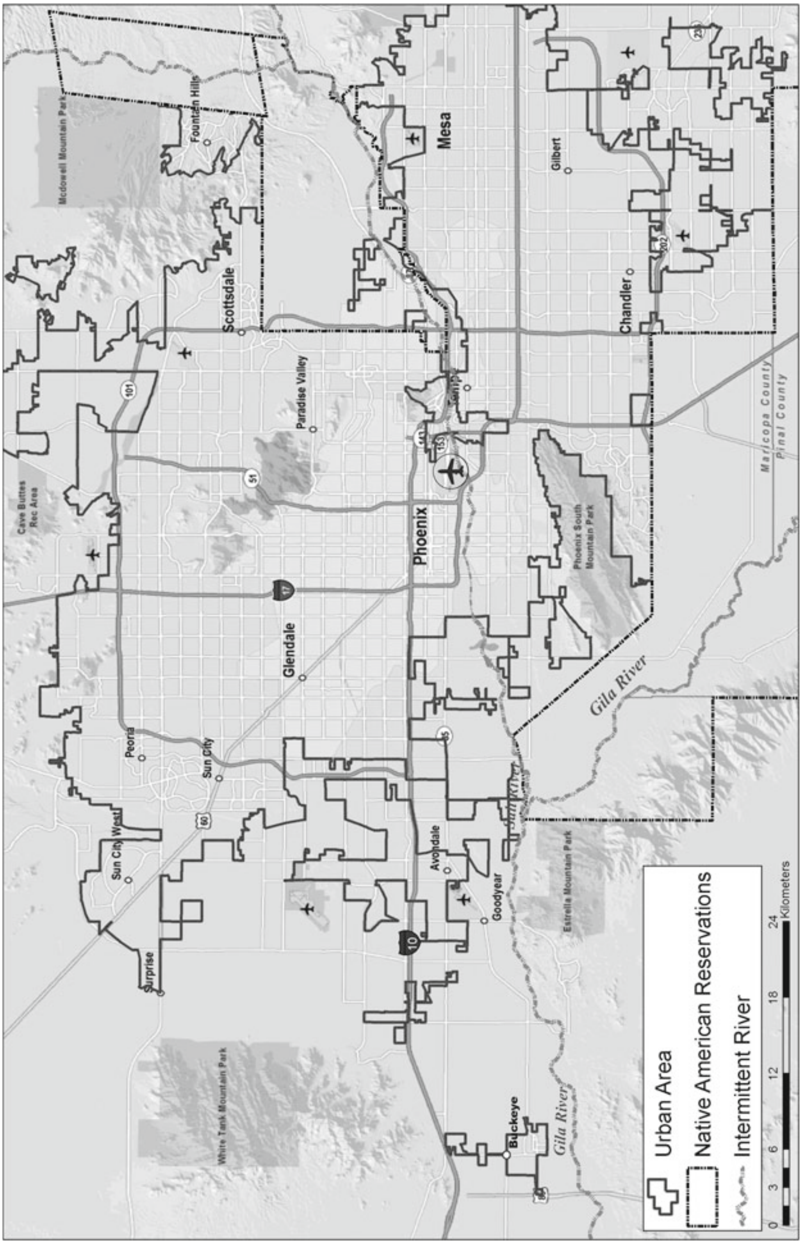

Fig. 10.1 Phoenix metropolitan area

promoted its image as "[…] a modern town of forty thousand people, and the best kind of people too. A very small percentage for Mexicans, Negroes, or foreigners" (from a 1920 Chamber of Commerce document quoted in Kotlanger 1983: 396). Despite the Chamber of Commerce publicity, Mexican immigrants provided both labor and knowledge critical to the development of agriculture in the Salt River Valley. The modest integration of Mexicans in the nineteenth-century Phoenix ended with major flooding along the Salt River in 1891. The flood prompted the movement of Anglos to higher ground north of the river, beginning a distinct pattern of racial segregation and uneven development (Luckingham 1994). The growth of railroad and trolley transportation systems anchored and then reinforced these divisions with the railroad becoming both a symbolic and physical dividing line between the Anglo north and the subaltern south (Bolin et al. 2005; Roberts 1973) while the urban trolley system supported northward expansion of Anglo residential districts (Gober 2006). Industrial activity in South Phoenix, dating back more than a century, included brick factories and quarries, foundries, steel mills, meat packing and dog food plants, ice manufacturers, a sugar-beet-processing facility, and wood- and oil-powered electric-generating stations, as well as stockyards and rendering plants. By 1921, there were more than 300 industrial firms in South Phoenix (Kotlanger 1983). Unregulated industrial pollution, dust, effluent flowing in open ditches, and the stench of stockyards and rendering plants all contributed to unhealthful living conditions, giving Phoenix the highest infant mortality rate in the USA. South Phoenix was designated as the country's worst slum in the 1930s (McLoughlin 1954; Russell 1986).

Politically, minorities lacked any voice in city affairs. In keeping with segregationist practices endemic in the USA prior to the 1960s, blacks were denied virtually all political representation in the city. Mexican Americans were politically disenfranchised in 1913 when the city of Phoenix went from a system of elected district representatives to an at-large election system. This effectively ended any possibility of minority political representation in a city that at the time was nearly 85% Anglo (Luckingham 1994). In this period, living conditions for many Latinos and African Americans in the area were more akin to Third World shantytowns than a US capital city. Hastily erected shacks of cardboard and scrap wood and migrant labor camps (Kotlanger 1983), with no water or sewage, were common. The sweltering summer heat (routinely exceeding 40°C) resulted in numerous heat-related deaths. Disease, including tuberculosis and typhoid, was pervasive and health care largely unavailable (Luckingham 1994). The segregationist geography at work from the city's earliest days was subsequently coupled with zoning, planning, and siting decisions that increasingly burdened these low-income areas with industrial and waste-handling facilities in the post-WWII period (Bolin et al. 2000; Pijawka et al. 1998). In 1947, a *Saturday Evening Post* article described the unpaved streets and shacks of South Phoenix as a match "misery for misery and squalor for squalor with slums anywhere" (quoted in Konig 1982: 21).

Persistent poverty, substandard housing, intrusive transportation corridors, and unbuffered industrial activity are still prominent across South Phoenix. In the mid-1960s, Phoenix was described as "saddled with square mile after square mile of some of the most run-down, dilapidated housing in urban America …whole blocks are served by one or two water taps … behind a street facing row of shacks is built a second row, and even a third, of equally inadequate structures" (Citron 1966). Such conditions have abated very slowly beginning with civil rights legislation and activism in the 1960s and the onset of federal environmental legislation in the 1970s. However, as the metro area has expanded, with massive residential growth on the periphery, the already-disadvantaged core has continued to bear the brunt of environmental inequities.

10.3 Suburban Expansion, "Sunbelt Apartheid," and the Foreclosure Crisis

This "Sunbelt apartheid" – disadvantaged minorities in the core and Anglos in the suburbs – was established in the early years of the city, anchored by the railroad and worsened by a variety of racist practices (Bolin et al. 2005). And it has not been attenuated during the rapid growth and suburbanization in the last several decades (e.g., Pijawka et al. 2001). Its persistence is part of a racialization of geography across the larger Phoenix metropolitan area, in which mostly white populations locate in the suburbs and a variety of processes distribute pollution and development unequally, increasing the burdens on the underprivileged and mostly minority core.

Expansion into the suburbs escalated in the aftermath of WWII, thanks to wartime spending and postwar defense dollars flowing into Phoenix area industry. Nine military bases near the city in the 1940s subsequently attracted electronics, aerospace, and weapon industries as well as their suppliers supporting an early high-tech industrial sector (Gammage 1999; Luckingham 1983). The dry air of Phoenix was conducive to electronics and aerospace manufacture, and the advent of reliable central air-conditioning made locating facilities in the desert heat feasible (McCoy 2000). Some larger electronics manufacturers such as Motorola, which moved its corporate headquarters to Phoenix in 1948, located factories outside of the older industrial zone of South Phoenix and maintained a strict whites-only hiring policy in the 1950s (Luckingham 1994). This initiated a decentralizing trend for large electronics factories that continues today (Bolin et al. 2000). Ironically, while municipalities heavily courted ostensibly clean, non-smokestack, high-tech industry, the legacy of a Scottsdale Motorola plant is today the largest Superfund site in Phoenix, with industrial solvents contaminating aquifers under Phoenix and Scottsdale.[1]

With federal dollars and new jobs in Phoenix, combined with returning WWII veterans supported by Federal Housing Administration programs, residential construction in the suburbs increased markedly. The mass production of housing became an industry in its own right and has since emerged as the major economic focus in the region (Gober 2006). In the 1950s the metro region's population increased by 311%, virtually all of it locating in new segregated suburban developments (Gammage 1999: 36).

[1] http://www.azdeq.gov/environ/waste/sps/phxsites.html#mot52a

Central city-suburb differences highlight a clear pattern of uneven geographic development across the metro area linked to environmental inequities (cf. Harvey 2000). Smith (2008) explains the political economic effects of suburbanization in the postwar period: "Capital was attracted to the rapid increase in ground rent that accompanied suburban development, and so the inner city… was systematically denied capital. This led to the steady devaluation of entire areas of the inner city, whether obsolete or not…." South Phoenix was further disrupted by the development of the I-10 freeway corridor (see Fig. 10.1), which was seen as a key part of the intraurban highway grid necessary to facilitate downtown access and airport access. A key section of I-10 was built across the eastern portion of the Golden Gate Barrio in the 1980s, providing direct freeway access to the airport and the Phoenix CBD (Dimas 1991). The fate of the Golden Gate Barrio encapsulates the long history of Anglo/Latino conflicts over land use and cultural values in the southwest (ibid.) and is emblematic of the power of growth coalitions to pursue accumulation strategies at the expense of people of color neighborhoods (e.g., Bullard et al. 2000; Harvey 1996). The residential population in the census tract containing Golden Gate Barrio dropped from 6,200 to 1,466 between 1970 and 2000. Between 1980 and 1990, 40% of residential land was converted to industrial uses, increasing the hazard burdens in the tract while facilitating new industrial growth anchored by the airport. The industrial presence also insures that home values stay low, denying minority homeowners gains in equity (Bolin et al. 2005). Paradoxically, some of these same conditions protected inner city residents from new vulnerabilities, including the lure of exorbitant home equity loans and subsequent threats of foreclosure, which has plagued Phoenix's peripheral suburbs.

During the past 15 years, deregulation of the mortgage industry fueled housing demand, leading to a rapid increase in prices and housing supply. This in turn has lead to an explosion of "boomburgs" in the Phoenix area (Lang and LeFurgy 2007). Like much of the country, speculation and overextended households' use of home equity credit further expanded the housing bubble (Akerloff and Shiller 2009). However, the result after the bust was more acute in Phoenix than most cities because of the tight linkages between the local economy and residential growth as well as the sheer volume of new, subprime, and risky home loans in the rapidly growing city (Mayer and Pence 2010). The fringe suburbs, a location where privileged groups largely escaped environmental inequities and injustices associated with toxic industrial and transportation infrastructure growths, are the centers of the foreclosure crisis and, as we discuss in the next section, face growing water insecurity.

10.4 Water and Growth

The development of the water infrastructure required to supply a metropolitan region of over four million in the middle of the Sonoran Desert poses particular risks, risks that are sociospatially variable and increasing with climate change. In this section, we outline the history of water provision, focusing on the different risks and problems faced by populations in the already-disadvantaged urban core and the apparently privileged expanding periphery, or the suburbanization of vulnerability.

The water supply developed by the Salt River Valley Water Users' Association and the Bureau of Reclamation in the early twentieth century to support rapid growth in agriculture also stimulated waves of real estate speculation and rising urban land values, beginning in the 1920s (Reisner 1993; Wiley and Gottlieb 1985). This system delivered water via unlined canals crisscrossing the area and produced an oasis environment of riparian ecosystems, citrus orchards, and green agricultural fields. The city, as part of its self-promotion and boosterism, attempted to "do away with the desert" (Luckingham 1989), planting trees along canals and streets to provide some relief from the withering summer heat (Gober 2006). Shaded canals were especially popular as recreational sites for minority populations, who were not allowed access to segregated community swimming pools (Simon 2002). However, in the name of resource efficiency, the Salt River Project (SRP), a regional water and power entity, began to cover the canals and line them with concrete in the 1950s, and trees that had shaded the canals were cut down because they were perceived as competing for the water. In the course of this deforestation, more than 20,000 trees were cut down (ibid.) and the urban canals lost their earlier shaded, recreational quality. The loss of trees in the central city and the urbanization of former agricultural fields intensified the urban heat island. Nighttime temperatures in the urban core have increased 12°F in the last five decades (Gammage 1999), which adds to the hazard burdens of minority communities in the core (Gober 2006).

To meet both urban and agricultural demands, groundwater pumping increased markedly by the 1950s (Maguire 2007). Then, "with post-WWII population growth and agricultural expansion, groundwater pumping expanded at a furious pace through the 1970s, producing an annual overdraft of 3.09 billion m^3 – or 2.5 million acre feet (MAF) – in central desert aquifers…" (Bolin et al. 2009), the drawdown causing aquifer compaction, sinkholes, and land subsidence over wide areas.

Arizona had legal entitlement to Colorado River water under provisions of the federally brokered 1922 Colorado River Compact, but it had no way of moving the water more than 500 km from the river to the Phoenix metro area (Sheridan 1995). A solution became a major political imperative, and it took the form of the multibillion federal Central Arizona Project (CAP) to lift and move the water to Phoenix (Reisner 1993; Gottlieb 2005). Completed to Phoenix in the late 1980s, the 535 km canal added approximately 1.5 MAF of surface water to the 1 MAF already available from the Salt and Verde watersheds (Bolin et al. 2010).

Federal funding of CAP was made contingent on Arizona enacting a strict groundwater management system to rein in its depletion of desert aquifers, a step that a historically antiregulation state government reluctantly agreed to in the name of future growth (Hirt et al. 2008; Sheridan 1998). These laws, the Groundwater Management Act (1980) and Assured Water Supply Rules, are of Byzantine complexity, but three policies are of importance for understanding the emergence of new zones of vulnerability. The Arizona Department of Water Resources (ADWR) created five Active Management Areas (AMA) where groundwater management rules apply, including the Phoenix AMA; it required all new residential developments in an AMA to demonstrate an Assured Water Supply (AWS) of 100 years; and it set a goal for the Phoenix AMA to achieve "safe yield" by 2025, defined as "a long-term balance between the annual amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge" (ADWR 2004; Collins and Bolin 2007).

The Phoenix AMA currently pumps 250,000 acre-feet in excess of safe yield, and this is expected to rise significantly by 2025 (Maguire 2007). Much of the excess groundwater pumping occurs in outlying suburbs beyond the reach of SRP and CAP water. Development continued in these areas because of a program, created in the 1990s as a result of political pressure from developers, involving the Central Arizona Groundwater Replenishment District (GRD). Under the provisions of this program, all groundwater pumped in the GRD is, in principle, to be offset by an equivalent quantity of CAP water purchased for aquifer recharge somewhere in the Phoenix AMA. Homeowners in the GRD are liable for fees to pay for the purchase of this renewable water (Avery et al. 2007).

Vulnerabilities across the metro region are likely to worsen with global climate change. The latest downscaled global climate models from the Intergovernmental Panel on Climate Change (IPCC) indicate that the western USA is very likely to be considerably warmer and drier over the coming decades, becoming, according to more apocalyptic pronouncements, a "permanent dust bowl," with Phoenix routinely hitting 130°F in the summer and the two major Colorado River reservoirs, Lakes Powell and Mead, functionally dry by mid-century (Barnett and Pierce 2008; Kerr 2007 Milly et al. 2005; Powell 2008; Seager et al. 2007). While the growing aridity will have its greatest impacts on outlying areas, the impacts of increasingly frequent extreme heat events will fall most heavily on the central city and the low-income minority neighborhoods with already disproportionate hazard burdens. The IPCC projects that average annual temperatures in the US southwest could rise 4.5–9°F in the next 100 years, ineluctably intensifying the heat island in Phoenix while increasing demand for water and electrical power (Lenart et al. 2007).

10.5 Shifting Sociospatial Patterns of Vulnerability

The geography of vulnerability in the Phoenix metro area is becoming increasingly complex. The financial crisis has disproportionately hit the peripheral housing markets in the Phoenix region generating very high rates of foreclosures and crippling local economies. In addition, the older central cities hold senior rights to renewable supplies of water, while newer groundwater-dependent suburbs in the outlying areas have far less secure water resources (Bolin et al. 2010) and face-escalating water costs. This vulnerability of the periphery reverses the sociospatial pattern described early in this chapter. However, low-income minority communities in the urban core continue to be differentially exposed to pollution, degraded industrial landscapes, and the urban heat island. In this section, we will explore the shifting sociospatial patterns of vulnerability associated with hazards, foreclosures, and water insecurity.

Bolin et al. (2002) developed a spatial methodology to assess the hazard burden of census tracts by calculating the cumulative hazard density based on four point source hazards (Toxic Release Inventory factories, large quantity hazardous waste generators, unremediated federal Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites and Superfund sites (Bolin et al. 2002)). The research identified a concentrated zone of some 20 high-hazard census tracts that border the central city on its south and west sides (Fig. 10.2).

As can be seen, there are strong associations between race/income and hazard exposure, demonstrating a clear pattern of environmental injustice (see also Bolin et al. 2000; Grineski et al. 2007). Figure 10.2 shows a higher concentration of minorities in the urban core along with a higher concentration of toxins in minority, urban core areas. These hazards are sociospatial expressions of more general processes of uneven geographic development at the urban scale.

In contrast, outlying communities are now at the center of the foreclosure crisis in a metro region that has among the highest rates of foreclosure in the USA (Mayer et al. 2009). Thousands of residents of new homes have slipped into foreclosure, and shopping centers and developers declare bankruptcy leaving a patchwork of abandoned homes and buildings (Inglis and Thompson 2009). The current economic crisis has hit hardest on the urban periphery, particularly among the marginal middles classes, and victims of predatory mortgage practices (ibid.). In Phoenix, foreclosures at the neighborhood (zip code) level are concentrated in the newest subdivisions, as illustrated in Fig. 10.3. Zip codes with higher numbers of foreclosures are located in the peripheral, exurban areas of the metro area.

These outlying communities, most of which are in groundwater-dependent regions, also face growing resource insecurities from the reduced availability of surplus surface water purchased to offset groundwater pumping. Bolin and colleagues examined the spatial variability of future water resource shortfalls in the metropolitan region, using alternative scenarios of declining supplies and conservation strategies at the water provider level[2] (Bolin et al. 2010). Several elements affect how water shortages will be spatially manifested. These include water rights seniority of municipal providers and the mix of water sources – SRP, CAP, groundwater, and treated wastewater – in provider portfolios. The providers most at risk of resource shortages are those with junior rights to SRP/CAP water and those with 100% groundwater portfolios (Fig. 10.4). Thus, newer communities and communities on the urban periphery enrolled in the GRD will be the first to experience shortages resulting in higher water costs.

This zone is a new region of economically distressed households, where many with marginal credit ratings who purchased new homes with dubious mortgage

[2] There are more than 100 water providers in the metro area, from small privately owned distribution systems serving a small subdivision to those that deliver to the cities of Phoenix, Scottsdale, Tempe, Mesa, and others (see Bolin et al. 2010, for a complete list). The geographies of providers in many cases does not map on to municipal boundaries very well. For example, Buckeye has 4 providers serving different sections of the city, a characteristic of many of the outlying suburbs that have recently annexed large areas of land in anticipation of growth that has now ground to halt.

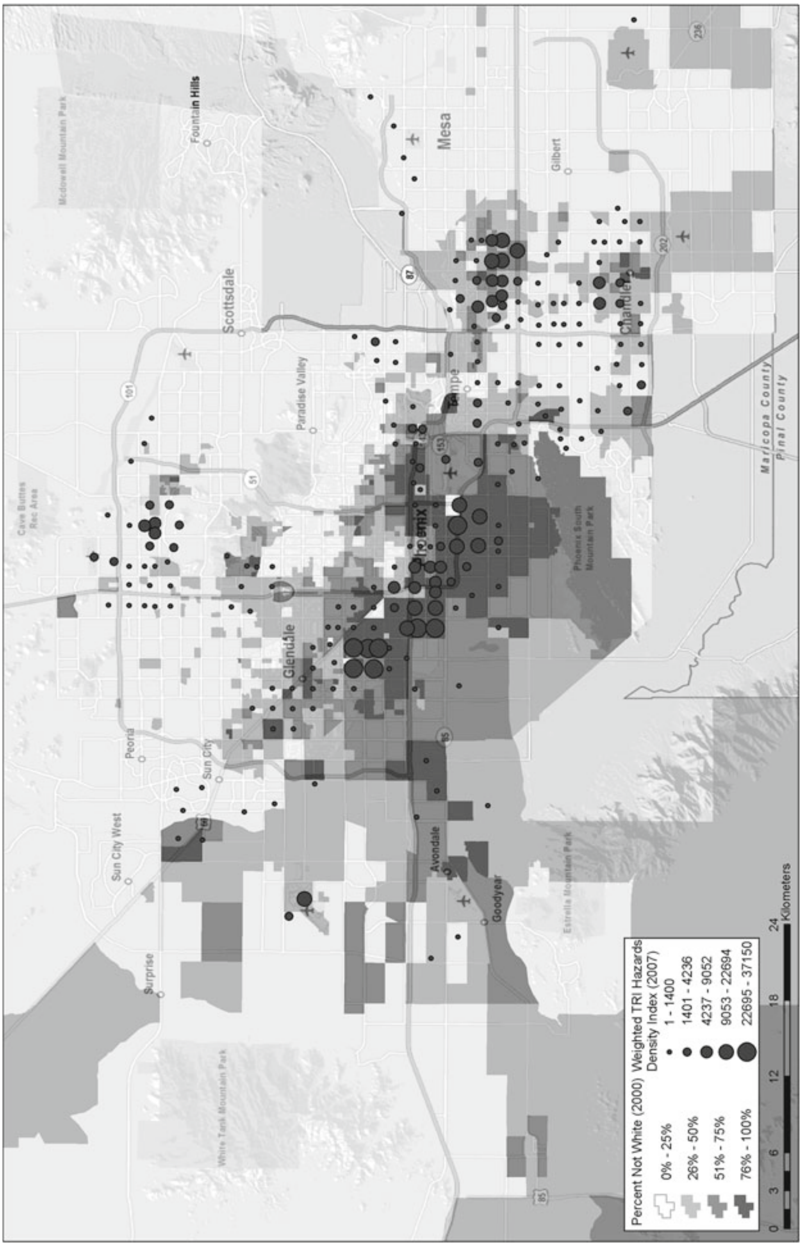

Fig. 10.2 Ethnic composition and distribution of TRI hazards sites

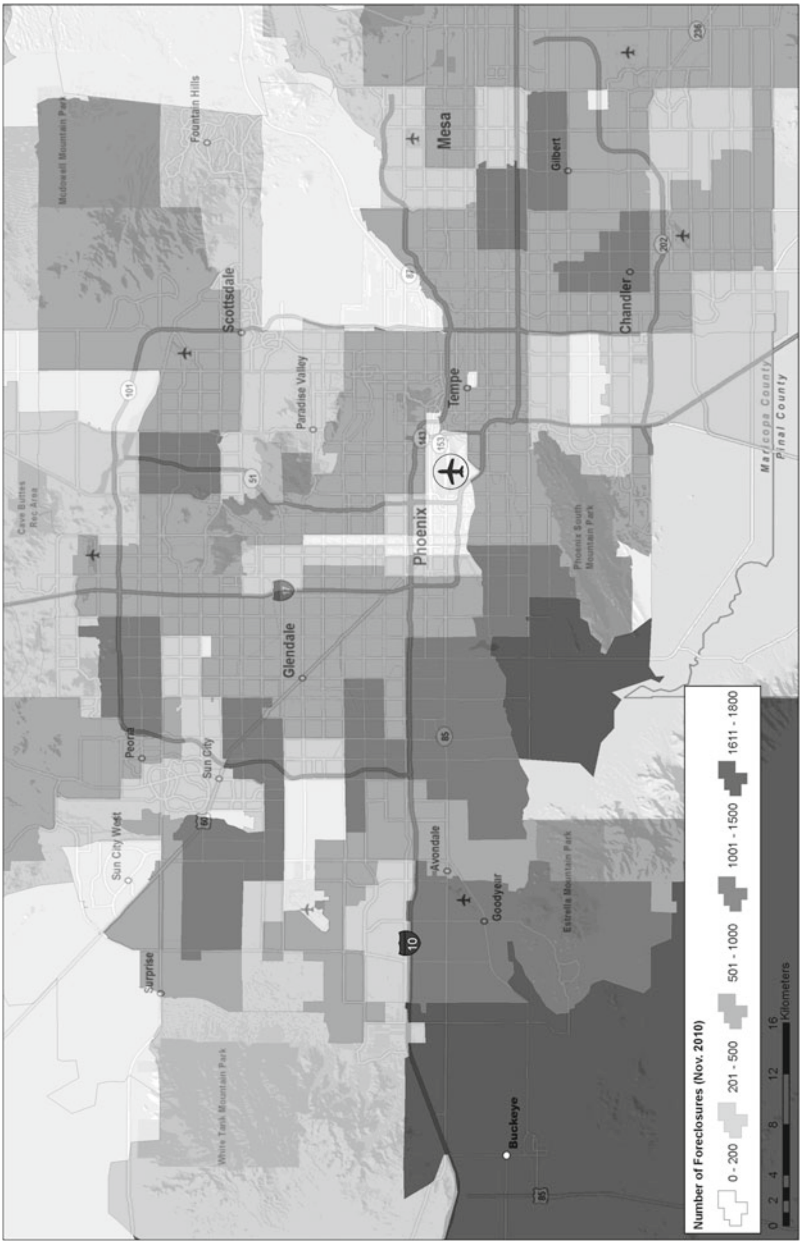

Fig. 10.3 Spatial dimensions of foreclosure crisis

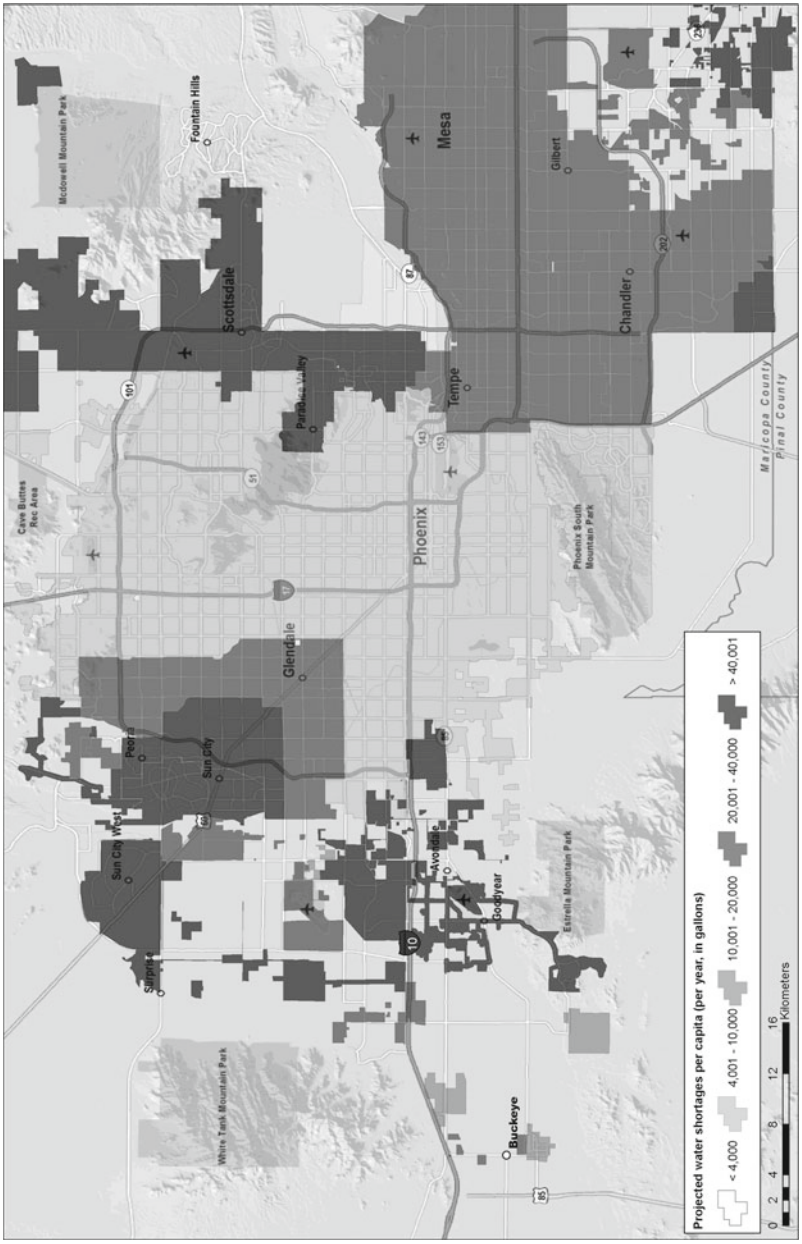

Fig. 10.4 Spatial dimensions of projected water insecurity (Adapted from Bolin et al. 2010)

terms now face rapidly declining home values, increasing mortgage payments, neighborhoods with abandoned and foreclosed homes, high transportation costs, and poor job opportunities. Due to their peripheral locations, they are also exposed to future GRD fees which could balloon up as climate change reduces available water supplies (ibid., Jenkins 2006). Outlying suburbs are thus experiencing a "double exposure," vulnerable to both the global financial crisis and the effects of global climate change (O'Brian and Leichenko 2000; Leichenko et al. 2010). The area where the foreclosure crisis is having its worst effect roughly coincides with the groundwater-dependent zone of development encouraged by the GRD (Fig. 10.4). Homeowners, many whom are already at risk financially due to high loan payments, are also exposed to GRD fees, which may increase to $2,000–$3,000 annually (Jenkins 2006).

The current paradox of risk has resulted from both Phoenix's history of rapid growth and the overdependence of the city's economic growth on the housing sector. Phoenix has used a model wherein current residential growth fuels the local economy paying for the infrastructure (water, energy, transportation) and services to support the next wave of growth (see Bolin et al. 2009; Jenkins 2006). It has been estimated that one-third of all economic activity in the metro area is connected to housing and housing construction (Burrough and Creno 2004). Without continual rapid growth, the urban economy falls into crisis as municipal revenues plummet and jobs disappear (Reagor and Hansen 2011). Phoenix's half century of superheated growth, with the exception of a minor lull during the 1980s, ended in 2007 and the housing and fiscal crisis in the state has deepened since that time (Dougherty 2009). Even before the collapse, developers were overbuilding homes such that more than 100,000 homes built in 2004–2006 remained unoccupied in 2009 (Reagor and Hansen 2011).

Whether the city will resume its space-consuming growth fueled by real estate speculation is a matter of conjecture, although the depth of the structural crisis in the US economy, and in Arizona in particular, suggests that recovery will be protracted if it occurs at all (Foster and Magdoff 2010; Harvey 2010; Krasny 2010). Indeed, there has been a substantial swing away from home ownership to renting in Phoenix, and in some areas home values have declined so precipitously that housing value recovery may not occur at all (Anderson 2011). Maricopa County, home to Phoenix and two dozen adjacent cities, at the time of this writing leads US counties in unoccupied housing units. According to the US Census, 14% of all homes are unoccupied nearly 228,000 units, roughly the size of the entire housing stock of Tucson, Arizona, the state's second largest city (Reagor and Hansen 2011). With tens of thousands of foreclosed and unsold single family homes in the city, the second highest rate of foreclosures in the West, and declining state revenues, it would appear that the building frenzy and housing bubble will not be repeated any time soon (Dougherty 2009). Nevertheless, growth proponents still estimate that the region's population will double to 8 million by 2040 although population growth all but stopped beginning in 2007 (Urban Land Institute [ULI] 2009).

The longer-term issue is whether climate change, rising fuel and commuting costs, and aquifer decline will make living on the urban periphery untenable, rendering these regions unattractive to homeowners and investors alike. While a suite of conservation measures to reduce per capita household consumption and agricultural consumption in the region could mitigate some of the effects of reduced water supplies, conservation has thus far gone against the metro area's triumphalist attitude toward water and its putative abundance (e.g., Kupel 2003). To conserve is to admit limits, and to urban booster resource limits are anathema to their unlimited growth model and Promethean schemes of new CAP canals and desalination plants dotting the California coast (Davis 2007; Jenkins 2006). For city boosters and water managers, climate change, if it is a concern at all, is something that only looms in the distant future (Gober et al. 2010).

10.6 Conclusions

The spatial reconfiguration of environmental risks and vulnerability has produced a new core-periphery geography of uneven development in the Phoenix metro area. These shifting sociospatial patterns are a result of three processes: First, the historic production of environmental injustices in the minority districts in South Phoenix has been the consequence of a century of urban development which has focused on industrialization and commercialization in the urban core and suburbanization of Anglo middle class in spatially dispersed developments. Second, the growth of an urban political economy with a distorted dependence on home construction and rapid population increases has resulted in an increasing exposure to the vagaries of finance capital, an exposure which has now produced a protracted housing and economic crisis with pronounced impacts on newer communities on the urban periphery. Third, the regionalized effects of global climate change will reduce available renewable water supplies over most of the West and will likely impact groundwater-dependent regions first, including the peripheral suburbs and exurbs of the Phoenix metro area.

These findings have a variety of environmental justice implications. On the one hand, we have the historic core of high-hazard census tracts and low-income minority neighborhoods in the central city, recently burdened with the construction of new highways and airport runways. This is also a zone subject to higher burdens of ambient air pollution and the worst effects of the urban heat island (Gober 2006; Harlan et al. 2008; Jenerette et al. 2011). A classic case of environmental injustice, the development and persistence of this situation of environmental racism are due to a variety of factors that denied these populations privilege of escaping to the urban periphery. On the other hand, communities on the periphery, the abode of white privilege, now face the corrosive effects of the financial crisis and mounting foreclosures coupled with the imminent effects of climate-related resource declines. Thus, what initially appears is a potentially more equitable distribution of environmental harm and risk. However, the reality of the situation is more complex. First, access to a more stable water source in the face of climate change does not necessarily equate with an ability to pay for that water, and any advantage of water security may be offset by the intensifying urban heat island centered on the inner city that dramatically increases costs of other utilities, such as energy for air-conditioning. The overall decline in the local and national economy impacts employment opportunities and the purchasing power of the residents of the core, an already economically vulnerable population who was largely too economically depressed during the housing boom to attain mortgages. Second, there is some uncertainty about the reliability of census data on the ethnic composition in the Phoenix area. Because the region is home to an unknown number of undocumented immigrants, it is not known whether these immigrants are concentrated in the core or the periphery or where these immigrants are relocating during the economic crisis. As housing stocks in the peripheral areas continue to lose value, more low-income undocumented Latino residents may move in, thus shifting the risks back onto a more vulnerable minority population. Third, we don't know what extent minority-owned households are affected by foreclosures. Nationally, Mayer and Pence found black households were more likely to hold subprime loans than white households and that households with lower incomes were also more likely to hold these higher cost loans (Mayer and Pence 2010). Further research is needed on the ethnic and racial identity of individual households in foreclosure in exurban areas.

Climate change is likely to affect both zones, core and periphery, though in somewhat different ways. Increases in ambient heat will have the greatest effects on the already environmentally degraded central city core. Lower-income residents in the core are most exposed to the growing heat island effect and are least able to afford technological or infrastructure alternatives such as air-conditioning and swimming pools. Increasing aridity is mostly likely to affect those on the periphery first, particularly in groundwater-dependent areas. Escalating fees coupled with particular exposure to the financial crisis create a double-risk exposure for residents of those previously privileged communities. While residents of both areas are increasingly likely to face considerable distress, the forms of distress and consequences of these vulnerabilities in the two zones are quite different. Inner city residents, who endure a relatively uniform and chronic exposure to numerous polluting industries and transportation corridors, face the greatest risk of health problems. Poverty exacerbates the situation (Grineski et al. 2007), but many health problems cannot be mitigated financially. In contrast, the dual risks of the housing crisis and climate change on the periphery are more variable and mediated by a variety of contingent factors, including financial differences. Only a fraction of all homes are being foreclosed and there is spatial variability in their distribution. Furthermore, at least in the short-medium term, the risks posed to the suburbs are more amenable to spatial fixes, often supported by public funds (Harvey 2010). Such fixes may buffer the affected populations but with long-term consequences for the environment and the region as a whole.

Some may argue that these problems are intractable within the urban desert environment, but there are glimmers of hope in the form of policy innovation. Phoenix has a sustainability initiative, although has not adopted a comprehensive sustainability program, giving it a middle ranking among major US cities and an opportunity for adoption additional policies and programs (Portney and Jeffrey 2010). Because Phoenix is affected by the urban heat island and will increasingly be affected by climate change, there is a great opportunity for adoption of mitigation programs for heat and water (Sharp et al. 2011). The salience of these risks, water availability and heat, is one factor necessary for collective action (Ostrom 2005) and intermunicipal cooperation (see, e.g., Feiock 2004; Feiock and Andrew 2010) providing one impetus for coming together to solve common problems. The East Valley Water Forum and Maricopa Association of Governments provide forums for these difficult conversations about disproportionate risk, collaboration and coordination, and opportunities for policy innovation spread (East Valley Water Forum 2011; Maricopa Association of Governments 2011). The economic crisis is beyond the scope of Phoenician policy making driven largely by national and global financial trends that play out at the local level (Martin 2010), but urban policy makers in Phoenix have an opportunity to decrease reliance on residential development for economic development preventing the probability of future foreclosure crises. Thus, expanding and linking sustainability, environmental justice, and economic development policies; coordinating policy across the valley; and shifting economic development strategies provide a means to reduce burdens and share risks that all too often disproportionately affect vulnerable populations.

Through exploration of shifting vulnerabilities, hazards, and risks in Phoenix, we extended a traditional environmental injustice analysis in order to consider the impacts of the financial crisis and climate change. The financial crisis and climate change create a new region of risk on the periphery, with stressed homeowners increasingly vulnerable to any increased costs due to declining household incomes and plummeting home equity. However, in identifying this region of double exposure, we do not suggest that the financial crisis and climate change are not impacting low-income communities of South Phoenix; these impoverished communities face reduced economic opportunities and increased exposure to an intensifying urban heat island. Paradoxically, the growth imperative that burdened minority communities in Phoenix throughout the last century through concentration of pollution and poverty now yokes the periphery to a double exposure of a financial crisis and water insecurity. Our integration of these domains (hazards, financial crisis, and water insecurity) allows a more comprehensive understanding of environmental injustice and shifting patterns of sociospatial vulnerability.

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Chapter 11
Climate Change, Urban Flood Vulnerability, and Responsibility in Taipei

Li-Fang Chang, Karen C. Seto, and Shu-Li Huang

Abstract Capital cities in Asia are rapidly growing both in size and in their vulnerability to climate change impacts. Although climate change mitigation and adaptation strategies have been drafted in many Asian cities, little is known about how a city's growth affects its vulnerability to climate change and how governmental agencies respond to climate risks. Nowhere is this more evident than in Taipei, Taiwan, a city whose population has doubled over the last 40 years, during which urban flooding has also increased. Here, we use Taipei as a case study to ask three interrelated questions: (1) What determines a city's vulnerability to climate change impacts, especially flooding? (2) How do land use regulations affect urban vulnerability to climate change? (3) What governmental agencies are responsible for regulations affecting the land use and ultimately climate change vulnerability? Our analysis indicates that the combination of unclear government responsibility and minimal coordination among governmental agencies has resulted in ineffective strategies to minimize flooding risk. Despite numerous policies, Taipei is still highly vulnerable to flooding, and the risks are not distributed equally among the population.

Keywords Climate change adaptation • Flood vulnerability • Flood control planning • Climate change mitigation • Land use planning

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11.1 Introduction

More than 40 years ago, the four Asian Tigers—Taiwan, Hong Kong, South Korea, and Singapore—embarked on a series of economic reforms of export-oriented development that ushered in large-scale urbanization and industrialization. Since then, other Asian countries, including China, India, and the four Asian Tiger Cubs—Thailand, Indonesia, Malaysia, and the Philippines—have also instituted similar reforms. As these economies industrialized, their populations became increasingly urban. A major consequence of these reforms is the increased and growing concentration of people and economic activity in dense urban areas. Although cities in Asia are not a new phenomenon, cities in contemporary Asia are a departure from the past in terms of their population size and physical extent. For example, the population of Seoul was 5.3 million in 1970. Today, it is over 10 million. Bangkok's population has more than tripled during this period, from 2.5 million in 1970 to 9.1 million in 2011. In contrast, population growth in European and American capital cities has been relatively slow. For example, the population of Greater London has been remarkably stable over the last 50 years, with an estimated population of 7.9 million in 1961 and 7.7 in 2009. New York City has also had similarly stable population levels, with an estimated 7.9 million inhabitants in 1950. Today, Asian metropolises are not only modern, and among the largest in the world, but many of them are located in vulnerable locations such as floodplains, deltas, valleys, or low-lying coastal areas and susceptible to floods. Over the last decade, severe floods have affected major Asian cities including Mumbai (2005), Singapore (2010), and Bangkok (2011).

In Asia, urban areas are particularly vulnerable to climate change due to their large populations and geography. There is growing concern that Asian cities are growing in ways that increase their vulnerability to climate change. And, while climate action or local climate adaptation plans have now started to be drafted in many Asian cities, little is known about how a city's growth affects its vulnerability to climate change and which governmental agencies are responsible for climate change adaptation.

In this chapter, we focus on the urban flood control issues and the practice of land use planning in Taipei, Taiwan, to examine three interrelated questions that are relevant to many Asian cities: (1) What determines a city's vulnerability to climate change impacts, especially flooding? (2) How do land use regulations affect urban vulnerability to climate change? (3) What governmental agencies are responsible for regulations that affect land use and ultimately climate change vulnerability? We use management of urban flooding in Taipei as a lens to understand the governance responses to climate change, because there are many parallels between the governance and institutions in place for urban flood management and those in place for climate change mitigation and adaptation.

We hypothesize that the processes of urbanization in Asian cities are wholly separate from the processes of climate change adaptation. That is, urbanization is occurring independent of plans to reduce urban vulnerability. We argue that for climate change adaptation policies to be more effective, they need to also steer and guide the urban development process and not just respond it. To evaluate this, we use a case study approach to examine government documents, published studies, archival materials, and interviews with government officials. Taipei makes a particularly interesting Asian case study for climate change adaptation for three reasons. First, its urbanization trajectories exemplify those of many Asian cities. Second, the country recently embarked on political reforms to a more democratic society, and these new political realities will shape civil discourse about climate change. Third, Taipei is a prosperous Asian city. All of Taipei's residents have access to municipal services such as clean drinking water and sanitation. In other words, Taipei is a developed city that has a fully functioning government. As such, it is a good case study to examine the capacities, institutions, and governance of a modern Asian city.

Climate change will result in a wide range of risks for urban areas. The influences of these risks on human society are multidimensional and will exacerbate existing vulnerabilities of urban areas. Among all the other risks from climate change, flooding is considered the most immediate threat to Taipei. Similar to most of the major cities in Asia, Taipei is also developed near a river mouth, characterized by floodplain and low-lying topography in a coastal zone. Taipei has experienced serious damage owing to typhoon events. Although Taipei is a highly developed city and has completed flood control projects, it is still very vulnerable to flooding when extreme climate events occur. Understanding how the government has dealt with flooding and the consequences from separate land use planning and flood control by different agencies can raise people's attention and hopefully help to anticipate future problems in Taipei arising from extreme climatic events.

11.2 Geography and Vulnerability of Taipei

In order to understand the vulnerability of Taipei to climate change, one must start with the geography of Taiwan and its regional and climatic context in Asia. Taiwan is a tealeaf-shaped island nation located in the Pacific Ocean (Fig. 11.1). Bisected by the Tropic of Cancer, it is at the confluence of the East and South China Seas, nearly equidistant between the southeast China coast and the southernmost Okinawa Islands. The country lies primarily north–south, with high mountain ranges running along the center of the island and creating distinct climatic zones in the eastern and western regions.

Taipei is the cultural, economic, and political center of Taiwan. With a metropolitan area covering 2,324 km^2, it has a population of 6.48 million as of 2010. The urban area is located within the Taipei Basin and bisected by the Tamsui River, which is formed by the confluence of three rivers: the Keelung from the northeast, the Sindian creek from the southeast, and the Dahan from the south. The urban area is enclosed by hills and mountains and essentially resembles a flat, wide bowl, and some areas are even below sea level. The topographic characteristics of the floodplain (Fig. 11.2) and the growing frequency of extreme weather events have resulted in

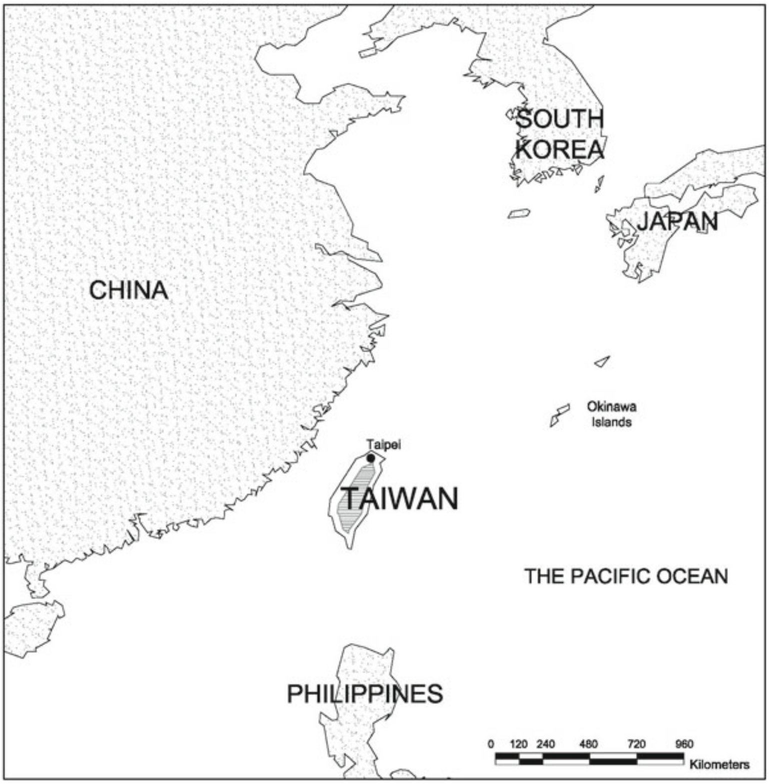

Fig. 11.1 The geography of Taiwan

Taipei becoming increasingly threatened by typhoons. Tropical cyclones—also called typhoons in this region of the Pacific or hurricanes in other part of the world—occur regularly in the South China Sea. Annually, the region is affected by an average of 27 typhoons (Central Weather Bureau 2011a), and Taiwan is affected by an average of 3 to 4 (Central Weather Bureau 2011b).

Numerous studies suggest that climate change will change the intensity, frequency, and trajectory of typhoons. Analysis of typhoon tracks from 1965 to 2003 shows an increase in typhoon activity in subtropical East Asia (Wu et al. 2005). Between 1971 and 2010, there were more than 201 typhoons that passed through Taiwan (Typhoons Affecting Taiwan 2011). The highest rainfall intensity generally occurs between August and October. During these months, the magnitude, frequency, duration, and areal extent of typhoon events are difficult to predict. Over the 100-year period from 1897 to 2006, Taipei experienced a gradually increasing trend in the amount of precipitation of 27 mm per decade (Wang et al. 2008). More dramatic than the slight increase in precipitation amounts is the change in precipitation days. Over this same period, the number of precipitation days per year steadily declined at rate of 2.6 days per decade. Prior to 1950, the average was 185 rainy days per year.

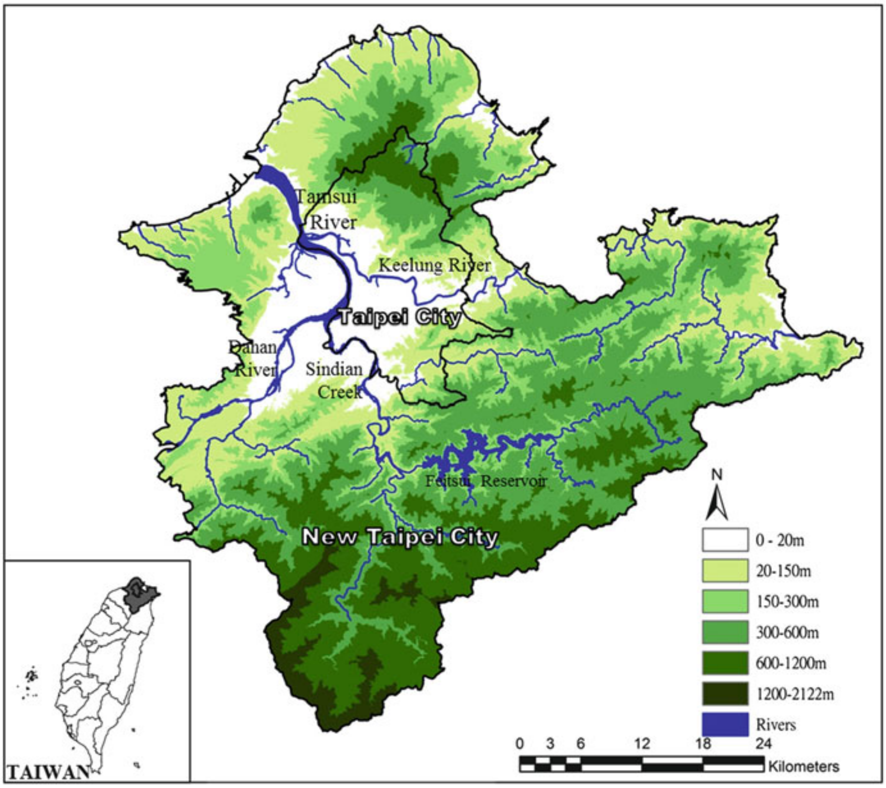

Fig. 11.2 The typographic characteristics of the Greater Taipei

Since 1997, the average annual precipitation days has fallen to 164 (Wang et al. 2008). The combination of these two trends indicates that more rainfall is occurring over shorter periods and that precipitation intensity is also increasing.

Extreme precipitation brought on by typhoons may cause flooding in low-lying areas. Case studies around the world, including the UK (Swan 2010), continental Europe (De Roo et al. 2001), and China (Weng 2001), have found that areas that are more urbanized are more prone to flooding due to reduced evapotranspiration and infiltration, and increased surface runoff. Although urbanization increases impervious surfaces and surface runoff, other studies show that best management practices can reduce flood impacts (Braune and Wood 1999) and channel management can reduce overall flood risk (Fox et al. 2012).

Despite increasingly intense storms, typhoons, and its topographic characteristics of the floodplain, the urban extent of Taipei continues to expand. From 1971 to 2006, agricultural areas shrank by more than 157 km^2, most of which were converted to urban areas. Similarly, Taipei's urban population increased 103% from 1971 to 2006 (Department of Budget, Accounting and Statistics, Taipei City Government 1971–2006; Department of Budget, Accounting and Statistics, Taipei

Table 11.1 Flood events of Greater Taipei (Source: Typhoons Affecting Taiwan, 2011)

Flood events	Rainfall (mm/24 h)	Flooded area (ha)	Highest flood depth (m)	Spatial distributions and characteristics
1971 Bess	150–200	6500	3.4	Flooded areas were mainly at downstream areas where the Tamsui and Keelung Rivers converge and with low flood protection. In addition, the flood occurred in area of low development. These events caused damage and loss to agriculture and affected food prices. The flood type is river overflow and inundation by the sea
1972 Betty	200–300	7053	3	
1977 Vera	150–200	1998	1.6	
1978 Ora	200–300	2602	2.2	
1987 Lynn	500–700	3332	7.5	Location of flooded areas changed from low flood protection area to midstream. The flooded areas began to occur in the steep slope areas with medium development. The total flooded areas declined, but the urban areas flooded increased. The flood was caused by river overflow and drainage failure
1996 Herb	200–300	1000	1.2	These flooding events were located in the high-density areas of Taipei. The damage and losses were huge and affected all major urban activities like transportation and commerce. The types of flood were due to drainage failure and river overflow
1997 Winnie	150–200	–	1.1	
1998 Zeb	400–500	291	7.5	
1998 Babs	200–300	286	3.8	
2000 Xangsane	400–500	441	7.5	
2001 Nari	500–600	6640	8.5	

County Government 1971–2006). During this 35-year period, 11 typhoons caused flooding problems in Greater Taipei (Typhoons Affecting Taiwan 2011). The flooded area and characteristics of flood events are summarized in Table 11.1. Even though the flood areas decreased, the amount of the 24-h duration rainfall and damage and loss increased.

In addition to increased frequency and intensity of flooding and typhoons, Taipei has also experienced a rise in air temperature. Over the 100-year period from 1911 to 2009, annual temperatures increased by 0.14 °C per decade, with a faster rate of increase since 1980, at 0.29 °C per decade, double the 100-year trend (National Science Council 2011). Other studies show an increase of 1.5 °C for the 1965–2005 period (Chen et al. 2007). In addition to an increasing trend in average temperatures, diurnal variations are also changing, with the mean minimum temperature rising faster than mean maximum temperature (Wang et al. 2008; Chen et al. 2007). This indicates that nighttime temperatures are becoming warmer and rising faster than daytime highs, effectively reducing the difference between nighttime and daytime temperatures. Furthermore, urban heat island effect also intensified climate change impacts in Taiwan's major cities. The urban heat island intensity of Taipei during summer nights is 4.5 °C (Lin et al. 1999). Lin (2010) argues that the intensity of urban heat island effect in Taiwan is not only affected by urbanization and climate change, it also likely affects the rainfall pattern and increases urban vulnerability to flood indirectly.

Taipei has a diverse range of urban neighborhoods. The central business district is typical of a modern metropolis: It is dotted with high-rises, office buildings, and dense multistory housing. The historic district houses a wide range of cultural assets such as temples and traditional urban forms. It is also home to many of Taipei's elderly population. Peri-urban areas contrast with central Taipei's rapid development of high-rise residential complexes. This diversity of urban form and urban neighborhoods directly impacts its vulnerability to climate change and assessments of who and which areas are more vulnerable to climate change. Over the last 40 years, Taipei has experienced major changes in its population, urban development patterns, economy, and social structure. The urbanization process transformed greater Taipei, with a growing number of people moving to peri-urban areas. Although the Taipei City government and surrounding municipalities have worked on reducing the risk to flooding over the past decades, the underlying issues of vulnerability to flooding and unsustainable patterns of urban growth are still ignored and will be heightened by climate change.

11.3 Urban Flood Control and Land Use Planning in Greater Taipei

Taipei is located within Tamsui River basin which lies in two local municipalities: Taipei City and New Taipei City, the latter previously known as Taipei County until December 2010 when the central government reorganized the region as a special municipality that includes 29 subdistricts (Fig. 11.3). A key point with regard to urban flood control and land use planning is that these two issues are discussed, managed, and legislated in different government agencies. The management of the Tamsui River is complex due to shared responsibilities for flood control issues that are divided among the central government and local authorities, Taipei City and New Taipei City. Flood control and management is further complicated by different land use planning systems in the two municipalities. In Taiwan, the major authorities of flood control and management is by the water resources sector; land use planning agencies have little authority. The 10th River Management Office is an organization under the Water Resources Agency of Ministry of Economic Affairs (central government) that administers the Tamsui River. It assists with planning, construction, and management of flood defense structures and the early warning system. The water resources sector only focuses on mitigating flood from rivers, but land use activities along Tamsui River must be controlled and managed to alleviate loss from flood disaster. Therefore, the issue of flood vulnerability in Taipei is affected by different land use planning systems in the two municipalities.

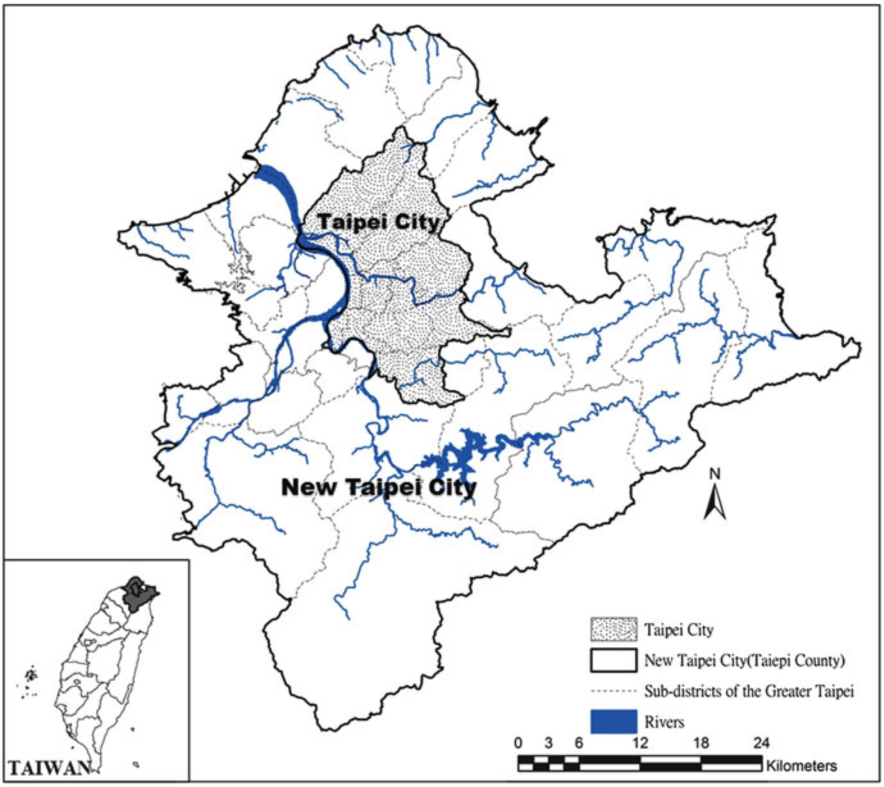

Fig. 11.3 Sub-districts of the Greater Taipei

Taipei City operates under a single urban plan that is controlled by the Urban Planning Act. In contrast, New Taipei City has some urban-planned districts controlled by the Urban Planning Act and some nonurban-planned areas, controlled by the Regional Planning Act and Non-urban Area Land Use Control Rule (Chen and Shih 2010). The Regional Planning Act was passed in 1974 and governs land use in nonurban areas. The planning administrative hierarchy in Taiwan is in two tiers, central and local. The municipalities and counties (with their constituent authorities) are regarded as local level. The responsibility of the central government is mainly for the provision of legislation, formulation of regional plans, and approval of local urban plans. The primary difference between the planning in urban-planned districts and nonurban-planned areas is that urban planning gives a clear picture of the future appearance of a specific developed area, including how its road network will be designed and the location of public facilities, while regional planning is mostly about control measures regarding the permitted land use in different zones (Chen and Shih 2010).

In both urban and nonurban areas in Greater Taipei, flood control has not been integrated in the formulation of land use plans. Rather, land use and flood control are separated at both the plan-making level and at the institutional or management level. Given that land use patterns affect flood risk and exposure and that flooding threatens land use, there is a need to coordinate land use and flood control. Yet, this has not occurred. More than 20 years ago, Huang (1989) observed that urban water management and land use policy and management for Taipei were largely independent. He argued that "rational land development planning requires consideration of urban storm-water management as an integrated and iterative process rather than merely a drainage design to mitigate increased run-off due to urban development" (Huang 1989, p39). Yet, it is clear that integrated planning has not occurred. Whereas in the past this separation of land use and flood control planning and management was largely discussed in the context of suitability planning and rational land use, in the context of climate change, it poses new challenges with regard to adaptation and vulnerability. What agencies are responsible for planning climate change adaptation and who is vulnerable to flooding?

11.3.1 A History of Flood Control Measures

Taipei City started to construct flood control works in 1899 during the Japanese colonial period. Starting from early 1960s, the Kuomintang government of the Republic of China reevaluated the flood control projects in Greater Taipei. Until 1982, the construction of flood control projects in Taipei was continued by the central government. Over the last 40 years, the history of Taipei has been punctuated by extreme flooding events, many of which have been brought on by typhoons. Flood control in Greater Taipei began with engineering efforts in 1982 that was the first of three phases of the Taipei Area Flood Control Project (Table 11.2), and the 10th River Management Office was the chief executive. This project was the biggest flood control measure in Taiwan.

The first phase focused on increasing flood capacity, developing river levees, and a better drainage system. In the second and third phases, additional dykes, levees, and drainage systems were constructed further upstream of the Tamsui River. In 1987, Typhoon Lynn dropped more than 1,100 mm of rain—6 months of normal rainfall activity—during 3 days. It flooded more than 1,000 ha in Taipei, and officials were forced to rethink flood management. After Typhoon Lynn, the Taipei City government proposed to and was subsidized by the central government to start the straightening project of Keelung River, a main branch of Tamsui River. The project was completed in 1993 and created approximately 270 ha of land for development (Department of Urban Development, Taipei City Government 1991). Although the project was successful in many respects, such as flood control and redevelopment, it was not integrated with the middle stream areas of the Keelung River, which are governed by New Taipei City. As such, this project is a harbinger of the lack of coordination among different city governments.

It further shows the disconnectedness of governance for cross border flood control issues. On the one hand, the flood control project created benefits for Taipei City

Table 11.2 Projects and costs for Greater Taipei flood control, 1982–2005

Taipei Area Flood Control Project (Tamsui, Dahan, and Keelung Rivers)		
Phase	Items	Cost[a] (billion New Taiwanese dollars)
I:1982–1984	Floodway and bridge systems	9.8
II:1985–1987	River levees and drainage systems	6.3
III:1988–1986	Land acquisition and others	99.6
Keelung River Flood Control Early Stage Project		
Phase	Items	Cost
1998–2001	River levees and water gates	12.2
	Drainage systems, bridges and pumping stations, others	
Keelung River Overall Improvement Project		
Phase	Items	Total cost
2001–2005	River levees and water gates, drainage and pumping station systems	31.6
	Yuansantze Flood Diversion Systems	
	Water and soil conservation systems, flood early warning systems	

[a]Engineering costs data provided by the 10th River Bureau (2010)

in terms of regeneration and new land permitted for urban development. However, the changes in the natural pathway of the river, mechanical failure of pumping station, and human carelessness also resulted in severe floods along Keelung River that were brought on by typhoons, including Typhoon Zeb (1998), Typhoon Babs (1998), Typhoon Xangsane (2000), and Typhoon Nari (2001). Therefore, the central government constructed the Yuansantze Flood Diversion Systems Engineering Project of Keelung River in 2005 to help mitigate flood risk in the Greater Taipei.

11.3.2 Land Use Regulations

In a flood-prone area, what roles should land use plans play in shaping the geography and vulnerability of Taipei? How have land use policies affected the vulnerability of Taipei to flooding? In order to examine this, we investigate planning regulations and major plans of land use, which has implications for land use changes in Greater Taipei.

Although the urban plan of Taipei City has been continuously revised since the passage of Urban Planning Act in 1939, urban planning continues to omit key components of flooding issues; rather, the goals of urban planning focused mainly on meeting the demands of socioeconomic growth. For example, development in floodplains that results in high flood vulnerability has been ignored by the land use sector simply because flood alleviation is considered the responsibility of the Water Resource Agency, Ministry of Economic Affairs. In addition, the management and

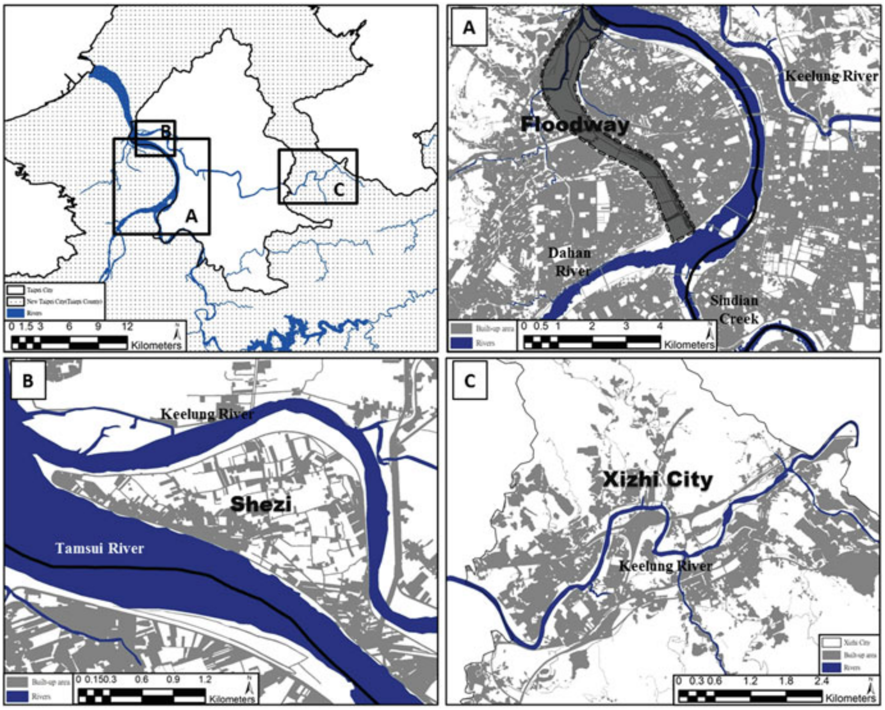

Fig. 11.4 Three cases of land use and urban flood control in the Greater Taipei

regulation of Tamsui River is directly governed by the water resource sector, and the land use sector does not have authority to participate in the control of land use activities on rivers. Therefore, the planning for levees or drainage systems is decided by the water resource sector, and there is little—if any—coordination between it and the land use sector. In the past, the land use sector has either ignored flood issues or has played only a passive role to alleviate floods.

The governance of floods in Greater Taipei is complex, but the structure of these institutions and their interactions may be similar to many other Asian cities and therefore deserves a more thorough discussion (Fig. 11.4). The first case of a conflict between flood control and land use occurred in 1982 when the water resource sector decided to build a big floodway in Taipei County (currently New Taipei City) that was the first phase of Taipei Area Flood Control Project to divert floods from Dahan and Sindian Creeks directly to the mouth of Tamsui River. The major purpose of this floodway was to resolve the flood issues in Luzhou and Sanchong of Taipei County. There were three villages that had to be evacuated because of the construction of the floodway. Although the original land use plan of these villages was designated as urban planning areas, the residents were relocated to other places.

The role of the land use sector was to help the water resource sector achieve the goals of completing the flood engineering projects, rezoning the area into a floodway, and changing some of the agriculture zones into residential zones for accommodating residents in those villages. However, these villages protested against this project because they did not want to leave their homeland for the purposes of resolving the severe flood issues of Luzhou and Sanchong. The land use sector has no authority to plan or to take an independent action about what these areas can be used for by Taipei County. This example showcases the conflicts between different sectors and their authority with regard to urbanization and flood issues in Taiwan. Because of this lack of coordination, whenever the water resources sector designates the location of flood control projects with 200 years of the frequency standard, the existing urban plans will need to be revised.

The second case of the deficiency of urban planning for flood control is Xizhi City of Taipei County, adjacent and east of Taipei City and located in the middle-streams areas of the Keelung River. From a geographic perspective, Xizhi is not suitable for development due to its location. Despite this, the city has rapidly developed, and the population has more than quadrupled since 1970. Since 1969, urban planning in Xizhi has been implemented and controlled by the Urban Planning Act. However, the land use sector does not consider the hydrologic characteristics of Xizhi, and the area along the Keelung River is not planned as a river zone for protection from floods. Furthermore, the water resource sector has not finished the flood control plan for Keelung River.

Consequently, most of the original residential areas and newly developed urbanized areas are concentrated along the river valley. Each year, the Keelung River causes flooding and serious damage, and the urban plan of Xizhi is subsequently criticized and reevaluated. In spite of the land being privately owned, the land use sector does not have the authority to readjust the urban land use plan of Xizhi by controlling land use activities and densities in the areas along the river. Thus, much blame occurred after the flooding disaster in Xizhi between October 31 and November 1, 2000. During this period, the Xangsane typhoon released 716 mm of rainfall over 48 h, equivalent to the total rainfall in excess of a 150-year frequency. The flooding caused by the Xangsane typhoon was exacerbated by insufficient channel capacity and clogging from containers that were washed away from nearby container storage plants into the river floodway. Approximately two-thirds of the urban-planned area was flooded. The highest flooded area was 7–8 m, and approximately 10,000 households and 65,000 vehicles were affected. Power supply was interrupted for 7 days, and roads were also extensively damaged. It took 7 days to clear away 20–40 cm of accumulated mud in the flooded areas. After the event of Xangsane typhoon, the Yuansantze Flood Diversion Systems was then built by the water resources sector in 2005. If, in 1969, the land use and water resource sectors had coordinated and discussed how Xizhi City should be developed and how the floods from Keelung River should be controlled, Xizhi's vulnerability to flooding should have been reduced. The case shows that the land use sector lacked the knowledge of planning with water, and simultaneously, the water resource sector only plans after a disaster. The confluence of these governance deficiencies combined with a lack of coordination between these two sectors underscores the challenges associated with urban climate change planning and will be revisited later in this chapter.

A third example of a conflict between development and flood control was the ongoing debate on whether a specific area should become urbanized or built-up. One illustrative case of this debate is Shezi, a small and narrow peninsula located at the northwest of Taipei City. Due to its low-lying topography and location where Tamsui and Keelung Rivers converge, the area is highly exposed to floods. Since 1967, the Shezi peninsula has been prohibited from development under the floodplain control system by the water resources sector. Because Shezi was prohibited from urban development, the area was primarily agriculture with some temporary manufacturing facilities, and the population size is around 10,000. Although the population in the area did not grow, the local voices became stronger and pressured mayoral candidates. There are over 10,000 residents in this area who have minimal dikes for protection from 20-year floods. Moreover, they cannot develop their lands or reconstruct their buildings due to restrictions by regulations. The combined lack of protection and individual choice on land use has made this area a lightning rod for environmental justice issues. Although the awareness of environmental justice has been raised in the issues of environmental protection since 1990 in Taiwan, the practice of land use planning and development still lacks public participation at each level of plan making and evaluation. The combined effect of lacking flood protection and neglecting local people's right on their land not only has brought another issue of environmental justice in Shezi but also raised the vulnerability issue in Taiwan for the people who live in areas with natural hazards.

Despite the flood risk in Shezi, the Department of Urban Development of Taipei City government proposed that this area be developed as a "Taipei Manhattan" and subsequently made an urban plan in 2010. Taipei City government strove for an agreement with the water resources sector, which eventually agreed to revise the flood control project and to permit development in Shezi as long as other flood control measures were in place. One of the main motivations behind Taipei City government's attempts to develop the area was protest from local residents. The local residents think that the flood control project can be reevaluated and adjusted and that the flood problems of Shezi can be alleviated. Additionally, the Taipei City government thinks that the flood control measures are working. Although the land use sector suggests the strategy of elevating the topography of the area by soil infilling and increasing the height of dikes to protect the area from floods of 200-year frequency, there will be plenty of debate—and blame—on which agencies should be responsible for the damage if (and when) a flood occurs.

11.3.3 Minimal Coordination Between Land Use and Other Sectors

According to the Water Act, urban development must follow the flood control plan of the Water Resources Agency of the Ministry of Economic Affairs. Most local governments have regarded flood control as the responsibility of central government and have relied on engineering approaches to mitigate and minimize loss from flood.

However, there were more than 200 urban plans for Greater Taipei. However, at the time these plans were developed (1970s to 1980s), there were few planning professionals and a lack of mechanisms for implementing the plans (e.g., monetary compensation). Furthermore, the urban plans did not have integrated perspectives for balancing urban growth and environmental conservation. The plans from 30 years ago were mainly created for controlling land use and not for sustainable futures.

From the three case studies on the issues of flood control and urban development, it is evident that the urban planning department of Taipei City government has changed from a passive reactive role to more assertive and active role toward overcoming the risks of flooding. However, the ultimate goal of Taipei City government is to increase urban economic growth by increasing developable urban land using engineering methods. The three cases show there was no coordination between land use and water resource sectors during the formulation of plans and policies. This implies that the plans cannot respond to the reality of development in the past and the challenges of climate change that the city currently face.

11.4 Land Use, Institutions, and Vulnerability to Floods

The flood control issue in Taiwan is administered by Ministry of Economic Affairs and is more or less a top-down process. However, the incorporation of flood control into land use planning and control is the responsibility of local government. Both the central and local governments aim to reduce the threats of risks and loss of lives and properties, but they all rely highly on engineering approaches and seldom coordinate to initiate nonengineering measures to reduce the vulnerability to flood. In order to cope with climate change, flood control cannot be regarded as only the construction of levees and flood diversion projects. The innovative techniques to mitigate flood risk must be integrated with local land use planning and urban development policies.

Our analysis of the current climate change policy of Taiwan indicates it does not include an assessment of vulnerability to floods in Greater Taipei. Although the risk of flood in Taipei seems to be reduced after the completion of flood control projects, it is still unlikely that current flood control levees and flood diversion projects can withhold an extreme event with similar rainfall intensity of 2009 Typhoon Morakot, when more than 2,900 mm of rain fell within 24 h (Center for Weather Climate and Disaster Research 2010).

A simulated flood in Greater Taipei, similar in magnitude to Typhoon Morakot, would result in severe flooding in areas that have the highest population density, in old developed districts with more elderly people (Datong, Zhongshan, Zhongzheng, Wanhua, Songshan, Sanchong, Luzhou, Xinzhuang, Taishan) (Fig. 11.5). These districts are located in areas with low-lying topography and are most vulnerable areas to flood risk. It is also clear that the protected area of Taipei Area Flood Control Project is still likely to be flooded. An important question to ask is if the flood control projects will reduce the three dimensions of vulnerability (exposure, sensitivity,

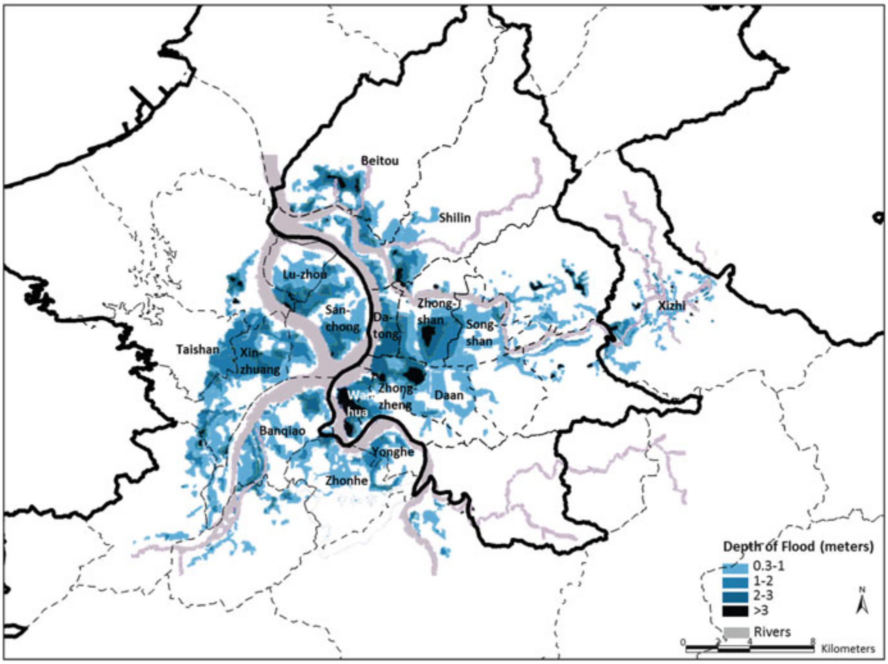

Fig. 11.5 The simulation of flood hazard with rainfall equivalent (Source: Redraw after Center for Weather Climate and Disaster Research, 2010)

adaptive capacity) in Greater Taipei. Despite the construction of levees and floodways, the low-lying floodplain in Taipei is still exposed to extreme events; it is very difficult to reduce exposure to floods in Taipei. Economic activities in Taipei have become larger in scale, meaning that the sensitivity of economic loss is higher than before. Relying only on engineering solutions to extreme climate event is limiting. Adaptive capacity depends also on institutional capacity to plan for and respond to extreme events.

11.5 National and Local Climate Change Policies of Taiwan

The examples of land use and flood control planning illustrate the lack of coordination and integration between government sectors that address issues with some degree of topical overlap. It also hints at the challenges of developing and implementing climate change policies in the country. The cross straits issue with the People's Republic of China (PRC) means that Taiwan is excluded from the any resolutions from the United Nations. Nonetheless, recognizing climate change as an important issue, Taiwan officials announced their intentions to seek official participation in UN specialized agencies with a priority target set on the United Nations Framework Convention on Climate Change or UNFCCC (Toward UNFCCC 2011).

Although Taiwan is not a member of UNFCC, like other countries, it has initiated climate change mitigation and adaptation actions. Compared with most other high-income countries, the climate change policies of Taiwan are relatively nascent, with only a 5- to 6-year history. There are three government bodies with oversight authority on climate change policies. The Executive Yuan is the executive branch of the Taiwan national government and the primary policymaking body of the government. Within the Executive Yuan, the National Council for Sustainable Development (NCSD) is the highest platform for carrying out climate change mitigation and adaptation policies. It coordinates activities among various national level cabinets. The Executive Yuan also houses the Environmental Protection Administration, which is the secretariat of council chair for coordinating climate change policies (National Council for Sustainable Development 2011). However, the NCSD is only an advisory committee to the Premier and does not have the capacity or authority to force the integration of different sectors. The mitigation and adaptation actions are separated by two high-level agencies: EPA and Council for Economic Planning and Development of Executive Yuan (CEPD). Recently, in order to participate in the UNFCCC as an observer and to enhance the cooperation among governmental ministries on energy and climate issues, the Executive Yuan Steering Committee on Energy Conservation and Carbon Reduction was established in December 2009. It proposed the National Energy Conservation and Carbon Reduction Master Program in April 2010, which consists of ten benchmark programs (see Table 11.3) that cover all aspects of energy conservation and carbon reduction in order to achieve the national carbon reduction target (Executive Yuan 2011).

Under this national master mitigation program, the secretariat role of the EPA was transferred to Ministry of Economic Affairs (MOEA). The EPA is one of the committee members of the program on Low-Carbon Communities and Society. Although the program established Taiwan's GHGs reduction goals and ten benchmark programs, it does not show the target amount of reduction by different sectors and how these ten benchmark programs should be coordinated by each sector. Moreover, although there are many demonstration programs, none of them has any scientific basis for whether or not they will make a difference in emissions reductions. The important legal foundation of a Greenhouse Gas Reduction Bill is still in draft form. The EPA has initiated a financial plan of low-carbon cities program since 2010; it selected four cities (New Taipei City, Taichung City, Tainan City, and Yilan County) to execute this program in 2011. However, the specifics of how the low-carbon programs will achieve their GHGs emission reduction goals are not clear. The EPA does not have a clear statement on the amount of GHG emissions for how each city should contribute to a low-carbon program. Although some small cities in Taiwan have small funds for mitigation plan, there is no budget for overall adaptation strategies in these small cities.

The climate change adaptation policy of Taiwan did not receive national attention until 2010, at which time the CEPD organized a working group for the Planning and Promotion of a Climate Change Adaptation Policy Framework and Associated Action Plans. The working group is responsible for developing long-term overall adaptation policies, strategies, and principles (Taiwan Institute of Urban Planning 2010).

Table 11.3 Mitigation and adaptation policies of Taiwan

Mitigation policy[1]	Adaptation policy[2]
1. Sound Legislation Improvement (EPA, MOF, MOEA) 2. Structuring Low-Carbon Energy System (MOEA) 3. Creating Low-Carbon Communities and Society (EPA) 4. Developing Low-Carbon Industrial Structure (MOEA) 5. Building Green Transport Network (MOTC) 6. Popularity of Green Landscape and Green Building (CPAMI, COA) 7. Extending Technology Momentum on Energy Conservation and Carbon Reduction (NSC) 8. Energy Conservation and Carbon Reduction on Public Engineering (PCC) 9. Deepening Education on Energy Conservation and Carbon Reduction (MOE) 10. Enhancing Promotion and Communication on Energy Conservation and Carbon Reduction (MOFA, GIO)	1. Disaster Reduction: To reduce disaster risk caused by climate change and to strengthen the overall adaptive ability of disaster reduction by further developing disaster risk assessment and adaptation policy (NCDR) 2. Water Management: Ensure the balance between supply and demand of water resources under the principle of sustainable utilization of water resources (MOEA) 3. Infrastructure: Enhance the adaptive capacity of infrastructure to ensure its operation under the impact of climate change and minimize its impact to human society (MOT) 4. Industry and Energy Supply: Develop energy supply and industrial system that is capable of adapting to climate change (MOEA) 5. Coastal Land Protection: Protect the natural environment of coastal area and decrease its natural hazards to alleviate the loss due to natural disasters (CPAMI) 6. Agriculture Production and Biodiversity: Develop a low climate risk agricultural production system and conserve biodiversity (COA) 7. Public Health: Improve health-related information system and decrease by 5% disability-adjusted life years (DALYs) (DOH) 8. Land Use Planning and Management: All levels of government must incorporate climate change adaptation strategies into the spatial planning laws and planning process (CPAMI)

Source: [1]Executive Yuan (2011); [2]Taiwan Institute of Urban Planning (2010) *COA* Council of Agriculture, *CPAMI* Construction and Planning Agency Ministry of the Interior, *DOH* Department of Health, *EPA* Environmental Protection Administration, *GIO* Government Information Office, *MOC* Ministry of Education, *MOEA* Ministry of Economic Affairs, *MOF* Ministry of Finance, *MOFA* Ministry of Foreign Affairs, *MOTC* Ministry of Transportation and Communications, *NCDR* National Council for Sustainable Development, *NSC* National Science

This framework is the first climate change adaptation policy of Taiwan, including the preliminary assessment of eight sector's impacts and challenges of climate change, and the formulation of proper adaptation strategies for each sector (see Table 11.3). However, according to the definition of IPCC (2007, p869), adaptation is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." Although the CEPD sought to address the cross sectoral adaptation policy, the policy is still limited by the lack of climatic downscale knowledge and information databases for who and where are most vulnerable to climate change.

There is a lack of coordination among the central government agencies' initiatives on mitigation and adaptation, and there in fact may even be a conflict. For example, mitigation and adaptation strategies are considered and treated separately. The EPA appears to have decreased authority to organize cross sector mitigation strategies, and the MOEA still has no clear actions to coordinate different sectors. Although the CEPD is considered a policy incubator, a policy coordinator, and a policy evaluator, there are gaps and oversight among their activities. Can the NCSD oversee or evaluate the policies of the EPA or CEPD?

After drafting the policy guideline for adapting to climate change, the CEPD continued to encourage the formulation of adaptation plans at the local level. It required local governments to establish a cross sectoral committee to develop adaptation strategies, and land use and spatial planning play a dominant role to coordinate different sectors.

However, strategies for mitigation and adaptation involve different stakeholders and must be cross sectoral. It is becoming clear in Taiwan that spatial planning processes must include climate change considerations. Likewise, climate change policies must include spatial planning considerations. Here, we have much to learn from the lessons of the land use and flooding sectors discussed earlier in this chapter. An effective spatial planning must have the capacity to coordinate different sectors. From planning and management perspective, spatial policy can provide a powerful lever in the shaping of urban forms and development patterns which related energy use and efficiency. Through the arrangement of land use activities, spatial planning can move a region toward becoming a low-carbon society by reducing GHG emissions and decrease the risks and vulnerability to extreme climate events by allocating land uses on areas with low hazardous potential. However, as evidenced by the flooding examples, there are institutional and structural barriers that are difficult to overcome.

Under the constraint of current institutional arrangements and the inflexibility of creating a new agency to cope with climate change, the Taiwan government separates the formulation of climate change policies into different agencies. The EPA is in charge of formulating mitigation strategies, while the CEPD is in charge of adaptation strategies. Since mitigation is considered a top-down procedure, the EPA can enforce the GHG emission reductions and provide funding for local government to develop low-carbon societies. However, the adaptation strategies require the cooperation of various sectors, and CEPD can exercise their authority of budget allocation to coordinate various ministers to comply with climate change adaptation strategies and action plans. Still, there is a lack of coordination and collaboration between sectors that deal with either mitigation or adaptation. While drafting the Climate Change Adaptation Policy Framework for Taiwan, the working group was aware of this problem and established the vision of the nation's adaptation strategies "to build for the long term a sustainable Taiwan with low climatic risks and a low carbon economy to reduce its further vulnerability to climate change" (Taiwan Institute of Urban Planning 2010, p1–6). There is a need to discuss at the policy level whether the current mitigation strategies will limit adaptation options in the future. Similarly, the adaptation strategies must also prevent the increase of GHG emissions. Starting from 2012, CEPD will administer local governments to formulate their climate change adaptation strategies; it will create an opportunity for local government to establish a platform to enhance the coordination between mitigation and adaptation strategies among various sectors to deal with climate change issues.

11.6 Conclusion

The increase of urban vulnerability to floods in Taipei due to climate change is not only from exposure to extreme climatic hazards but also from barriers of wide-ranging socioeconomic factors such as the incapability and inflexibility of institutions as well as the unclear responsibility and minimal coordination among governmental agencies. Therefore, it is not surprising that after the completion of flood control projects, Taipei is still highly vulnerable to flooding. The main issue of vulnerability to floods in Taipei is the lack of integration between flood control and land use planning. In addition, national mitigation and adaption policies are formulated separately, which needs to be integrated at the local level. The case of Taipei further reveals that urbanization has not decreased people's vulnerability to climate change, because Taipei relies on engineering control projects as the only solution to adapt to extreme climatic events. In order to decrease vulnerability to floods in the long run, Taipei should incorporate flood control strategies into land use planning to adapt to extreme climatic events in the future. The critical tasks of examining the current capacities, institutions, and governance of flood vulnerability in Taipei cannot be delayed. The local experiences and knowledge to overcome flood vulnerability will also be critical to meet the challenges for sustainable development in an era of uncertainty and climate change.

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C.G. Boone and M. Fragkias (eds.), *Urbanization and Sustainability: Linking Urban Ecology, Environmental Justice and Global Environmental Change*, Human-Environment Interactions 3, DOI 10.1007/978-94-007-5666-3,